Contribution of the European Kodak Research Laboratories to Innovation Strategy at Eastman Kodak

Nicolas Le Guern

Submitted for the degree of Doctor of Philosophy

Photographic History Research Centre
Faculty of Art, Design and Humanities
De Montfort University
Leicester, UK

January 2017

In memory of Professors Bernard Leblanc and Jacques Desautels

Abstract

This study provides a new understanding of the nature of Eastman Kodak Research. The thesis considers the European context between 1891 and 1912, before the creation of the first Kodak Research Laboratory in 1912 at Rochester, New York, and between 1928 and 1950 with the opening of two additional Research Laboratories in the United Kingdom and in France. It sheds light on the technological and organisational relationship between the main Kodak Research Laboratory in Rochester and the later, related, Kodak Research Laboratories in Europe.

Analysis of publications from numerous independent photochemists demonstrates that industrial secrecy during the interwar years limited the sharing of scientific knowledge and delayed developments in photographic science. The first Kodak Research Laboratory was created in Rochester in 1912 to address this issue internally. Its first director, Kenneth Mees, developed an innovative organisational model which combined fundamental and applied research in order to protect scientific facts about the photographic process that were discovered in-house and to create the appropriate preconditions for the development of new and marketable products.

Qualitative analysis of unpublished research reports stresses the multi-faceted nature of the photographic research undertaken at the Harrow Research Laboratory from 1929 onwards. It shows that the British Laboratory was open to external sources of scientific knowledge and innovative technologies. Photographic knowledge was shared significantly during the 1930s between the American, British and French Research Laboratories and Production Departments, as also evidenced by the previously undiscovered personal notebooks of a number of photochemists. Analysis of the British and more recently uncovered French Kodak archives also reveals that long-term Kodak research about colour photography was interrelated with the European Kodak Research Laboratories during the interwar period. Original analyses of unpublished patent correspondence demonstrate that the editorial drafting of strategic patents

during the Second World War was at the core of the scientific collaboration between Kodak Limited and independent inventors.

This thesis concludes that the work of the European Kodak research laboratories was fundamental to Eastman Kodak in the twentieth century. Despite cultural disparities, the three laboratories followed an organisational model that promoted scientific collaboration. Furthermore, the modest size of Kodak Research in Europe during the early years forced the company to partially adopt an “Open Innovation” model, combining external sources of technology with in-house research. This is the first study to address the question of the European nature of Kodak Research using unpublished laboratory archives. It unveils the complete organisation of Kodak research, including knowledge transfer and scientific collaborations, as well as the actors in Kodak Research that marked the history of twentieth century photography.

Acknowledgements

As I reflect back on my PhD years and write my acknowledgements, I realize that such an individual activity of academic research was only made possible with the help and efforts of a great number of scholars, colleagues, family and friends. Whilst working for a photographic filter manufacturer in France in 2011 and having long left behind the world of academia, I was really happy but also surprised to obtain a PhD position in the UK. What's more, I was fortunate to be awarded a three year full-time research bursary, supported by the Arts and Humanities Research Council, through De Montfort University. A new world opened up to me, with many comings and goings across the Channel, and the necessary campus life at intervals required a period of adjustment for a "mature student" like myself. Apart from the practical side, one of the main difficulties was to undertake a PhD in the history of photography without the study of photographs. During these three years and beyond, a great many people have been very supportive and enabled the progressive writing of my thesis, somewhat appropriately for a thesis about teamwork and scientific collaboration.

In the United Kingdom, De Montfort University and its whole staff welcomed the foreign student that I was. In the Graduate School Office, the members always dispelled my doubts, in particular Silvana McAuley, Kerry Mason, Kerry-Ann Smith, Jimi O'Callaghan, Julie Nutting and Claire Kaylor-Tilley. Linda Butt, Archivist at the Special Collections of Kimberlin Library, introduced me to the Kodak Collection and its many treasures.

Dr Kelley Wilder took the role of first supervisor, but her role cannot be restricted to the unique supervision of my PhD. Her great optimism and energy, her wide knowledge and questions about photography, its nature and the role of photography in science progressively shaped my own questioning about my PhD subject and my research questions. She developed my interest in the scholars of Science and Technology Studies and the bibliographical research that followed dramatically changed my literature review. Kelley was always supportive of my frequent stays in Leicester and helped me frequently despite her own family commitments, and I will always be grateful to her for that. Professor Stephen Brown was my second supervisor and helped me to progressively shape the structure of my first drafts to be compliant with the requirements of a PhD thesis. He has always been wise in his criticism of my drafts, and frequently challenged me about several aspects of the thesis such as my methodology or the structure of the literature review. The great supervision of both Kelley and Stephen has made the final version of this thesis possible.

At De Montfort University, I am also indebted to Professor Emeritus Elizabeth Edwards and to Dr Gil Pasternak for their help in Leicester, for our discussions and for the excellent annual conferences of the Photographic History Research Centre. I thank, in particular, Professor Edwards for agreeing to become the internal examiner of my viva and for questioning me about my work. I am also sincerely grateful to Dr Charlotte Bigg, of the Centre Alexandre-Koyré CNRS/EHESS/MNHN, for agreeing to become my external examiner.

On the campus, several seminars and conferences organised by the Photographic History Research Centre permitted the creation and development of a new community of international students, professors and curators to discuss many issues in the field. I was happy to meet and exchange ideas with a heterogeneous body of new friends from De Montfort

University and beyond, in particular Dr Tom Allbeson, Professor François Brunet, Professor Catherine Clark, Katie Cooke, Dr Caroline Fuchs, Professor Thierry Gervais, Malgorzata Grabczewska, Damian Hughes, Professor Nicoletta Leonardi, Laureline Meizel, Mario Pagano, Denis Pellerin, Sylvie Pénichon, Dr Shannon Perry, Nuno Pinhiero, Dr Françoise Poos, Mike Robinson, Professor Emeritus Roger Taylor, Baiba Tetere, Dr Kim Timby, Ben Tree, Dr Chris Tucker, Marta ZIętkiewicz-Szlendak.

Pertaining to the data collection, the irreplaceable inventory of the Kodak Collection archive at the British Library created by Dr Michael Pritchard, Director-General of the Royal Photographic Society, made the identification of the relevant boxes for my research possible among a huge quantity of archival materials. I am indebted to Michael for an exceptional meeting in the storage areas of the British Library to discover the British Kodak archive and its numerous grey boxes. In the same institution, I would also like to sincerely thank John Falconer, Head of Visual Materials, Curator of Photographs, for facilitating the organisation of my many trips to London and the necessary logistics over two years. Boxes and research reports were always on a special shelf at my disposal, with the help of all the Library staff in the Asian & African Studies reading room as well. Regarding my accommodation in London, I warmly thank my aunt Jacqueline Lavanant for lodging me many times.

Kodak Limited's former archivist, Chris Roberts, as well as Dr Sam Weller, former Director of the Kodak European Research Laboratories in Cambridge, introduced me to the Kodak Collection in Kimberlin Library, De Montfort University. They also helped me to obtain the reproduction of some critical documents and research reports from the Kodak Collection archive at the British Library. Although the historical period of my research did not directly concern their time at Kodak Limited, my only hope is that they find this thesis of great interest in retelling the history of Kodak Limited and more generally, the history of industrial research. I, myself, am indebted to them for their wise decisions to keep, save and organise the gift of this extraordinary archive to De Montfort University and the British Library.

In France, Professor François Brunet was the first to inform me about the PhD proposal at De Montfort University and is therefore indirectly responsible for this great adventure. I was very pleased to meet him later at De Montfort University during an annual conference. I also warmly thank Dr Sylvie Aubenas, Chief Curator of the Department of Prints and Photographs at the Bibliothèque Nationale de France in Paris, and Professor Jean-Paul Gandolfo at The National Film, Photography & Sound Engineering School (ENS Louis Lumière) for their help as referees to my application and for their ongoing support.

Several French libraries have been my refuge against my sometimes unruly children as well as a source of additional bibliographical research. At the Société Française de Photographie, Luce Lebart, Curator of the Collections, was a big help in identifying rare documents about the research laboratories in the photographic industry. At the Bibliothèque Nationale de France, I found many relevant references for the literature review with the help of the Library staff in the Science and Technology reading room at the François-Mitterrand Library. In Fontainebleau, I was fortunate to be allowed to work in the Doriot Library at INSEAD Business School as a PhD candidate. I thank Mary Boldrini for introducing me to the library's collections, particularly relevant for the "models of innovation" and their meanings in the current economic context.

At the ENS Louis Lumière, Jean-Paul Gandolfo and Florent Fajole helped me to understand the nature of their Kodak Collection, issued from the former research library of Kodak-Pathé.

At the Fondation Jérôme Seydoux-Pathé in Paris, I am deeply indebted to Stéphanie Salmon and Sophie Seydoux for their support in my research and their invitation to the conference about the Pathé research notebooks in December 2015. This conference provided me with the opportunity to meet, in particular, Dr Céline Ruivo, François Ede, Jacques Malthête and Professor Joshua Yumibe and to have exciting discussions about Kodak research and colour processes. Thanks to Stéphanie Salmon, I was also able to learn of the existence of the French Kodak-Pathé archive kept by the Association CECIL. Jean-Pierre Martel, its President and formerly CEO of Kodak Industries Europe, always welcomed me in Chalon-sur-Saône and let me reproduce as many reports as necessary. His kindness is only equalled by his motivation to make the Kodak-Pathé archive widely known. I must also thank all the other CECIL volunteers for their work and passion for this important actor of the photographic industry in France.

In the United States of America, Jeffrey Sturchio, former historian of business and industrial research, helped me to locate his seminal conference about Kodak Research at the Hagley Museum and Library. There, I was assisted by Marsha Mills, Archival Specialist. Robert Shanebrook, Product-Line Manager at Eastman Kodak, procured for me some fundamental publications about the photographic industry, in particular the recollections of Fritz Wentzel.

In Canada, I was really happy to hear that the former independent photochemist Pierre Demers was still active and busy with other research projects. I thank him for his interest in this research. A good friend of mine, who I only knew through correspondence, unfortunately passed away in the first months of my PhD. Professor Jacques Desautels, former Dean of the Laval University of Québec, who rediscovered the photographer Joly de Lotbinière, sincerely encouraged me to embark on this doctoral journey. The result of my PhD work into the universe of Kodak Research is dedicated to his memory.

From a practical point of view, I would like to thank MM. Toru Yamanaka, President of Kenko Tokina Co., Ltd., Kazumi Oshioka, Masaaki Kondo and Mrs. Cynthia Thomas for allowing me to work part-time at the Cokin France company for three years.

At a more personal level, I am glad to have had my friend Olivier Degeorges, nineteenth century photography collector, for our discussions about the PhD methodology from his own experience. I also thank Jean Coquin, founder of the Cokin photographic filters, for frequently discussing photographic techniques and innovation with me. Natalie Watchman did excellent proofreading on Chapters 1, 2 and the conclusion, despite her family life. My sister Aurélie and my parents always encouraged me in spite of the distance during these challenging research years. In Italy, my wife's family welcomed us and provided me with quiet weeks to write my thesis, during these last few summers. But nothing would have been possible without the ongoing support of my wife Chiara and the living joy of my children Matteo, Noémie and Raphaël.

Contents

Figures, Tables and Illustrations

Figures

Tables

Illustrations

Chapter 1: Introduction

1.1. General Introduction

1.1.1 Preliminary discussion

Right from the birth of photography in 1839 the nature of the light-sensitive material and the operating principles of the photographic process have always been an important field of study. During the first years of the medium, photographic processes were short-lived and developed with rather simple photochemical technology. The making of the sensitive image layer was shared and discussed by amateurs, early photographers and photochemists in treatises or through the first photographic journals. The sensitive material was either on metal, paper, glass or celluloid and it was quite easy to acquaint the fundamental recipes of a process and even to improve some of its characteristics through basic experimental work. This situation of sharing photographic knowledge within the small but growing community of photographers changed progressively towards the end of the nineteenth century. The industrialisation applied progressively to photography led to new behaviours towards the science of making sensitive materials, whose production increased substantially. From the year 1871 and the development of gelatine silver-bromide plates by Richard Leach Maddox, photography became more and more a matter of investment, entrepreneurship and innovation as well. To ensure the continued existence of this new industry it was necessary to protect its assets in several ways. The time to diffuse and discuss photographic knowledge without restrictions was over. The know-how developed and improved within the photographic plants was progressively hidden by means of managerial procedures organizing industrial secrecy or by way of patenting the innovative technology. The central figure of innovation in the film and plate factories became the photochemist, frequently the manager and owner or a “master emulsion maker” working frequently on his own or with a restricted staff of assistants. This "model of innovation"[1] was hazardous for the company's owner as it depended on the skills and loyalty of one individual employee or paid consultant.

This thesis deals directly with these processes and discusses the circumstances that led Eastman Kodak to a deep reorganisation of its "model of innovation". It clarifies, using unpublished archival material, the nature of industrial research undertaken by the photochemists, managers and researchers before and after 1912. To move away from the old "model of innovation" for which scientific knowledge produced by employees was not sufficiently protected, the Eastman Kodak Company was one of the first industrial organisations in the photographic field to promote innovation in-house through the creation of a Research Laboratory. Taking other industries as a "model of innovation" through this new structure of research, George Eastman decided to hire a well-known director who would be in charge of managing and structuring the technical and scientific areas to study. From now on innovation became controlled and performed by a substantial and increasing staff of researchers sorted into several scientific departments according to their technical and academic backgrounds. Up to 2009 and the transfer of the Kodak Limited archive to the British Library, it was impossible to undertake historical research into such a community of scientists from a corporate archive. Access to such artifacts, comprising primary sources such as correspondence, research reports or individual notebooks, was impossible until now due to their confidential nature. One could only speculate about the daily work of the researchers, the organisation of their research, the sharing of scientific knowledge or the transfer of a theoretical invention to the experimental work and manufacturing routine.

[1] The concept of innovation relates to the set of activities taken by the firm to eventually release a new product for which a market could be found. In the 1950s and 1960s technological innovation was seen as a model of "linear innovation" in several phases from invention to innovation to diffusion. See Benoît Godin, "The Linear Model of Innovation: The Historical Construction of an Analytical Framework," *Science, Technology, & Human Values* 31, no. 6 (2006): 639-667. For the evolution of "innovation models" through the twentieth century and the last decade consult the literature review related to "innovation models".

Nevertheless, the time has now come to open the "Black Box" of research activities undertaken by the major film manufacturers of the twentieth century. When the corporate and scientific archive of Kodak Limited was donated to the British Library, it was clear that research could be planned to progressively unveil the *silver curtain*[2] that was still masking the activities of this industry a few years ago. The discovery of a second corpus of data from Pathé and Kodak-Pathé in France modified the scope of the research questions and generated more findings and analysis than initially expected. In particular, the study of a specific archival source, namely the research reports produced by the staff of the two research laboratories from 1929, provided key information about the production of scientific knowledge but also its transfer and the collaborative work organized among the American, English and French Kodak Research Laboratories and third parties. It transpired from the research that it was a community of heterogeneous specialists who undertook the development and making of photography during the twentieth century. Researchers, scholars, independent photochemists and executives shaped the physical nature of photography by developing “innovative” photographic processes. This global teamwork was a radical shift compared with the situation in the nineteenth century and the monopoly of the almost independent entrepreneur and inventor working with his emulsion maker.

Finally, the study of the organisation of industrial research and the management of innovation at Eastman Kodak during the twentieth century is crucial because it complements our understanding of the photographic medium as a whole.[3] The visual universe of photography during the last century was directly connected with the photosensitive emulsions that the film manufacturers could provide. The artistic,

---

[2] This expression was used during the twentieth century by technical and scientific staff of Eastman Kodak Company at Rochester to define the procedures as a whole to set up industrial secrecy during the manufacturing process. It concerned in particular the confidentiality of formulas, ingredients’ nature and production departments’ know-how. See Robert L. Shanebrook, *Making KODAK Film. The Illustrated Story of State-of-the-Art Photographic Film Manufacturing* (Rochester, NY: Robert Shanebrook Photography, 2010).

[3] Similar researches about innovation and development of processes already exist for the primitive period of the medium 1839-1860 because the scientific knowledge involved was not yet protected through intellectual property or trade secrets and could therefore be studied.

vernacular and professional use of photography was therefore related to a set of technological constraints with which the cine and photographic film manufacturers had to deal. These constraints represent a direct correlation between industrial actors who were inventing and making photography and individuals who were using photography as a finished product.

1.1.2. Research design and research questions

The aim of my research is to qualify and quantify the contribution of the European Kodak Research Laboratories to scientific and industrial Research at Eastman Kodak, leading to theoretical discoveries in the photographic process and to the diffusion of new innovative products. In other words, the aim is to ascertain the production and transfer of technological and scientific knowledge between the three Kodak Research Laboratories in Rochester, Harrow and Vincennes from 1928 to 1950. The final aim of the research is to define the “models of innovation” used by Eastman Kodak in Europe and its evolution for the longer period 1891-1950, before and after the creation of the Kodak Research Laboratories.

For this purpose and in order to ascertain the production and transfer of scientific knowledge between the Kodak Research Laboratories, we need to clarify the historical context of photographic research in Europe before the creation of the first Kodak Research Laboratory at Rochester, New York, in 1912. It is also necessary to identify the nature of industrial research at Eastman Kodak before and after 1912. Concerning the European side of Kodak Research, we need to study the Eastman Kodak strategy that led to the opening of two additional Research Laboratories in Europe at the end of 1928. The next stage of the research is to draw from the analysis of the French and British research reports some findings about the daily work of the researchers, the nature of the technological and scientific fields of study, the organisation and methods of industrial research and of international scientific collaboration. Furthermore, it is important to demonstrate that the analysis of some researchers’ notebooks confirms Kodak’s scientific research and the transfer of photographic knowledge. In a similar context of knowledge transfer, we need to clarify from the analysis of some corporate documents in the British Kodak archive terms of scientific collaboration between independent inventors and Eastman Kodak. To this end, several case studies raise the question of the patent system in the innovation process at Eastman Kodak. These studies clarify that it was used as a gatekeeper for scientific knowledge and acted as the guarantor of the company's intellectual property. Some unpublished correspondence in the British Kodak archive about the drafting of patent literature provides new findings concerning the production of scientific knowledge and the organisation of scientific collaboration. Finally, considering the complete set of data gathered from the archives about the industrial research activities at Eastman Kodak, it is possible to qualify in the conclusion the "models of innovation" used by the company from 1928 to 1950.

In brief, the three main chapters of the thesis contain the following topics.

In chapter 2, the study of the historical context of photographic research in Europe demonstrates that the practice of industrial secrecy in the process of film manufacturing restricted the sharing of photographic knowledge to a large extent in the first half of the twentieth century. In spite of these practices, the same chapter demonstrates that there is some evidence of basic and industrial research at Kodak Limited before 1912. The Works chemist at Harrow, Thomas Krohn did some research into the measurement of emulsion speed and collaborated with the British chemists John Sterry, Ferdinand Hurter and Vero Charles Driffield from 1894 to 1899, thereby benefiting from their research in this field. The situation is similar for the French competitor Pathé before 1912 and chapter 2 recounts the research work in France about a new nonflammable film base. This additional study makes sense in the framework of the research because most of the researchers at Pathé would eventually constitute the scientific team of the Kodak-Pathé Research Laboratory in Vincennes after the merge with Eastman Kodak in 1927. The next section of chapter 2 introduces the context of the creation of the Kodak Research Laboratory at Rochester in 1912. It also analyses the personality of the first director of research Kenneth Mees and the organisation of the Research Laboratory progressively set up under his management.

Similarly, chapter 3 introduces the European Kodak Research Laboratories opened in Britain and in France at the turn of 1928. The first section analyses Mees' decision to create an international network devoted to industrial research. It also points out differences between the British and French Laboratories. The first one started from scratch from an evolving industrial structure at Harrow focused on cine and photographic film production. The second one already had a long-term tradition of fundamental and applied research in the photographic field. Chapter 3 also shows how the European Kodak Laboratories partially adopted the organisation of the main Kodak Research Laboratory at Rochester through external publications dedicated to the scientific community and through the in-house production of research reports at Harrow and research notebooks at Vincennes, which where only available to a restricted audience.

In the next section of chapter 3, an exhaustive study of the production of knowledge at the Harrow Research Laboratory is conducted through the analysis of the British research reports. The sampling consists of the full sets of reports for the six first years 1929-1935. Two qualitative analyses are performed on these reports numbered from H.2c to H.350. The first one is a statistical analysis made with the complete reports' titles using a Computer-Assisted Qualitative Data Analysis Software (CAQDAS). It provides an overall view of the most important topics studied by the Harrow Research Laboratory for the period 1929-1935. The second analysis is more refined and addresses the reports' content as well. It relies on the concept of interactional expertise developed by Collins and Evans in 2002 to justify the selection of several case studies from the many reports.

Following these important narratives of the British Laboratory's activities, the situation of the Kodak-Pathé Research Laboratory is then studied. This study uncovers for the first time the qualitative and quantitative nature of the scientific collaboration and knowledge transfer between the two Kodak Research Laboratories. The study first analyses the exchange of research reports made by the director of the French Laboratory Marcel Abribat from Vincennes to Harrow during the period 1928-1935. The second part of the study details a similar exchange with Harrow for 1935 only, but this time it concerns the full staff of the Kodak-Pathé Research Laboratory. The analysis shows who the British addressees were as well as identifying their position within the company. The third part of the study clarifies the evolution of knowledge transfer in the year 1950. It shows the bilateral exchange of scientific literature between Rochester, Harrow and Vincennes.

The final section of chapter 3 provides an additional insight into the production of scientific knowledge in the photographic industry through the analyses of some personal notebooks. Photochemists, researchers and production managers used these key tools to keep formulas of experimental emulsions or recipes. The study of these personal notebooks reveals that they were as important as the research reports for the production and exchange of technical and scientific knowledge.

While chapter 3 deals with the nature and methodology of Kodak Research at the two European Research Laboratories, chapter 4 is devoted to the long-term research for colour photographic processes undertaken by the three Kodak Research Laboratories from 1914 to 1950. The narrative of Kodak research in colour photography is split into several case studies to ascertain the multifaceted aspect of industrial research and the nature of innovation used. These histories involved heterogeneous historical sources such as secondary sources, archival sources and patent literature. They are all connected together to clarify the evolution of Kodak Research’s strategy as it hesitated between additive and subtractive colour processes.

Thus, the first section of chapter 4 introduces the research work of the photochemist John Capstaff at the Kodak Research Laboratory in Rochester from 1914 to 1918. He developed a two-colour subtractive process on glass plates, which was named Kodachrome. The process was only used on an experimental basis and never took off due to technical issues and the outbreak of the First World War. This first Kodachrome process involved two negative glass plates of the same subject made through red and green filters. After the bleaching and dying of each plate, the coloured image could be viewed by superimposing the plates. Technically, two major characteristics announced the second Kodachrome process launched in 1935: the use of filters and the superimposition of two photographic layers.

Moving away from this first attempt at a colour subtractive process, the second section describes the pioneering research work of the optical engineer Rodolphe Berton at Pathé from 1913 to 1914. The French scientist developed the basis of an additive lenticular process able to reproduce three colours. The discovery of Berthon’s research notebooks in the French Kodak-Pathé archive is exceptional because his colour technology, after being improved during his association with the industrial Keller-Dorian, was eventually purchased by Eastman Kodak and launched as the first Kodacolor process in 1928.

However, the lenticular colour process could not compare with cinematographic colour processes developed by the Technicolor Motion Picture Corporation. This is why George Eastman and his director of research Kenneth Mees were investigating other technologies at the same time. Thus, the next section of chapter 4 introduces the long-term research work of the two independent photochemists Leopold Mannes and Leopold Godowsky into an innovative subtractive tripack process. This section shows how the scientific collaboration with Eastman Kodak led to the incorporation of the two scientists into the Kodak Research Laboratory at Rochester. It also sheds light on the existing secondary sources concerning the three-colour Kodachrome process with unpublished archival sources such as the exclusive licence agreements between the photochemists and the firm. Finally the end of the section points out that methods and strategies of patenting scientific facts and innovation represented a major and growing constraint for photographic research in the 1930s. Concerning Mannes, Godowsky and Eastman Kodak, the major threat to the three-colour Kodachrome process was the patent work and applications of Leonard T. Troland, director of research at Technicolor. Despite Troland’s sudden death in May 1932, Technicolor was granted the well-known patent reissue 18680 which forced Eastman Kodak to purchase a license and to modify its agreement with the inventors Mannes and Godowsky.

The second part of chapter 4 confirms the predominance of the patent system in photographic industrial research. It also brings to an end the long narrative about the three-colour Kodachrome and clarifies that the positive process in colour was far from perfect when it was launched in 1935. Unpublished documents show how the British scientist Franck B. Phillips from the Kodak Research Laboratory at Harrow was cooperating closely with Mannes and Godowsky to perfect the Kodachrome developing process at Rochester in May 1935. These documents also reveal that Phillips discussed how to simplify the Kodachrome processing with the American researcher Lot Wilder in February 1938. Through Wilder's further research work into the innovative technologies used in subtractive tripack processes, the end of the section demonstrates that Kodak research in colour photography grew significantly after 1935 as new scientific ways of mastering visible light through the three-layer monopack film were explored.

The next section of chapter 4 deals with one of these technologies through the analysis of files related to the drafting of patent literature between the independent inventor Michele Martinez and the staff of Kodak Limited's Patents and Trademarks Department. This innovation secured through the scientific collaboration with Martinez was fundamental to the future of colour photography because it was a new solution to prevent the couplers from wandering into the adjacent layers of monopack films. The technology of couplers incorporated in resin or protected couplers was used in particular in new Kodacolor negative films from 1942. The narrative of the patent application's drafting becomes intermingled with the history of the United Kingdom because in 1941, at the time of the collaboration with Kodak Limited concerning the application 9657/40, Martinez was interned on the Isle of Man as an Italian alien and potential enemy. Despite this major constraint caused by the Second World War, the collaborative work succeeded and the corresponding patent GB543606, concerning the incorporation of colour couplers in the emulsion, was finally obtained in March 1942.

Similarly, the last section of chapter 4 expands the notion of the patent system as an essential tool in the industrial research undertaken by the photographic industry. It deals with the scientific collaboration of the American and British Kodak Research Laboratories and the prolific inventor Karl Schinzel from 1936 to his death in 1951. Scientific collaboration between Schinzel and Eastman Kodak represents a synthesis between the similar collaborations with Martinez, Mannes and Godowsky. Indeed Schinzel was first employed by Eastman Kodak at Rochester, but was later commissioned as an expert consultant to open a new Research Laboratory in Switzerland that would be financed by the American firm. The project for this experimental Research Laboratory is first studied through the analysis of legal documents identifying the terms of collaboration between Schinzel and Eastman Kodak. Despite the failure to open the laboratory, these archival sources have a fundamental role in clarifying the methods and the rationale used by an industrial firm to develop its own research activities within the framework of modern innovation.

As to Schinzel's patent literature, its significance in colour photography technologies and their intellectual properties was even more important for Eastman Kodak than Martinez's patent work. For the first time this mutual work between Schinzel and the researchers and managers at Eastman Kodak to secure and patent theoretical inventions in colour photography is established, including the background behind the drafting of some applications. This section also points out that despite constraints similar to those faced by Martinez during the Second World War, Schinzel's various experiences during the War did not prevent the Kodak managers and researchers from getting the patent literature signed and the patents granted.

1.2. Literature review

1.2.1. Previous studies about Kodak history and Kodak research

In the literature about industrial science, there are no comparable studies of photographic companies. This industry is dominated by small and medium-sized enterprises and corporate archives are often neglected and not preserved. Big firms such as Eastman Kodak are rare. For instance, as the British and French Kodak archives only recently become available to researchers, no study has used these corpora of marketing, scientific or legal artifacts as yet. Concerning my study about the nature of Kodak research, the existing literature about Kodak history and technology is consequently restricted and rather heterogeneous. Some information about technology and industrial research can be found in two biographies of George Eastman, the founder of Eastman Kodak.[4] In particular Elizabeth Brayer constructed her narrative of Eastman's life through the analysis of his extensive correspondence. This way it not only provided information about the founder and his decisions but also crucial data about some of the company's key managers and scientists. The content of chapter 13, about the research for a viable colour photographic process clarifies this long-term period of technological uncertainty which was dominated by many theoretical and experimental processes.[5] In a very different style, the vast study of Kodak history published by Collins provided valuable information about three-colour Kodachrome in particular.[6] Collins gathered documentation about the science of photography and the Kodak Research Laboratories from the research archivist Murray Pierson, who worked for the Eastman Kodak Company before her retirement and from the coordinator of Research Communications in the same company, Timothy Hughes at the end of the 1980s. Despite some invaluable information and important details, the goal of Collins' publication was to offer an overall view of the Eastman Kodak

[4] Carl W. Ackerman, *George Eastman* (Boston; New York: Houghton Mifflin Co., 1930); Elizabeth Brayer, *George Eastman: A Biography* (Baltimore: Johns Hopkins University Press, 1996).

[5] Brayer, *George Eastman*, 217-227.

[6] Douglas Collins, *The Story of Kodak* (New York: H.N. Abrams, 1990).

Company's history. Consequently, this publication lacks an academic structure with no detailed footnotes and an incomplete bibliography.[7]

Fifteen years before, Jenkins' *Images and Enterprise* was the first academic research study to ascertain the development of the photographic industry in America from 1839 to 1925 at the end of George Eastman's management period.[8] It deals particularly with the growth of the Eastman Kodak Company and a chapter was devoted to the founding of the Research Laboratory at Rochester in 1912. Jenkins introduced the notion of *master emulsion maker* and explained how these trained chemists took part in the transfer of photographic emulsion knowledge by moving frequently from one company to another.[9] Like Brayer, Jenkins analysed the correspondence of George Eastman along with some public documents and records such as the very long court transcript of Goodwin Film & Camera Company v. Eastman Kodak Company dated from 1914.[10] The influence of Jenkins remains important in recent studies about Kodak history and innovation in the photographic industry. Some scholars mentioned his original academic work and his pioneer methodology of collecting and analysing George Eastman's correspondence.[11] In his biography Brayer recognized that "of all secondary sources, only Jenkins, Butterfield and Ackerman are based on the rich primary source

---

[7] Unfortunately, Collins did not provide the complete references in footnotes regarding the most important information gathered. He only included some partial text credits p. 386 but no bibliography. The author only gave in his acknowledgements pp. 12-13 the name of some Kodak employees at Rochester having provided some information or the access to some specific archives.

[8] Reese Jenkins, *Images and Enterprise: Technology and the American Photographic Industry, 1839 to 1925* (Baltimore: Johns Hopkins University Press, 1975).

[9] Ibid., 223-224.

[10] *Goodwin Film & Camera Company v. Eastman Kodak Company*, U.S. Circuit Court of Appeals, Second Circuit, 10 March 1914, no. 194, *Transcript of Record*, 6 vols. (c. 4000 pages). See Jenkins, *Images and Enterprise*, 355-356.

[11] David C. Mowery, "Industrial Research and Firm Size, Survival, and Growth in American Manufacturing, 1921-1946 : An Assessment," *The Journal of Economic History* 43, no. 4 (1983): 953-980; Risto Sarvas and David M. Frohlich, "From Snapshots to Social Media - the Changing Picture of Domestic Photography," *Computer Supported Cooperative Work* (2011): 5-22; John Taylor, "Kodak and the "English" Market between the Wars," Journal of Design History 7, no. 1 (1994): 29-42; James M. Utterback, "Developing Technologies: the Eastman Kodak Story," *The McKinsey Quarterly* 1, (1995):130-144.

of Eastman's extensive correspondence".[12] However the studies of Jenkins, Brayer and Collins do not provide clear and complete indications of the methods used by the researchers or the chemists and individual inventors working and developing new ideas, processes and products before them. The Eastman Kodak scientific archive was simply not available during the writing of these studies.

Publications directly connected with the history and activities of the Kodak Research Laboratories are scarce. Some descriptive papers written by Eastman Kodak executives were published from the start of the Research Laboratory at Rochester up to the Seventies[13] and equivalent papers appeared from time to time from external writers[14]. These papers usually introduced specific fields of photographic research and pointed out technical and scientific milestones with some biographical indications about the researchers involved. In 1962 Roy Davies, the second director of the Research Laboratory of Kodak Limited, gave a lecture on research in photography at the Royal Photographic Society.[15] But his talk gave no additional indications about the methodology used by the English researchers. Instead, he discussed the legitimacy of a research laboratory in the industrial sector, stressing that such a structure was vital, providing solid resources and a continuous flow of innovation.

---

[12] Brayer, *George Eastman*, 535.

[13] J. H. Altman, "Microphotography and the Kodak Research Laboratories," *Applied Optics* 11, no. 1 (January, 1972): 22-25; Walter Clark, "Photography's Research Genius," *New Scientist* (December 20/27, 1979): 953-956; G. C. Higgins, "Kodak Research Laboratories," *Applied Optics* 11, no. 1 (1972): 1-3.; E. W. Marchand, "Optics in the Kodak Research Laboratories," *Applied Optics* 11, no. 1 (1972): 60-63; C. E. Kenneth Mees, "A Photographic Research Laboratory," *The Scientific Monthly* 5, no. 6 (1917): 481-496; C. E. Kenneth Mees, "The Kodak Research Laboratories," *Proceedings of the Royal Society of London. Series A*, *Mathematical and Physical Sciences* 192, no. 1031 (1948): 465-479; C. E. Kenneth Mees, "Fifty Years of Photographic Research," *Image, the Bulletin of the George Eastman House of Photography* 3, no. 8 (1954): 49-54; C. E. Kenneth Mees, *Dr. C.E. Kenneth Mees: An Address to the Senior Staff of the Kodak Research Laboratories*, November 9, 1955 (Rochester N.Y.: Kodak Research Laboratories, 1956).

[14] Gary Jacobson, "KODAK: Research is in the Driver's Seat," *Management Review* 77, no. 10 (1988): 32-32; J. D. Ratcliff, "Eastman Kodak's Research Odyssey: Profitable Sidelines Add to Company's Earnings from Photographic Products," *Barron's*, June 23, 1941, 3; Martin Sherwood, "Photographic Research in Focus," *New Scientist* (February 8, 1973): 301-303.

[15] E. Roy Davies, "Reports of Meetings. Scientific and Technical Group's Second After-Dinner Lecture - 15 February 1962", *The Journal of Photographic Science* 10, no. 4 (1962): 252-257.

At Eastman Kodak, two publications prepared the ground for an official history of the industrial research undertaken into photography within the Research Laboratories of the company. The first was Mees's last book, printed after he died in 1961. *From Dry Plates to Ektachrome Film* is a reference book frequently cited by later authors when Kodak research in the photographic science is studied.[16] Mees consulted the historian Beaumont Newhall and many scientific experts of the Rochester Research Laboratory for the writing of some chapters.[17] It was also the first publication to introduce the French and English Research Laboratories, with some indication about staff and organisation.[18]

A celebratory book was published by Eastman Kodak in 1989 on the occasion of the 75th anniversary of the American Research Laboratory.[19] During the research work for the book, Jeffrey Sturchio and Arnold Thackray, at that time independent scholars of the Center for the History of Chemistry at the University of Pennysylvania, undertook a series of interviews of Kodak researchers and managers. Although providing often relevant data about scientific research as well as reproductions of exceptional material and artifacts, *Journey: 75 years of Kodak Research* did not avoid the pitfall of the long technological narrative to depict what was perceived as a history in progress. Indeed, Kodak research was feeling the beginnings of its slow decline after having been at its peak. The change between 1985 and 1986 in its organisation confused the existing

[16] C. E. Kenneth Mees, *From Dry Plates to Ektachrome Film; a Story of Photographic Research.* (New York: Ziff-Davis Pub. Co., 1961).

[17] Mees collaborated with Beaumont Newhall for the early history of photography (chapter 1, 1), Mr. John Tupper for sensitometry (chapter 5, 59), Dr. F. Perrin and Dr. G.C. Higgins for the structure of the developed image (chapter 6, 87), Dr. J.H. Webb for the sensitivity and the latent image (chapter 7, 99), Dr. T.H. James for developers and development (chapter 8, 109), Dr. L.G.S. Brooker for the sensitizing dyes and their application (chapter 9, 119), Dr. J. Russell for gelatin (chapter 10, 133), Dr. C. J. Staud for cellulose derivatives (chapter 11, 141) and for emulsion research (chapter 12, 149), Dr. Staud and Dr. W. T. Hanson for color photography (chapter 17, 203), Mr. R.B. Wilsey, Dr. R.L. Griffith and Dr. J. Russell for X-ray research (chapter 18, 227), Dr. W. Clark, Mr. G.T. Eaton and Dr. H.C. Yutzy for documentary photography (chapter 19, 241), Dr. Clark and Dr. C.A. Horton for research in the graphic arts (chapter 20, 255), Dr. B. H. Carroll and Dr. J. Spence for special photographic materials for scientific use (chapter 21, 269), and Dr. J.A. Leermakers, Mr. S.W. Davidson, Mr. E. R. Davies, Dr. P. Clément and Dr. M. Abribat for the Kodak Research Laboratories in 1955 (chapter 23, 293).

[18] Mees, *From Dry Plates to Ektachrome Film*, 293-301.

[19] *Journey: 75 Years of Kodak Research* (Rochester, N.Y.: Eastman Kodak, 1989).

teams of researchers accustomed to the centralized system of management from the Mees era. It seemed therefore like an appropriate moment to remember and to count the scientific milestones provided by successive generations of Kodak researchers. In parallel to this publication, Sturchio gave a talk at the Hagley R&D Pioneers Conference at the Hagley Museum and Library in 1985.[20] His speech very likely presented a unique in-depth study of the evolution of Kodak research before and after 1912. Sturchio provided the context for the industrial research in the early years of the twentieth century. He also introduced Mees's vision of the organisation of research, and studied the structure and methods of the Rochester Research Laboratory such as the conference system. His findings provide the necessary backdrops for a study of the European Research Laboratories, and for a discussion of the international structure and organisation of Kodak Research. Nonetheless he did not introduce the European part of Kodak Research and did not anticipate the collaborative work and exchange of knowledge between the three Laboratories.

In 1920, Mees published his first *Organization of Industrial Research* which contained his philosophy of the organisation of a research laboratory.[21] Initially focused on the photographic industry, Mees wanted his theory to be applied to other industries.[22] The book was reworked with the researcher Leermakers who would later become a director of the Kodak Research Laboratory at Rochester and a second edition was published in 1950 together.[23] Recent scholars have studied the role of Mees in Eastman Kodak's strategy of research and innovation. Buckland studied how Mees used his academic and professional network to attract some skilled scientists to the

---

[20] Jeffrey L. Sturchio, "Experimenting with Research: Kenneth Mees, Eastman Kodak, and the Challenges of Diversification" (paper presented for the Hagley R&D Pioneers Conference, Hagley Museum and Library, Wilmington, Delaware, October 7, 1985).

[21] C. E. Kenneth Mees, *The Organization of Industrial Scientific Research* (New York: McGraw-Hill Book Company, Inc, 1920).

[22] "The principles dealing with the various aspects of scientific research […] may be applied directly to the design of a research laboratory for a specific purpose, and it is proposed in this chapter to attempt to outline some typical laboratories as a guide to the directorate of any firm contemplating the establishment of a research department." Mees, *The Organization*, 145.

[23] C. E. Kenneth Mees and John A. Leermakers, *The Organization of Industrial Scientific Research*, 2nd ed. (New York: McGraw-Hill, 1950).

Research Laboratories through the example of the physicist and photochemist Emanuel Goldberg. As soon as he was appointed by Eastman as the director of the new laboratory, Mees unsuccessfully attempted to hire his friend Goldberg, with whom he stayed in touch through the years.[24] Shapin discussed at length Mees's ideas from the analysis of the two editions of the *Organization of Industrial Research*.[25] The author particularly stressed the uncertain characteristic of industrial research. For Mees and his contemporaries, uncertainty governed fundamental or pure research while applied research could be predictable in producing regular outcomes. Shapin pointed out that Mees's view about research work's uncertainty remained the same during his whole professional life. Research work could not be scheduled and its outcomes were unpredictable.[26] For Mees, the difficulty of planning industrial research was also due to the frequent technological advance of inventions worked out within the laboratory but not yet ready for the market. In chapter 3, analysis of the British research reports precisely ascertains the amount of fundamental research work related to uncertainty and whose outcomes could not be determined. Shapin also introduced many other faces of Mees's view such as his faith in research disorganisation. For Mees, this way of reducing industrial research's planning was a strategy to increase the continuity of the scientific work undertaken by the researchers.[27] Finally, Fisk stressed the strategic importance of secretive practices at Eastman Kodak.[28] Mees, who was a photochemist, encouraged his researchers to publish their findings about pure scientific advances. However, he considered that companies should not publish results related to the improvement of manufacturing technology. For Mees, technology was different from pure science but in direct relationship with the methods used for production. This

---

[24] Michael Keeble Buckland, *Emanuel Goldberg and His Knowledge Machine Information, Invention, and Political Forces* (Westport, Conn.: Libraries Unlimited, 2006).

[25] Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008).

[26] Ibid., 136-137.

[27] Ibid., 198-199.

[28] Catherine L. Fisk, *Working Knowledge Employee Innovation and the Rise of Corporate Intellectual Property, 1800-1930* (Chapel Hill: University of North Carolina Press, 2009).

explains why it is impossible to find literature from Kodak researchers that details scientific topics and technologies studied by the Research Laboratories.[29]

Moving away from the historical context of the Kodak Research Laboratories, a series of papers published at the end of the twentieth century took into account the structural changes in the organisation of research. Uthman discussed the new laboratory information management system (LIMS).[30] The goal of this system was to improve the sharing of data among Eastman Kodak's many laboratories and it was progressively implemented at several Kodak sites from 1990 to 1993, among them the Research Laboratories at Harrow and Chalon-sur-Saône (France). It echoes the system of in-house knowledge transfer from 1929 to 1950 that is studied in chapter 3. Gove et al. mentioned an example of scientific collaboration between the Kodak Research Laboratory and a public institution.[31] They clarified how a collaborative research program was undertaken with the members of the Nuclear Structure Research Laboratory of the University of Rochester and some researchers at Kodak Park concerning silver halide imaging research. As for Strong, he introduced the recent marketing turn of the company at the end of the 1980s.[32] He pointed out in particular that "the outdated functional organisation was replaced by a series of business units focused on specific customers and markets".[33] He also insisted that the new organisation wanted to increase communication between research, manufacturing and marketing. This new organisation compares with the centralized organisation of Mees's era that is studied in chapter 2. The structural change also had consequences on the methodologies used to innovate, as ascertained by Kanter et al. or Utterback,

---

[29] Ibid., 192-193. See also C. E. Kenneth Mees, "Secrecy and Industrial Research," *Nature* 170, no. 4336 (1952): 972.

[30] Alan P. Uthman, "Laboratory Information Management Systems at Kodak: Foundation for the Future," *Chemometrics and Intelligent Laboratory Systems* 17, no. 3 (1992): 289-294.

[31] H. Gove et al., "Applications of AMS to Electronic and Silver Halide Imaging Research," *Nuclear Instruments and Methods in Physics Research* 52, no. 3-4 (1990): 502-506.

[32] Frank P. Strong, "Kodak: Beyond 1990," *Journal of Consumer Marketing* 5, no. 3 (1988): 53-60.

[33] Ibid., 54.

and the notion of competency within the context of rapid technological change.[34] This same context was reconsidered by Munir and Phillips through the example of the photographic industry to illustrate how firms facing a radical discontinuity could suffer from uncertainty if they did not anticipate this technological turn.[35] Actually, the outcomes of industrial research are supposed to reduce the uncertainty created by the adoption of new technologies and chapter 4 demonstrates how this process was successful regarding colour photography. The release of lenticular Kodacolor in 1928 was the opportunity to test the market and to ascertain that Eastman Kodak had to improve the process and resume the research.

Finally, the most recent papers about Eastman Kodak provided analyses of the fall of one of the biggest photographic companies. Facing the digital revolution, the managers fell behind by suggesting hybrid solutions of "*film-based digital imaging*" such as the Photo CD.[36] The Christensen theory of "disruptive innovation"[37] has been advanced or extended by several scholars.[38] However Munir and Phillips balanced the notion of disruptive technologies, arguing that the marketing discourse of institutional entrepreneurs to construct the social context of a technology was at least as important

---

[34] Rosabeth Moss Kanter et al., "Engines of Progress: Designing and Running Entrepreneurial Vehicles in Established Companies; the New Venture Process at Eastman Kodak, 1983–1989," *Journal of Business Venturing* 6, no. 1 (1991): 63-82; Utterback, "Developing Technologies," 130-144.

[35] Kamal A. Munir and Nelson Phillips, "The Concept of Industry and the Case of Radical Technological Change," *Journal of High Technology Management Research* 13, no. 2 (2002): 279-297.

[36] Giovanni M. Gavetti, Rebecca Henderson and Simona Giorgi, "Kodak and The Digital Revolution (A)," Harvard Business School Case 705-448, November 2004 (Revised November 2005): 1-18.

[37] Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston, Mass.: Harvard Business School Press, 1997). A "disruptive innovation" is the introduction of a technology that enables a new business model and the progressive development of a new market.

[38] Jonathan C. Ho and Chung-Shing Lee, "A Typology of Technological Change. Technological Paradigm Theory with Validation and Generalization from Case Studies," *Technological Forecasting & Social Change* (Article in press, 2014); H. C. Lucas and J. M. Goh, "Disruptive Technology: How Kodak Missed the Digital Photography Revolution," *Journal of Strategic Information Systems* 18, no. 1 (2009): 46-55; Christian G. Sandström, "A Revised Perspective on Disruptive Innovation : Exploring Value, Networks and Business Models" (PhD, Chalmers University of Technology), 1-209; Haydn Shaughnessy, "Recognizing the Ecosystem Phase-Change: A Guide to Four Types," *Strategy & Leadership* 42, no. 1 (2014): 17-23.

as the nature of the technology itself.[39] The authors drew their conclusions from original research implying critical discourse analysis of Kodak marketing and the study of the introduction of the roll-film camera by Kodak in 1882. Despite their interest in understanding the recent economic situation of Eastman Kodak, these papers only addressed the final stage of the innovative process, which is the release and diffusion of new technologies. They did not tackle the concrete nature of Kodak Research and its organisation, which are the subjects of this thesis.

1.2.2. Studies about the photographic industry at large

The literature about Eastman Kodak found up to now partially enlightened my research questions. However, the challenge was also to find if publications dealing with other manufacturers in the photographic industry could provide further elements of knowledge and methodology. Aside from the Kodak managers already cited above, few documents were found about other film manufacturers in Europe. Didiée provided a thorough description of the Pathé-Cinéma works at Vincennes just before the acquisition by Eastman Kodak.[40] In Italy, Cassinis, the technical director of the film and plates manufacturer FILM at Ferrania during the Interwar, published some articles about the photographic industry in Italy and its evolution.[41] In particular, the author pointed out that a research laboratory was created in 1935 at Ferrania along the lines of the Kodak and Agfa Research Laboratories. However very little was known about this Italian Research Laboratory. In 1953 the director of Research G. B. Harrison at Ilford Limited published a descriptive paper about the Ilford laboratories from his

[39] Kamal Munir and Nelson Phillips, "The Birth of the 'Kodak Moment': Institutional Entrepreneurship and the Adoption of New Technologies," *Organization Studies* 26, no. 11 (2005): 1665-1687.

[40] Louis Didiée, *Le Film Vierge Pathé : Manuel De Développement Et De Tirage* (Paris: Les Établissements Pathé-Cinéma, 1926).

[41] Paolo Cassinis, "I Progressi Dell'Industria Fotografica Italiana," *Il Progresso Fotografico* 40, no. 7 (1933): 207-211.; Paolo Cassinis, "I Prodotti Fotografici E L'Autarchia," *Il Progresso Fotografico*, no. 6 (1939): 230-233.

lecture delivered to the Royal Society on May 1952.[42] Although his paper provided a relevant history of the laboratories over more than 50 years, Harrison listed only the most significant of the company's milestones and the principal scientific fields studied. One year later, the Chartered Patent agent of Ilford Limited, Victor Gallafent gave a more pertinent lecture when he discussed the organisation of photographic research at Kodak Limited and Ilford Limited.[43] In particular, he stressed the importance of the patent system as an aid to research and the significant role of independent inventors. In 1960, Sipley of the American Museum of Photography decided to publish the autobiography of an intriguing photochemist, Wentzel.[44] German born, Wentzel painted in his own *memoirs* a portrait of the European photographic industry up to and including his period at the American Ansco company. He reported some of the methods and secretive practices employed by the many photographic plants he worked with. Both Wentzel's recollections and Gallafent's views are used in chapter 2 to contextualize the photographic industry in the first half of the twentieth century and its management of scientific knowledge. More recently, Sauteron published his recollections of his period at Kodak-Pathé and some historical insights from his personal research using unidentified archives of the company.[45]

In terms of academic studies, very few contemporary scholars have studied the photographic industry. Löhnert and Gill recently discussed the development of scientific and industrial research at Agfa and the contribution of the director of the Agfa Research Laboratories at Wolfen in Germany, John Eggert.[46] Nevertheless the

---

[42] G. B. Harrison, "The Laboratories of Ilford Limited," *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 220, no. 1143 (December 22, 1953): 9-20.

[43] Victor Gallafent, "The Direction of Photographic Research," *The Photographic Journal* 94 (April, 1954): 104-118.

[44] Fritz Wentzel, *Memoirs of a Photochemist* (Philadelphia: American Museum of Photography, 1960).

[45] François Sauteron, *Une Si Jolie Usine : Kodak-Pathé Vincennes* (Paris: Harmattan, 2008); François Sauteron, *La Chute De L'Empire Kodak* (Paris: Harmattan, 2009). It is not possible to use Sauteron's findings in the framework of my research as the telling is novelistic and made of a succession of anecdotes without references.

[46] Peter Löhnert and Manfred Gill, "The Relationship of I.G. Farben's Agfa Filmfabrik Wolfen to its Jewish Scientists and Scientists Married to Jews, 1933-1939," in *The German Chemical Industry in the Twentieth Century*, ed. John E. Lesch (Dordrecht; Boston: Kluwer Academic Publishers, 2000), 123-145.

principal research question studied by the authors was the social and political situation of the Jewish employees at Agfa and in the *Filmfabrik* Wolfen during the National Socialist period in Germany. Moving away from a historical perspective, Kadiyali studied the U.S. photographic film industry in the context of industrial organisation economics.[47] The author used the methodology of the new empirical industrial organisation for the period 1970-1990 to ascertain how at the turn of 1980, Fuji had entered the market dominated thus far by Eastman Kodak. Concerning the history of the twenty century British photographic industry, the only study of the subject was apparently published by Edgerton.[48] Like Gallafent, he compared the research at Kodak Limited and Ilford Limited, but with additional data, describing the financial means and the staff of scientists and photochemists who were progressively hired during the interwar years. The author argued that the lack of knowledge in dyestuffs chemistry within Ilford drastically limited the expertise of the English firm in colour processes. He defined Eastman Kodak's research as more separate from production than Ilford's. Edgerton also noticed that at the time of writing studies about industrial research within British firms were rare. Edgerton and especially Horrocks progressively revived this subject. In 1994 as co-authors they tried to estimate the R&D investment in the British industry before 1945 from analysis of corporate archives. [49] From their findings, they argued that the amount of R&D undertaken by British companies was higher than estimated in previous studies and rejected in particular the conclusions of Mowerey and Chandler about the matter.[50] Later, Horrocks continued to investigate the British industry through the archives of industrial and scientific organisations and individual

---

[47] Vrinda Kadiyali, "Entry, its Deterrence, and its Accomodation : A Study of the U.S. Photographic Film Industry," *The Rand Journal of Economics (Washington)* 27, no. 03 (1996): 452-478.

[48] D. E. H. Edgerton, "Industrial Research in the British Photographic Industry, 1879-1939," in *The Challenge of New Technology: Innovation in British Business since 1850*, ed. Jonathan Liebenau (Aldershot: Gower, 1988), 106-134.

[49] D. E. H. Edgerton and Sally M. Horrocks, "British Industrial Research and Development before 1945," *The Economic History Review (London)* 47, no. 02 (1994): 213-238.

[50] Alfred D. Chandler and Takashi Hikino, Scale and Scope: *The Dynamics of Industrial Capitalism* (Cambridge, Mass.: Belknap Press, 1990); David C. Mowery, "Industrial Research in Britain, 1900-1950," in *The Decline of the British Economy*, eds. Bernard Elbaum and William Lazonick (Oxford: Clarendon Press, 1986), 189-222.

firms.[51] She also discussed the alliances between academic researchers and industrial organisations[52] and the internationalization of R&D activities, citing the example of Kodak for which “the greatest degree of internationalization of research activity was found”.[53] The pioneering work of Edgerton and Horrocks about the British industry is partially used in chapter 3 for the description of Kodak Research at Harrow and for the question of knowledge transfer. It is also worth noting that the scarcity of British industry studies increases the relevance of my research into the European Kodak Research Laboratories, which will complement this recent field of study.

1.2.3. The question of industrial research and large-scale organisations

Horrocks’ literature about the British industry contextualized photographic research at Kodak Limited on the economic level, but it did not indicate how the involvement of scientists in the process of innovation should be assessed within the same organisation. In the 1960s, Hamberg stated that to a large extent industrial laboratories were principally major sources of “improvement” inventions and minor sources of major inventions.[54] This abrupt conclusion was far from satisfying. By analysing patent data to find out how many patents resulted in marketed products, Hamberg denied the importance of fundamental research and considered only the profitability of industrial laboratories. Ten years later, Sanderson published an essay about research within the firm compared with research in universities or research

---

[51] Sally M. Horrocks, "Enthusiasm Constrained? British Industrial R&D and the Transition from War to Peace, 1942–51," *Business History* 41, no. 3 (1999): 42-63.

[52] Sally M. Horrocks, "Industrial Chemistry and its Changing Patrons at the University of Liverpool, 1926-1951," *Technology and Culture* 48, no. 1 (2007a): 43-66.

[53] Sally M. Horrocks, "The Internationalization of Science in a Commercial Context: Research and Development by Overseas Multinationals in Britain before the Mid-1970s," *British Journal for the History of Science* 40, no. 145 (2007b): 236.

[54] D. Hamberg, "Invention in the Industrial Research Laboratory," *Journal of Political Economy* 71, no. 2 (1963): 114-115.

organisations in the interwar years.[55] Stating that the importance of industrial research had been underestimated by historians, the author took the example of rubber tyres and the photographic industries in a short paragraph. These industries experienced similar shifts concerning the evolution of research when the core of the research activity, initially managed by a research organisation, was re-located within the firm.[56] The role of the industrial research laboratory was also highlighted in the well-known *Visible Hand* of Chandler. In chapter 13 the author introduced four case studies of large industrial enterprises (Standard Oil, General Electric, United States Rubber and Du Pont).[57] Chandler illustrated how the research organisation was only one part of the structural machinery of the complete enterprise and interrelated with the other components of the so-called managerial firm. The Research Laboratory was only touched upon as the author remained focused on the role of the top managers and on the consequences of mergers and shifts.[58] In fact a body of literature about the history of corporate laboratories started to grow in the 1980s. The historians of science and technology Reich and Wise studied the development of the General Electric and AT&T Research Laboratories and the life of the first director of Research at GE, Willis Whitney.[59] The "organizational focus" commended by Chandler was used by Reich and Wise in their histories and criticized by Dennis,[60] who stressed the importance of links between the history of university science and the corporate laboratories.[61] In the first

[55] Michael Sanderson, "Research and the Firm in British Industry, 1919-39," *Social Studies of Science* 2, no. 2 (1972): 107-151.

[56] Ibid., 133-134. For Ilford and Kodak Limited, the research organization was the British Photographic Research Association. For Dunlop, it was the Rubber and Tyre Manufacturers Research Association.

[57] Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass.: Belknap Press, 1977), 415-454.

[58] "The managers looked to their research organizations, originally set up to improve product and process, to develop the new products that might be particularly suitable to their production processes or marketing skills." Chandler, *Visible Hand*, 474.

[59] Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (Cambridge; New York: Cambridge University Press, 1985); George Wise, *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research* (New York: Columbia University Press, 1985).

[60] Michael Aaron Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science," *Social Studies of Science* 17, no. 3 (1987): 479-518.

[61] Ibid., 510.

part of his paper Dennis discussed the rare studies about a few big American firms such as General Electric, At&T, Eastman Kodak and Du Pont and discussed the origin of the idea of investing in research.[62] Shortly after, Jones published a paper about the investment of foreign multinationals in the British industry in the interwar period. He pointed out the "*superior research and development methods*" of the American companies.[63] Despite this statement, the thesis demonstrates in chapters 3 and 4 that, at Eastman Kodak, the European Research Laboratories strongly influenced the organisation and conduct of industrial research in the company. For instance, the sharing of scientific and technological knowledge was really two-sided between Rochester and Harrow.

Recent studies about industrial research do not go far enough in ascertaining the many activities of scientists within industrial research organisations. For instance, Varma published a study about the evolution of the role of industrial research, identifying a shift toward the implicit mission of centralised corporate laboratories from the end of the 1980s.[64] Fundamental research was no longer carried out first and then applied to the production. From that time onwards, research became "mission-oriented toward development".[65] However the author only studied the structure and development of the corporate laboratories. Some laboratory studies have attempted to define the role and the evolution of research and development within an industrial group. In 2007 Van Rooij published a case study of the Dutch chemical company DSM that opened a Research Laboratory in 1938.[66] The author argued that DSM was not the typical company chosen for R&D case studies and that this academic field principally focused on large German or American companies for the pioneering period 1870-1920.

---

[62] Ibid., 487.

[63] Geoffrey Jones, "Foreign Multinationals and British Industry before 1945," *The Economic History Review* 41, no. 03 (1988): 437.

[64] Roli Varma, "Changing Research Cultures in U.S. Industry," *Science, Technology, & Human Values* 25, no. 4 (2000): 395-416.

[65] Ibid., 414.

[66] Arjan van Rooij, *The Company that Changed itself: R&D and the Transformations of DSM* (Amsterdam: Amsterdam University Press, 2007).

Following a chronological structure, Van Rooij's study was the opportunity to clarify how the evolution of innovation at DSM led to three major transformations, from coal and coke to high value-added products. For his study the author analysed corporate archives, company newsletters and unpublished reports about DSM's history. He also conducted interviews with existing researchers at DSM principally to discuss his draft manuscript.[67] Within the same context of industrial research in the Netherlands, a paper discussed the development of the Research Laboratory of Philips, the "Nat.Lab." opened in 1914 in Eindhoven.[68] The authors concluded that industrial research at Philips followed a similar evolution to that defined by Varma, "from a scientific-investigation attitude to product-driven orientation".[69] But they also stated that research at Philips often evolved differently to that of USA laboratories. Boersma & Vries analysed various archival data collections relating to Philips research and conducted interviews with former researchers at the Nat.Lab. to better ascertain the role of the research structure in Philips' innovation process. But Vries also used earlier investigation work he had been allowed by the company to gather some corporate archives directly from the Philips laboratory during the 1990s.[70]

The growing body of literature about large-scale organisations was approached in my literature review as an extension of the field of industrial research studies.[71] It refers to historical studies of large-scale scientific research that is usually nationally funded. The field provided for instance studies about high-energy accelerators, the large-scale collider, big national laboratories or the early development of the cloud chambers. From the initial definition, the research organisation had to receive a large amount of

---

[67] Ibid., 285.

[68] F. Kees Boersma and Marc de Vries, "Transitions in Industrial Research: The Case of the Philips Natuurkundig Laboratorium (1914-1994)," *Business History* 50, no. 4 (2008): 509-529.

[69] Ibid., 523.

[70] Marc J. de Vries, *80 Years of Research at the Philips Natuurkundig Laboratorium : (1914-1994) : The Role of the Nat.Lab. at Philips* (Amsterdam: Pallas Publications, 2005), 7-9.

[71] Large-scale organisations studies partially relate to the concept of "Big Science" conceptualised by Weinberg and Price in the 1960s. See Alvin M. Weinberg, "Impact of Large-Scale Science on the United States," *Science* 134, no. 3473 (1961): 161-164; Derek J. de Solla Price, *Little Science, Big Science* (New York: Columbia Univ. Press, 1963).

funding, be structured with a big staff of scientists, be equipped with massive material and be incorporated in big laboratories.

Du Pont de Nemours, an important American company, interfered progressively in the area of large-scale organisations studies. This was logical because Du Pont was incorporated into the Manhattan Project during the Second World War to produce plutonium in large quantities. The private company was therefore temporarily linked to the military-industrial complex (MIC),[72] as was Eastman Kodak during the same period. In 1985 Smith and Hounshell introduced in *Science* the pioneering work of Wallace Carothers who directed the new fundamental research program at Du Pont from 1928 on.[73] The authors analysed how Carothers and his teams of scientists were able to discover neoprene and nylon materials and to contribute to polymer science. To this end, they collected data notably from the Du Pont archives in the Hagley Museum and Library, Wilmington. In 1988 Smith and Hounshell attracted a lot of attention when they published an in-depth study of R&D at Du Pont covering the period 1902-1980.[74] However, the most significant study of Du Pont's large-scale R&D was published by Hounshell in the well-known book *Big Science. The growth of large-scale research* edited by Galison and Hevly in 1992.[75] Hounshell's study was accepted notably because the author wanted to ascertain "the important similarities and differences between big science within industry and the government-funded big

[72] The military-industrial complex (MIC) is a temporary collaboration between a national army and private industries used as suppliers to develop and produce military technologies and weapons.

[73] John K. Smith and David A. Hounshell, "Wallace H. Carothers and Fundamental Research at Du Pont," *Science* 229, no. 4712 (1985): 436-442.

[74] David A. Hounshell and John K. Smith, *Science and Corporate Strategy: Du Pont R&D, 1902-1980* (Cambridge ; New York: Cambridge University Press, 1988).

[75] Peter Galison and Bruce William Hevly, *Big Science: The Growth of Large-Scale Research* (Stanford, Calif.: Stanford University Press, 1992). The book originated from a conference at Stanford University in 1988 with science historians including Kevles, Everitt and Galison. 13 chapters investigate the big physics of small particles, the sponsored research and external interests, "Big Science" and national security. Some topics were classical large-scale organisations studies such as physics research at the Berkeley Laboratory, at Stanford University or at MIT, the Los Alamos implosion program or the early history of CERN.

science projects that dominate the existing historical scholarship (…)”.[76] A significant part of the paper was devoted to Du Pont’s involvement in the Manhattan Project. The author indicated how Du Pont’s successful nylon model was applied in designing a plutonium separation plant and in which context the collaboration between the Metallurgical Laboratory physicists at Chicago and the industrial researchers took place. This was the confrontation between two universes that could be summed up as “science” versus “engineering”, and the scientific collaboration was only partial. For N’Diaye, the example of Du Pont was inconvenient because the firm ceased its collaboration with the federal state in 1945.[77] He suggested a further study with General Electric for instance, as this firm was committed to nuclear physics and more engaged with federal projects. The author also stressed that a study of fundamental research at Du Pont was not the best methodology to demonstrate that “Big Science” is not only concerned with high-energy physics, because fundamental research is neither *big* nor *light*.[78] However, Hounshell had briefly shown how a scientific collaboration could be analysed and studied. Recently, Cerveaux, while researching his PhD dissertation about colloidal chemistry, dyes and fundamental research at Du Pont, discovered the existence of the Du Pont archive at the Hagley Museum and Library and collected additional data from this corpus. [79] According to the French author, colloidal chemistry had been underestimated in preceding studies about Du Pont. He also stressed the importance of the interwar period in the development of fundamental

---

[76] David A. Hounshell, "Du Pont and the Management of Large-Scale Research and Development," in *Big Science: The Growth of Large-Scale Research*, eds. Peter Galison and Bruce William Hevly (Stanford, Calif.: Stanford University Press, 1992), 237.

[77] Pap N'Diaye, "Peter Galison et Bruce Hevly (Dir.), Big Science. The Growth of Large-Scale Research," *Annales. Économies, Sociétés, Civilisations* 48, no. 2 (1993): 414-417.

[78] Ibid., 416. In the 90s N’Diaye undertook some PhD research in the United States of America about innovation at Du Pont and pointed out the rise of chemical engineers as a professional group and a key asset into Du Pont’s corporate culture. See Pap Ndiaye, *Du Nylon Et Des Bombes : Du Pont De Nemours, Le Marché Et L'Etat Américain, 1900-1970* (Paris: Belin, 2001).

[79] Augustin Cerveaux, "« *From an art to a science* » : chimie colloïdale, pigments et recherche « fondamentale » chez du Pont de Nemours, 1900-1945" (PhD diss., Université de Strasbourg, 2010). Most of his dissertation dealt with fundamental and industrial research performed in the interwar years by the colloidal chemistry group.

research.[80] This is a further argument that large-scale organisations also grew during the interwar years and did not suddenly emerge during the Second World War. It is worth noting that academic studies about industrial research and about companies incorporating large-scale organisations make good indicators in the context of this thesis. They show how to handle corporate archives to draw a company's social narrative and answer research questions. The relationship between Eastman Kodak and these academic fields is therefore significant.

Can Kodak Research be defined as a large-scale organisation for some periods of its history? It was certainly true during the Second World War from 1943 to 1945. During this two year period several hundred of scientists from Eastman Kodak and Tennessee Eastman Company took care of the electromagnetic separation of plutonium stage in the Y-12 plant at Oak Ridge, Tennessee. Hanson, Leermakers, Ballard and Webb among others had to adapt the theory developed by the physicists from the University of California, Berkeley, to high-end chemical processes to separate uranium-235 from uranium-238.[81] This episode is however not sufficiently documented either in existing publications or in the many documents of the Kodak Collection archive in London.[82] For this reason, further consideration is merited, although it will not be treated in this thesis. It is a particularly relevant case study in the context of large-scale organisations that remains to be written using other Eastman Kodak archives, if any exist. In this thesis, it is more difficult to describe the fundamental and applied research work that occurred at Kodak Limited, Pathé and Kodak-Pathé as large-scale research projects.

---

[80] See also Augustin Cerveaux, "Taming the Microworld: Dupont and the Interwar Rise of Fundamental Industrial Research," *Technology and Culture* 54, no. 2 (2013), 262-288.

[81] "*There were two stages of the electromagnetic process – the stuff would come out of the first one and you'd get out 2 percent or 3 percent of what you put in it. Then you would have to put that through a chemical reaction and put it through another electromagnetic process.*" Recollections of Wesley T. Hanson in *Journey: 75 years of Kodak Research*, 89.

[82] The best testimony of the period was made by the chemical engineer Dr. Robert Schrader, who was employed by Eastman Kodak to work on the Manhattan Project from 1943 to 1945. See Robert J. Schrader, "Eastman Kodak & The Manhattan Project," September 30, 2002, The Manhattan Project Heritage Preservation Association, Inc., accessed June 15, 2013, www.mphpa.org/classic/COLLECTIONS/OR-RSCH/STORY/Pages/RSCH_Gallery_01.htm ; Robert J. Schrader , *Eastman Kodak and the Manhattan Project at Oak Ridge, Tennessee : the atomic bomb* (Longview: Robert J. Schrader, 2004).

Budgets and staff numbers are not of the same. But the analysis of the body of large-scale organisations studies was particularly important in decrypting the methods used by Eastman Kodak to undertake fundamental and industrial research and to start thinking about a social study of this multifaceted community of researchers.

Apart from the Du Pont case and its legitimacy for integrating the field of large-scale organisations, other scholars of the discipline have focused their research on the many activities of the scientists facing a major project with multiple constraints. The prominent academic figure to have taken on the subject remains Galison, with his thorough studies of communities of scientists and his concept of the *trading zone*. In 1997 Galison wrote: "I find it helpful to begin thinking through the relation of physics and technology by focusing on specific sites - laboratories - in which instruments and experimental practice come face to face with technological structures".[83] The author was deeply concerned with experimentation and instrumentation and both aspects were treated in a publication at the end of the twentieth century. In 1987 Galison addressed the neglected subjects of laboratory practice and experimentation in his doctoral dissertation.[84] He used three case studies (the measurement of the gyromagnetic ratio of electron, the discovery of the muon and of weak neutral currents) to discuss the nature of experiments in the history and philosophy of science. In his preface, Galison also explained the methodology he used to write such case studies and what kind of documents he analysed. The growth of collaborative experiments provided new archive material for the historian such as progress reports, conference proceedings, proposals and photocopied minutes along with standard artifacts such as notebooks or letters. In *Image and logic*, Galison focused on instrumentation, considered as a subculture of microphysics.[85] Breaking with the dominant theorists of the historiography of microphysics at the time, the author stressed the materiality of the scientist's activity. In his review of *Image and Logic*,

---

[83] Peter Galison, "Three Laboratories," *Social Research* 64, no. 3 (1997b): 1128.

[84] Peter Galison, *How Experiments End* (Chicago: University of Chicago Press, 1987).

[85] Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997a).

Ziman noted that "scientific facts are not just made by attentive, imaginative observers: they are made by material devices and cultural institutions".[86] Galison thoroughly reviewed several fundamental scientific instruments of the twentieth century such as cloud and bubble chambers or Geiger counters. The author also used the concept of the *trading zone* taken from the anthropology literature to define the nature of the interface between different categories of scientific communities. How could physicists, engineers or computer scientists collaborate despite their distinct languages and paradigms? It is in the *trading zone* that distinct languages merge and that creoles progressively materialize during the scientific collaboration. For Galison, the *trading zone* and its "creolization" constitutes "the social, material, and intellectual mortar binding together the disunified traditions of experimenting, theorizing, and instrument building".[87] After the publication of the book, the metaphor of the *trading zone* was frequently discussed or criticized.[88] With regard to this thesis, Galison's thinking elucidates many organisational aspects of Kodak Research. For instance, it explains why a scientific fact discovered during fundamental research in a specific laboratory, was successfully used by different actors throughout an innovation's process and converted from theory to practice, up to and including the manufacturing of new Kodak products. Therefore, the existence of this beneficial "mortar" which links Kodak heterogeneous scientists, managers and engineers stresses the many similarities between industrial research at Eastman Kodak and large-scale research projects management. It definitely connects the American manufacturer with the field of large-scale organisations through its research structure.

---

[86] John Ziman, "An Evolutionary History of High Energy Particle Physics, with Metascientific Goals," *Minerva* 36, no. 3 (1998): 289.

[87] Galison, *Image and Logic*, 803.

[88] See for example Olivier Darrigol, "Critical Review. Image and Logic: A Material Culture of Microphysics by Peter Galison," *Revue d'Histoire des Sciences* 54, no. 2 (2001): 255-260; Vaughan discussed how the concept of *trading zone* was used at the Nasa, see Diane Vaughan, "The Role of the Organization in the Production of Techno-Scientific Knowledge," *Social Studies of Science* 29, no. 6 (1999): 913-943; Ziman, "An Evolutionary History", 289-293.

Since the 2010s, the same field was used to study present large-scale projects in high-energy physics. Giudice clarified why the Large Hadron Collider (LHC), a particle accelerator operating at the European laboratory CERN near Geneva, should be considered a “Big Science” project.[89] The author provided a comparison of costs between the LHC project and famous large-scale projects such as the Manhattan Project, the Apollo Program or the International Space Station. In 2012 McDonald and Widlake published a report about the Gambit and Hexagon satellite reconnaissance programs a few months after the declassification of confidential records from the National Reconnaissance Office of the United States of America.[90] For this long-term reconnaissance program, developed during the Cold War, collaborations were set up with several industrials, Perkin-Elmer and Eastman Kodak in particular. The photochemists of Rochester developed improved high-definition and fine-grain films, as well as mono-dispersed films. Even more recently ten scholars published a book about the development of the European Spallation Source (ESS), a new large-scale research project at Lund University, Sweden.[91] The authors stressed the complex nature of this large-scale organisation and studied its cultural, social and political aspects from various scholarly disciplines. These recent studies, as well as Galison’s publications, are an appropriate introduction into the methodology and routine work of scientists undertaking fundamental and applied research. However, another recent academic discipline goes further into the analysis of the researcher’s role, activities and tools, to discover scientific facts.

---

[89] Gian Francesco Giudice, "Big Science and the Large Hadron Collider," *Physics in Perspective* 14, no. 1 (2012): 95-112.

[90] Robert A. McDonald and Patrick Widlake, "Looking Closer and Looking Broader: Gambit and Hexagon - the Peak of Film - Return Space Reconnaissance After Corona," *National Reconnaissance* (2012).

[91] Thomas Kaiserfeld and Tom O'Dell, *Legitimizing ESS: Big Science as a Collaboration Across Boundaries* (Lund: Nordic Academic Press, 2013).

1.2.4. The contribution of Science and Technology Studies

The Science and Technology Studies (STS) approach, an interdisciplinary scholarly field that has challenged the history of science during the last decades, provides some indications for understanding how social historians conducted their historical studies on scientific institutions or on industrial research activities. However, the task of deciphering the several waves of social history of science was not easy. [92] This new generation of historians wanted to increase the knowledge about the quotidian activities of scientists in the laboratory. In short, they wanted to refresh the social study of scientific practice.

The discipline of STS has produced flagship publications investigating this practice as well as the scientific knowledge produced. Kuhn's *Structure of Scientific Revolutions* directly influenced the cohort of STS scholars during the second half of the twentieth century.[93] Kuhn stressed in particular the importance of scientists and their role into the research organisation. [94] As Dear pointed out in 2012, the investigation into scientific communities and their own paradigm has not been followed by many studies from historians of science.[95] As to the SSK, this new field grew in the 1970s both in the University of Edinburgh with Barry Barnes and David Bloor and in the University of Bath with Harry Collins. This "strong program" of science studies developed partially in opposition to some Kuhnian theories. Science is seen as a social activity: sociologists of scientific knowledge take into account the various social factors of scientific practice such as history, economy or culture, in the construction of knowledge.

---

[92] In his editorial to the special issue on artifact and experiment of the *Isis* journal in 1988, Sturchio made a clear review of the main areas of scholarly investigation undertaken until then by social historians of science. The three *complementary programs* identified were the sociology of scientific knowledge (SSK), the ethnography of laboratory life and material culture studies. See Jeffrey L. Sturchio, "Artifact and Experiment," *Isis* 79, no. 3 (1988): 368-372.

[93] Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).

[94] "If science is the constellation of facts, theories, and methods collected in current texts, then scientists are the men who, successfully or not, have striven to contribute one or another element to that particular constellation." Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1970), 1.

[95] Peter Dear, "Fifty Years of *Structure*," *Social Studies of Science* 42, no. 3 (2012): 425.

In 1971, Ravetz discussed the nature of scientific fact and its social construction, and by extension the importance of the scientist's research work.[96] In particular the author studied the social processes involved in the conversion of an individual research report into scientific knowledge. Scientific reasoning was also defined as craft reasoning, the craft researcher demonstrating some tenuous links with the reasoning of an artist. Ravetz was somewhat ignored by the new generation of historians of science in the 1980s. One of the rare scholars to study Ravetz's thought was the philosopher Ackermann in a chapter devoted to scientific facts and scientific theories.[97] The scientists themselves became a privileged case study as they greatly influenced the results of scientific research.[98]

In 1979 Latour and Woolgar moved into the research laboratory transforming it with an original ethnographic methodology to better analyse scientists' research work. For two years they studied the activities of a community of researchers in the context of biomedical research at the Salk Institute and established how the *scientific fact* (the discovery of the structure of a peptide) was constructed in the laboratory.[99] They made great use of the process and meaning of writing scientific papers in a research structure. For them, the researchers' descriptions created evidence of their work, making it possible for the non-specialist observer to better ascertain the organisation of the laboratory and the collaboration between researchers and the production of knowledge in the end. The scientific literature produced became this knowledge and material evidence of the scientific fact that had just been discovered. But Latour and Woolgar investigated the products of scientific research, not the scientific reasoning and the mechanisms of research directly. It is these lacunae this thesis fills, in the

[96] Jerome R. Ravetz, *Scientific Knowledge and its Social Problems* (Oxford: Clarendon Press, 1971).

[97] Robert John Ackermann, *Data, Instruments, and Theory: A Dialectical Approach to Understanding Science* (Princeton, N.J.: Princeton University Press, 1985). See the beginning of chapter 4, "Scientific facts and scientific theories", 112-117.

[98] "The individual experimental scientist is not a machine, noting pointer readings, counting blips, but rather he or she brings highly developed craft skills to the relevant tasks". Ibid., 113.

[99] Bruno Latour and Steve Woolgar, *Laboratory Life: The Social Construction of Scientific Facts* (Beverly Hills: Sage Publications, 1979).

framework of Eastman Kodak Research.[100] On the heels of Latour, Knorr-Cetina showed in greater detail how a scientific paper is conceived from the grounding of a research effort in the laboratory, the writing of the many versions of the paper including the rationale and the *Methods* and *Results* sections. The scientist is seen as a *Literary Reasoner* from which the scientific product of the laboratory is transformed into the written product of a scientific paper.[101] Knorr-Cetina's methodology is partially used in chapter 3 to analyse the Harrow research reports from Kodak Limited.[102]

In 1987, Latour clarified his newly developed concept of Actor-Network Theory (ANT), in which both human and nonhuman entities can interact, through the publication of *Science in Action*.[103] How can the living activity of a scientific community be gauged? For Latour, the challenge was to "penetrate science from the outside" but without becoming a scientist or an engineer once got into science. Scientists, or *insiders*, generated the products of science. But "how they did it, we don't know". While

---

[100] Furthermore, the ethnographic methods used by the authors, acting as anthropologists going to visit an unfamiliar culture, was particularly convenient for a social study of an existing community. In the context of my research however, this strategy could not be used since the Kodak Research Laboratories, as depicted in the archives, were no longer active.

[101] Karin Knorr-Cetina, *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science* (Oxford; New York: Pergamon Press, 1981), 94.

[102] The pioneering study of Latour, Woolgar and Knorr-Cetina was discussed, as well as other studies of social history of science, during a workshop held at the University of Twente, The Netherlands, in July 1984. In 1987, the collected papers formed a work which marked a turning point in the STS field, alongside Shapin and Shaffer's *Leviathan and the Air-Pump*. The goal of this interdisciplinary workshop was to broaden speakers' profiles and to mix sociologists with historians of technology. Thus, a great variety of scholars invested the topic such as Pinch, Hughes, Callon, Collins or Woolgar. The title of the workshop finally resulted in the new field, social studies of technology, a branch of STS. See Wiebe E. Bijker, Thomas Parke Hughes and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, Mass.: MIT Press, 1987); Steven Shapin, Simon Schaffer and Thomas Hobbes, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life: Including a Translation of Thomas Hobbes, Dialogus Physicus De Natura Aeris by Simon Schaffer* (Princeton, N.J.: Princeton University Press, 1985). As summed up by Bijker and Pinch, "*we all agreed that describing the activities of actors […] was more interesting than a promethean history of technology that emphasized how heroic inventors and engineers stole great ideas about technology from the gods and gave them to mere mortals*." Wiebe E. Bijker and Trevor Pinch, preface to *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* by Wiebe E. Bijker and Trevor Pinch, Anniversary ed. (Cambridge, Mass.: MIT Press, 2012), xvii.

[103] Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, Mass.: Harvard University Press, 1987).

regretting that few people had studied "*from the inside*" the mechanisms of science and technology, the author noticed that "there exist, fortunately, a few people, either trained as scientists or not, who open the black boxes so that outsiders may have a glimpse to it."[104] Except for the historical context, my own research about the community of Kodak researchers sound like a response to Latour's call. And while sticking to Kodak, it is striking to read how Latour applied his metaphor of the black box to the famous slogan "*Push the button, we'll do the rest*". The "rest" is this black box that the customer did not see but that was necessary. It was made of a large commercial network as well as an industry involving know-how and high-end technologies. "When you push the button you do not see the salesmen and the machines that make the long strips of celluloid films and the trouble-shooters that make the coating stick properly at last; you do not see them, but they have to be there none the less".[105] By opening the black box of Kodak Research to analyse the scientists and engineers' many activities, this thesis responds to Latour's wish in *Science in Action*.

As summed up by the sociologist and historian of science Pickering, the ethnographic approach of *Laboratory life* (Latour & Woolgar 1979) and the *Manufacture of knowledge* (Knorr-Cetina 1981) as well as the ethnomethodology developed by Lynch, Livingston and Garfinkel[106] in 1983, challenged the foundations of sociology of scientific knowledge (SSK).[107] For Pickering this discipline also faced a problem: scientific practice had been neglected by SSK scholars, who concentrated on the products of science and on knowledge in particular.[108] For the author, the activities of

[104] Ibid., 15.

[105] Ibid., 137.

[106] Michael Lynch, Eric Livingston and Harod Garfinkel, "Temporal Order in Laboratory Work," in *Science Observed: Perspectives on the Social Study of Science*, eds. K. Knorr-Cetina and M. J. Mulkay (London; Beverly Hills: Sage Publications, 1983), 205-238.

[107] Andrew Pickering, ed., *Science as Practice and Culture* (Chicago: University of Chicago Press, 1992).

[108] "*SSK simply does not offer us the conceptual apparatus needed to catch up the richness of the doing of science, the dense work of building instruments, planning, running, and interpreting experiments, elaborating theory […]*". Ibid., 5.

the scientists were as important as the knowledge produced by them. But, how does one undertake such a science study? According to the social epistemology claimed by Fuller in the same publication, "science must be studied in its own terms, not in terms that are alien to the scientific enterprise."[109] For the author, this view of science studies opposes the view of classical epistemology. The problem is that science could only become understandable by "insiders", in the framework of Polanyi's "tacit knowledge". That is to say, scientific knowledge that is transferred from expert to novice in the laboratory. Finally, for Fuller, the epistemologist is an interpreter of the scientists' activities and he has to use the "context" or "background knowledge" to provide the sense of scientific practice. With his "scientific turn", what Fuller claimed could be defined as an expert epistemology of science studies. And the expert nature of the epistemologist makes sense when it comes to analysing the scientific practices of Kodak researchers in the twentieth century.

In 2002, Collins and Evans questioned the nature of the legitimacy of a sociologist or an historian in technical and scientific decision-making.[110] By extension, it could also be applied to the legitimacy of doing social historical studies about scientific knowledge. Like Fuller, the authors made proposals concerning the level of expertise necessary for the researcher. They proposed a third Wave of Science Studies, the Studies of Expertise and Experience. Collins and Evans identified three levels of expertise: no expertise at all, interactional, and contributory expertise. The second one "means enough expertise to interact interestingly with participants and carry out a sociological analysis" and the last one "means enough expertise to contribute to the science of the field being analysed".[111] With regard to my own place in this classification, within the

[109] Steve Fuller, "Social Epistemology and the Research Agenda of Science Studies," in Andrew Pickering, ed., *Science as Practice and Culture* (Chicago: University of Chicago Press, 1992), 391.

[110] H. M. Collins and Robert Evans, "The Third Wave of Science Studies: Studies of Expertise and Experience," *Social Studies of Science* 32, no. 2 (2002): 235-296; see also Michael E. Gorman, "Levels of Expertise and Trading Zones: A Framework for Multidisciplinary Collaboration," *Social Studies of Science* 32, no. 5/6 (2002): 933-938; Michael E. Gorman, *Scientific and Technological Thinking* (Mahwah, N.J.: L. Erlbaum, 2005).

[111] Collins and Evans, "The Third Wave," 254.

context of my historical research, I can define my profile as a “social epistemologist” with an interactional expertise, due to my educational background and my scientific knowledge of the photographic industry.[112] This characteristic is particularly significant for studying the Harrow research reports in chapter 3 and for deciphering the many patents related to color photography in chapter 4.

Finally, the present thesis also adopts the rationale of studies of functioning laboratories, or ‘lab studies’ as they are called by Doing, Sismondo and other scholars[113], as discussed above. Alongside notebook studies, lab studies are frequently described as an academic field that arose in the 1980s but that lost momentum in the twenty-first century.[114] In his excellent historiography of the discipline, Doing made a critical study of the real contribution of lab studies to the epistemology of scientific practice and the nature of the scientific fact. Revisiting Lynch,[115] Knorr-Cetina (1981), Latour & Woolgar (1979), Collins[116] and Pinch,[117] the author noticed that laboratory studies did not address the way scientific activities produce an enduring fact.[118] Indeed, this weakness may represent a limitation of the anthropological approach to

---

[112] Finally, the definition that corresponds best to me is the title of “expert epistemologist”.

[113] Park Doing, “Give Me a Laboratory and I Will Raise a Discipline: The Past, Present, and Future Politics of Laboratory Studies in STS,” in *The Handbook of Science and Technology Studies*, ed. Edward J. Hackett and others, 3rd ed. (Cambridge, MA; London: The MIT Press, 2008): 279-295; Sergio Sismondo, *An Introduction to Science and Technology Studies* (Chichester, U.K.: Wiley-Blackwell, 2010).

[114] The laboratory also interested other academic discipline such as cognitive science. For instance Nersessian considered research laboratories as “*evolving distributed cognitive systems*”. The study of scientific thinking within the laboratory is possible with a cognitive approach. See Nancy J. Nersessian, "Interpreting Scientific and Engineering Practices: Integrating the Cognitive, Social, and Cultural Dimensions," in *Scientific and Technological Thinking*, ed. Michael E. Gorman and others (Mahwah, N.J.; London: Lawrence Erlbaum Associates, Publishers, 2005), 51.

[115] Michael Lynch, *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory* (London; Boston: Routledge & Kegan Paul, 1985).

[116] H. M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London; Beverly Hills: Sage Publications, 1985).

[117] Trevor Pinch, *Confronting Nature: The Sociology of Solar-Neutrino Detection* (Dordrecht, Holland; Boston; Higham, MA, U.S.A.: D. Reidel Pub. Co, 1986).

[118] From his analysis of early or recent lab studies the author concluded that there was “*a cleavage in the field with subsequent and important anthropologies of laboratories bringing out important modalities of scientific research, but not pursuing particular episodes of fact making*”. Doing, “Give me a laboratory,” 289.

laboratory studies. As the paradigm of the sociologist or the ethnographer is so far from the paradigm of the scientist, when the first is studying the scientific practices of the second, both researchers do not see the same thing.[119] Within the context of this thesis and in my capacity as "expert epistemologist", I use my background knowledge as an asset to study the Kodak research organisation, while remaining outside the Kodak laboratories, which no longer exists. The notebook studies approach used in chapter 3 for the study of the Harrow research reports and the personal notebooks enhances our understanding of the multifaceted activities of the Kodak researchers and their methods of innovation.[120]

1.2.5. The management of scientific knowledge

While reviewing the field of STS, I soon noticed that this discipline could not provide answers to some scientific and organisational practices within a research laboratory. STS and lab studies may clarify the context of the creation of a scientific fact but they cannot truly ascertain the nature of the scientific knowledge produced. Furthermore, the following questions could not be solved: How do scientists process new knowledge produced in the laboratory? What do they do with it? How is the collaborative work planned to increase the production of knowledge? Referring to industrial laboratories and not only to fundamental research done in national laboratories, do researchers follow a model to innovate and direct their work towards specific knowledge?

---

[119] Sismondo, *An Introduction to Science*, 107.

[120] Notebooks studies represent an important branch of the history of science. They can provide an enhanced historical reconstruction of the scientist's experimental research work and rationale. See for example Charles Darwin and al., *Charles Darwin's notebooks, 1836-1844: geology, transmutation of species, metaphysical enquiries* (London: British Museum (Natural History), 1987); Frederic Lawrence Holmes, *Lavoisier and the chemistry of life: an exploration of scientific creativity* (Madison, Wis: University of Wisconsin Press, 1985) ; Frederic Lawrence Holmes and Hans Adolf Krebs, *Hans Krebs: the formation of a scientific life, 1900-1933* (New York, N.Y.: Oxford Univ. Press, 1991) ; Frederic Lawrence Holmes, Jürgen Renn and Hans-Jörg Rheinberger, *Reworking the bench: research notebooks in the history of science*, (Dordrecht [u.a.]: Kluwer, 2003).

1.2.5.1. Industrial secrecy or knowledge transfer

These questions stress the importance of the nature and management of knowledge. In industrial research, and in the field of photographic research in particular, two opposite fundamental practices control the management of knowledge: secrecy and transfer of knowledge. This thesis examines the use of these two notions within the photographic industry. As early as 1952, Mees made use in a short paper of the outdated view of science versus technology to justify the use of industrial secrecy. Scientific advances had to be published "because science advances as a whole", but knowledge related to manufacturing technology was not supposed to be published.[121] However, as it is difficult to keep industrial secrets in the factory, Mees mentioned that the use of the patent was a solution for firms to protect themselves from competitors. Consequently, this practice also partially contributed to the diffusion of technical and scientific knowledge. Apart from Mees and other people involved directly with industry in general, the notion of secrecy has received scant attention from scholars. In 1998, a workshop was held at Ithaca, New York about secrecy and knowledge production. Scholars studied "the relationship of secrecy to the production of scientific and technical knowledge" within the context of national security and industry.[122] In particular, Dennis stressed Merton's view about the relationship between science and secrecy, and Shuldiner provided a history of secrecy at Corning, and some historical facts about the collaboration between this well-known glass manufacturer and the military during the two World Wars.[123] More recently, Balmer argued that secrecy could not always be criticized but could instead be used as an "active spatial-epistemic tool" to help governments to define reality.[124] Discussing the potential threat of the

[121] Mees, "Secrecy and Industrial Research," 972.

[122] Judith Reppy, ed., preface to *Secrecy and Knowledge Production* (Ithaca, N.Y.: Cornell University Peace Studies Program, 1999), ii.

[123] Alec Shuldiner, "Learning to Keep Secrets: The Military and a High-Tech Company," in *Secrecy and Knowledge Production*, ed. Judith Reppy (Ithaca, N.Y.: Cornell University Peace Studies Program, 1999), 76-90.

[124] Brian Balmer, "A Secret Formula, a Rogue Patent and Public Knowledge about Nerve Gas: Secrecy as a Spatial-Epistemic Tool," *Social Studies of Science* 36, no. 5 (2006): 691-722.

diffusion of a patent about VX nerve gas in 1975, the author discussed the concepts of dangerous, secret or public knowledge.

Nevertheless, beyond the dangerous or innocuous nature of knowledge, the constant dilemma for scientists and inventors is to balance its sharing with its non-disclosure. A newly developed technology can be replicated if its inventor shared too much critical information about it or by reverse engineering.[125] By contrast, the scientist needs to disclose his findings when seeking the recognition of his scientific community. Evans introduced both behaviours towards scientific knowledge, by comparing the use of secrecy by academic scientists and industrial researchers.[126] In his study, the author explored how academics shared their knowledge during collaboration with industrial researchers. He concluded that "academics were seen, by the companies that partnered with them, as inconsistently professional and often unreliable in protecting research ideas and resources".[127] To share or to withhold knowledge? This teamwork with industrial researchers forced academic scientists to reduce their use of the principle of knowledge sharing.

In modern industries, the concept of sharing knowledge is discussed more and more through the term of technology transfer. Some authors such as Headrick have provided historical studies.[128] He demonstrated how large transfers of technologies such as railways and plantation agriculture from the Commonwealth to its African and Asian colonies succeeded in various ways and were progressively influenced by

---

[125] Reverse engineering practices mean the analysis of a physical product to understand the nature of its components and how it was manufactured. The goal of this method can be the production of a similar product. Kodak researchers at Harrow conducted some reverse engineering studies with products from the competition, see section 3.2.3.

[126] James Evans, "Industry Collaboration, Scientific Sharing, and the Dissemination of Knowledge," *Social Studies of Science* 40, no. 5 (2010): 757-791. Evans also mentioned Merton and his norm of communism for which all discovered knowledge should be shared. Thus academic secrecy, if any, was seen as necessary only before the publication of the discovery and the recognition of the scientific community.

[127] Evans, "Industry Collaboration," 779.

[128] Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford University Press, 1988).

research work in the colonies.[129] Other studies are more professionally oriented, such as that of Speser or Sullivan who provided a complete method for scientists to manage their intellectual property, including the writing of a technology transfer agreement or the creation of a company to secure a possibly patented technology.[130] Recently, Ganguli et al. mixed the historical and practical with their publication about technology transfer in biotechnology.[131] The authors stressed how this practice of transfer was shaped regionally and how in this industry the intellectual property was firmly controlled by the patent system. Beyond the nature of technology transfers, the direction of the knowledge flow can also be a source of information. The Lichtenthalers studied the two ways technology can be transferred within the context of "Open Innovation" that I discuss at the end of this section.[132] To measure the performance of outward technology transfer between companies, they used the concept of desorptive capacity as opposed to absorptive capacity.[133]

1.2.5.2. Patent strategies

This heterogeneous body of literature about "knowledge management" does not deal with the control of scientific knowledge companywide. Industrial research laboratories need and do protect their scientific assets through a policy of intellectual property of which the patent system is one of its tools. During data collection from the Kodak Collection archive, more and more artifacts surfaced, related to patents and business relationships with independent inventors. It appeared possible to estimate the

---

[129] See for example Headrick, *The Tentacles of Progress*, 248-250.

[130] Phyllis L. Speser, *The Art & Science of Technology Transfer* (Hoboken, N.J.: John Wiley Sons, Inc, 2006); Neil F. Sullivan, *Technology Transfer: Making the most of Your Intellectual Property* (Cambridge; New York: Cambridge University Press, 1995).

[131] Prabuddha Ganguli, Ben Prickril and Rita Khanna, eds., *Technology Transfer in Biotechnology: A Global Perspective* (Weinheim; Chichester: Wiley-VCH ; John Wiley, 2008). See also Sifeng Liu et al., ed., *Theory of Science and Technology Transfer and Applications* (Boca Raton: CRC Press, 2010).

[132] Ulrich Lichtenthaler and Eckhard Lichtenthaler, "Technology Transfer Across Organizational Boundaries: Absorptive Capacity and Desorptive Capacity," *California Management Review* 53, no. 1 (2010), 154-170.

[133] "*While absorptive capacity refers to a firm's ability to recognize, assimilate, and apply external knowledge, desorptive capacity describes a firm's ability to transfer its own knowledge to external partners.*" Ibid., 166. It can be noted that Kodak Limited showed an absorptive capacity to assimilate Martinez and Schinzel scientific knowledge, as studied in Chapter 4.

contribution of independent inventors to Eastman Kodak's research and innovation. In order to do that, however, it is necessary to ascertain the part this external scientific knowledge played in the results of industrial research performed within the laboratory's departments. The appearance of independent inventors in the archive provided an opportunity to study some scientific collaborations with the exterior. As to the status of such inventors and the resulting patent system, Hintz recently clarified to what extent American independent inventors cooperated with corporate research and development laboratories.[134] The status of "independent inventor"[135] did not quickly disappear with the rise of industrial research in the first half of the twentieth century. Models given by Hintz to describe the innovation strategies of independent inventors and firms can clarify the scientific collaboration between the – initially - independent chemists Mannes, Godoswky, Martinez or Schinzel and the Eastman Kodak Company. For instance, the "ally" model for which inventors enter into contracts with firms and license their patent on a royalty basis is particularly relevant (see Figure 1).[136] After all, as pointed out by Nicholas, independent inventors retained a major role in U.S. technological development in the interwar years as they still represented 53% of the U.S. granted patents in 1930.[137] The same author used a similar methodology to conclude that this figure was approximately the same in 1930 for Britain and Japan.[138] But he also stressed that British inventors were disadvantaged compared with their American counterparts because patent fees were far more expensive and patent life shorter, even if the 1883 Patents Act reduced patent filing fees drastically in Britain.[139]

---

[134] Eric S. Hintz, "The Post-Heroic Generation: American Independent Inventors, 1900-1950," *Enterprise & Society* 12, no. 4 (2011): 732-748.

[135] Ibid., 733-734.

[136] Ibid., 739-741.

[137] Tom Nicholas, "The Role of Independent Invention in U.S. Technological Development, 1880–1930," *The Journal of Economic History* 70, no. 01 (2010): 57.

[138] Tom Nicholas, "Independent Invention during the Rise of the Corporate Economy in Britain and Japan," *The Economic History Review* 64, no. 3 (2011a): 997.

[139] Ibid., 999, 1009; see also Tom Nicholas, "Cheaper Patents," *Research Policy* 40, no. 2 (2011b): 331.

Strategy	Independent inventors	Flow of patents and technical information	Firms
Make	Inventor–entrepreneur	Not applicable	Industrial research
Sell/buy	Assign (sell) patents	→	Buy patents, outsourcing
Ally	License patents, alliance/consulting	↔	Pay royalties, alliance/retainers
Mixed/hybrid	Both independents and firms can pursue multiple strategies simultaneously		

Figure 1. Innovation strategies between independent inventors and firm.[140]

In the same field of literature, some authors clarified the contribution of the patent and its nature to scientific knowledge. In her original study about patents, knowledge and technology transfer, De Laet used the patent document as a *carrier of knowledge* and an active *mediator*. Basing her study on transfer of technology between pharmaceutical industries and African countries, the author opposed the protective aspect of the patent to its sharing nature, a vehicle for knowledge. The patent is finally granted a role in the transfer of technology and knowledge. One might indeed wonder to what extent scientific knowledge produced is hidden within the many claims of the patent literature. After all, this knowledge and the resulting invention that is claimed within the patent is a fragile artefact. As Myers pointed out, “an invention is established in the world only when there is someone to make it, to sell it and, if necessary, to defend its status in the courts”.[141] Sometimes, the final owner of the manufactured invention as well as its intellectual locus are even subject to debate. Latour took as a model the eventful development of the Diesel engine at the end of the nineteenth century. The initial patent of Diesel of 1887 never worked and the technology was finally developed by the engineers of the MAN company. Latour lastly wondered if the working engine had to be called a Carnot, Diesel or a MAN engine.[142] By extension, with regards to a major technological innovation, scientific knowledge is

[140] Hintz, “The Post-Heroic Generation,” 739.

[141] Greg Myers, "From Discovery to Invention: The Writing and Rewriting of Two Patents," *Social Studies of Science* 25, no. 1 (1995): 97.

[142] Latour, *Science in Action : How to Follow Scientists and Engineers through Society*, 107.

frequently scattered through a “wave” of successive patents and not totally contained in a founding patent. This multi-level rise of knowledge allows the team of researchers to refine the technology in question.[143]

However, the patent does not always result in a manufactured invention. Firms frequently used this protective aspect of patenting a scientific invention in the last century and still do today. Thus, this strategy of countering the competitors in a specific technological direction acts as an innovation shield.[144] On the contrary, the patent can also become an offensive weapon, used to sue competitors and counterfeiters before a court. This rather negative side of the patent should not be neglected. Mangolte used the case study of the motion pictures “patents war” from 1897 to 1908 to show how the offensive aspect of the patenting strategy between the Edison company, the American Mutoscope & Biograph Company and other actors of the movie industry was a dead end for the business of the whole sector.[145] Belligerent parties finally had to come to an arrangement and created the Motion Picture Patents Company in 1909 to gather a pool of patents and to organize a licensing system. From a bureaucratic perspective, Fisk illustrated how the universe of inventors and research organisations was more and more surrounded by a set of legal constraints such as contracts or noncompeting agreements, progressively established by patent and Copyright laws.[146] Finally, to the detriment of the patent system, Moser recently found through historical analyses that the existence of patent laws in one country did not

---

[143] I want to thank Etienne Weber, Agent of the Patent Department of Kodak Industrie, Chalon-sur-Saône, for our discussion about patent strategies in March 2013.

[144] With a couple of patents, a company can control a promising technology that has been theorized but not used to launch a new product. Due to this “shield” a competitor cannot innovate using this technology and must bypass it, or buy a licence, to develop a similar product. Therefore, protective patents act principally as a brake on innovation.

[145] Pierre-André Mangolte, "Brevets et Émergence de l'Industrie Cinématographique, Une Étude Comparative Etats-Unis - Europe (1895-1908)," *Annales, Histoire, Sciences Sociales* 61, no. 5 (2006), 1123-1145; Pierre-André Mangolte, "Patents Wars : Brevet d'Invention et Patent, Une Comparaison" (working paper, HAL, Centre d'Economie de l'Université Paris Nord, http://hal.archives-ouvertes.fr/hal-00624454, 2010).

[146] Fisk, *Working Knowledge Employee Innovation and the Rise of Corporate Intellectual Property, 1800-1930*.

increase the number of innovations produced when compared with a country without patent laws.[147] Even more surprising, according to Moser the part of innovations developed outside of the patent system prevailed in countries with patent laws.[148] This means that the patent could also act as the enemy of innovation processes despite its possible capability to transfer knowledge.

1.2.5.3 "Innovation models"

Scientific knowledge, patents and innovation are all interrelated. My literature review ends with the concept of innovation, because during the data collection in the Kodak archives, I encountered several methods used to conduct scientific research, perform in-house experiments, and collaborate with other firms or independent inventors. In short, the methods used by the Kodak Research Laboratories to innovate were amazingly varied and far from the image of the industrial research laboratory in which "Closed Innovation" is performed. One of the first economists to seriously tackle the concept of "technological innovation" was the Austrian Schumpeter. It is striking to note that his first important study about entrepreneurship, economic development and innovation was published in German in 1911, just when Mees and Eastman were organizing the new Research Laboratory at Rochester.[149] In the first English version of *The Theory of Economic Development*, Schumpeter provided a definition of the innovation concept.[150] For the author, it represented the introduction of a new product or a new method of production, the access to a new market or a new supply of raw materials, or a new industrial organisation.[151] Consequently the innovation process operates after the process of invention. It neither integrates discoveries of

[147] Petra Moser, "Patents and Innovation: Evidence from Economic History," *The Journal of Economic Perspectives* 27, no. 1 (2012): 23-44.

[148] Ibid., 40.

[149] Joseph A. Schumpeter, *Theorie Der Wirtschaftlichen Entwicklung*, ed. Duncker & Humblot (Leipzig: Verlag von Duncker und Humblot, 1911).

[150] Joseph A. Schumpeter and Redvers Opie, *The Theory of Economic Development. an Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle* (Cambridge, Mass.: Harvard University Press, 1934).

[151] Thomas J. Allen and Günter Henn, *The Organization and Architecture of Innovation: Managing the Flow of Technology* (Amsterdam; Boston: Elsevier; Butterworth-Heinemann, 2007), 7.

scientific facts nor inventions. As clarified by Gaudin, invention is an act of intellectual creativity, while innovation consists in an economic decision to adopt an invention.[152] For the same author, Schumpeter did not clarify how the process of innovation itself works, as did the economic historian Maclaurin from the MIT. This scholar studied the mechanisms of technological change and clarified how a new scientific discovery could lead from the theoretical stage to a commercial success. Maclaurin developed, after the Second World War, the theory of a "linear model of innovation", different from Schumpeter's views. Technological innovation was seen as a sequential process made of four distinctive stages: pure research, applied research, engineering development and production. He later refined his theory with five stages, namely pure science, invention, innovation, finance and acceptance or diffusion.[153]

As regards the measurement of innovation within firms, Arundel et al. clarified the many tools available to estimate knowledge creation such as patents, bibliometrics, numbers of research staff, research and development budgets or journal articles.[154] They also provided the knowledge flows between firms and thus introduced the mechanisms of patent innovation, protection of knowledge through secrecy, licensing agreements or reverse engineering. My present research ascertains if all or any of these mechanisms were used at Eastman Kodak. In recent years, the concept of "innovation model" has often been linked to the organisation of research and development (R&D).[155] New theories have emerged to increase the efficiency of R&D within the framework of a worldwide competitive economy. Cooke introduced the notion of "regional innovation systems". He showed that this "systemic innovation at the regional level" was recent in Europe but less efficient than in the United States

---

[152] Benoît Godin, "In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation," *Minerva* 46, no. 3 (2008): 344.

[153] Ibid., 349.

[154] Anthony Arundel et al., *The Future of Innovation Measurement in Europe: Concepts, Problems and Practical Directions* (IDEA paper n°3, Maastricht: STEP Group, 1997).

[155] "Innovation model" is a recent term particularly used in economic and business studies. It is used in the present thesis to identify the nature of Kodak research methods in the scope of these studies, in parallel with my social historical research.

because it was mostly driven by the public system.[156] Successful or not, this modern organisation of innovation in which a cluster of regional firms gather their R&D and collaborate remains worthy of interest. With this cooperative aspect in mind, Chesbrough claimed a paradigm shift from “Closed Innovation” (the classic in-house R&D) to “Open Innovation”.[157] The last model tends to treat R&D as an open system by favouring external sources of technology in the innovation process. Consequently, this process is no longer confined to the industrial Research Laboratory. Thus “great inventions can come from both inside and outside the company”.[158] “Open Innovation” was not supposed to remain confined to academia. It was seen as a new method of innovation by its inventor and is still used within the present industry.[159] However, Chesbrough’s model also attracted criticism. Trott and Hartmann pointed out that many previous researchers found concepts similar to those used by “Open Innovation”. While the authors recognized that Chesbrough’s model popularized the need to share and exchange knowledge, they also questioned, “if Open Innovation is in essence nothing new, why then has this concept been so readily embraced by firms and the R&D community?”.[160] As a new “model of innovation” can have some historical background, the academic debate above illustrates the difficulty of defining a

---

156 Philip Cooke, "Regional Innovation Systems, Clusters, and the Knowledge Economy," *Industrial and Corporate Change* 10, no. 4 (2001): 958.

157 Henry William Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting from Technology* (Boston, Mass.: Harvard Business School Press, 2003); Henry William Chesbrough, Wim Vanhaverbeke and Joel West, *Open Innovation: Researching a New Paradigm* (Oxford: Oxford University, 2006).

158 Robert J. Allio, "Interview with Henry Chesbrough: Innovating Innovation," *Strategy and Leadership* 33, no. 1 (2005): 21.

159 See for instance Roland Berger et al., *Innovating at the Top: How Global CEOs Drive Innovation for Growth and Profit* (Basingstoke; New York, NY: Palgrave Macmillan, 2009); Philipp Herzog, *Open and Closed Innovation: Different Cultures for Different Strategies* (Wiesbaden: Gabler, 2011); Henry William Chesbrough and Sabine Brunswicker, “A Fad Or a Phenomenon? The Adoption of Open Innovation Practices in Large Firms,” *Research Technology Management* 57, no. 2 (2014), 16-25.

160 Paul Trott and Dap Hartmann, "Why 'Open Innovation' is Old Wine in New Bottles," *International Journal of Innovation Management* 13, no. 4 (2009): 731. See also David C. Mowery, "Plus Ca Change: Industrial R&D in the "Third Industrial Revolution"," Indu*strial and Corporate Change* 18, no. 1 (2009): 1-50; Cécile Ayerbe and Valérie Chanal, « Droits de Propriété Intellectuelle et Innovation Ouverte : les Apports de Henry Chesbrough, » *International Management* 14, no. 3 (2010): 99-104.

clear boundary between the history of industrial research or business history, and business and economic studies, as these fields are interrelated.

Using this literature, it is possible to ascertain if a specific “model of innovation” was used at Eastman Kodak principally during the interwar years. The extensive body of the archive allows an in-depth study of the transfer of scientific knowledge, the patent strategy and the “models of innovation” used by the three Research Laboratories.

1.2.6. Approaches used and historiographies to which this study contributes

The science and technology studies approach is used in this thesis to avoid the pitfall of telling a linear history of technological and scientific milestones. More than that, STS researchers conduct social analyses of under-studied communities and professional networks and thereby bring a complete understanding of the ins and outs of the progress of large-scale research projects or the narrative of “science in the making”. Such an approach has been fundamental in focusing my research on the specific network of this community of photoresearchers, either insiders or outsiders to Eastman Kodak, and its heterogeneous activities. The STS approach underpins the major argument of this thesis that science and technology do not exist per se but only derive from the desire and the research work of the scientists, engineers and technicians, and in the case of Kodak research specifically, following managerial decisions. A scientific or technological fact does not wait for a brilliant scientist to suddenly discover its existence one day and claim it as an invention. By contrast the “fact” is progressively identified and characterised by the thought and the rationale of scientists through experimentation and observation. In this way, the social study of these particular actors, their organisation, their networks and their management of scientific knowledge in the framework of the thesis provides a holistic understanding of what industrial research at Kodak in Europe really was in the first half of the twentieth century. With the exception of Peter Galison’s study of nuclear emulsions, few STS scholars have focused on the photochemical industry although it provides a rich source for studies of this sort.

But this thesis also relies on other fields of study. An interdisciplinary approach is made necessary by the complexity of Kodak industrial research, as well as the heterogeneity of the primary and secondary sources used during the research work. The STS methodology could not address what the thesis proposes to do, namely to prosecute social historical research of a community of researchers so far ignored by history, although the tracks of its activities are still recent and vivid. Considering the nature of the primary sources used in this thesis, the contribution of bureaucracy studies was important as well.[161] In addition to the group of secondary sources about Eastman Kodak and the photographic industry, which provided various information for this research, the qualitative analysis of a full set of bureaucratic artefacts provided the core of the research findings: research reports, legal agreements, unpublished internal reports, patent folders, personal notebooks and typescripts about project supervision. The wealth of information gathered from this heterogeneous corpus of corporate documentation proves that the use of bureaucratic archives, although rather technical sometimes, is a successful strategy for the conduct of historical research. Such an archive should not be neglected by historians of the photographic industry and the same strategy could be applied to the study of Kodak research at Rochester, Ilford or Agfa research.

The bureaucratic studies approach can also contribute to other historiographies, such as business history, to which this thesis is oriented.[162] The production and sale of

---

[161] On bureaucracy studies, see, for example, Peter Becker and William Clark, *Little tools of knowledge: historical essays on academic and bureaucratic practices* (Ann Arbor, Mich: University of Michigan Press, 2001); Frank Fischer and Carmen Sirianni, *Critical studies in organization and bureaucracy* (Philadelphia: Temple University Press, 1984); Yehouda A. Shenhav, *Manufacturing rationality: the engineering foundations of the managerial revolution* (Oxford: Oxford University Press, 1999) and Alexander Styhre, *The innovative bureaucracy: bureaucracy in an age of fluidity* (London: Routledge, 2007).

[162] A good introduction to the discipline is given by Alfred D. Chandler, *The visible hand: the managerial revolution in American business* (Cambridge, Mass: Belknap Press, 1977). For a recent analysis related to visual technology and culture, see Sean F. Johnston, *Holographic visions: a history of new science* (Oxford: Oxford University Press, 2006). Johnston recently clarified that this publication "provided an in-depth account of the creators and concepts behind the subject of holography as a scientific concept, an

analogue photographic and cinematographic films were a successful business for a very long period from the early years of cinematography to the end of the twentieth century. Total margins generated from the photographic industry, and Eastman Kodak in particular, remained exceptionally high for decades and directly financed the conduct of industrial research. A history of Kodak research made from the analysis of Kodak bureaucratic practices contributes to a better understanding of the corporate mechanisms leading to scientific milestones and market success. Technology and innovation brought by the Kodak research laboratories were used by the firm to further develop a popular culture of products, allowing market expansion and the achievement of new business targets. Pertaining to the methods of innovation used by large business organisations, this thesis shows that Kodak research was governed by the concepts of risk, uncertainty, technological and even historical constraints.

I mentioned at the beginning of the introduction that the study of Kodak research was crucial because it complements our understanding of the photographic medium as a whole. It is worth pointing out here that this thesis also contributes to the history of photography, in particular to the notions of the lengthy invention of photography and the processes of innovation used by the photographic industry.[163] It complements existing studies about the nature of the photographic industry, the development of

---

engineering tool and a business. See Sean F. Johnston, *Holograms: A Cultural History* (Oxford: Oxford University Press, 2015), 4.

[163] Contributions to the photographic industry have been explored by, for example, Elizabeth Anne McCauley, *Industrial Madness: Commercial Photography in Paris, 1848-1871* (New Haven: Yale University Press, 1994) and Michael Pritchard, "The Development and Growth of British Photographic Manufacturing and Retailing 1839-1914" (PhD diss., De Montfort University, 2010). Recent histories of colour photography are given by, for example, Jack Howard Roy Coote, *The Illustrated History of Colour Photography* (Surbiton: Fountain, 1993) and Pamela Glasson Roberts, *The Genius of Color Photography: from the Autochrome to the Digital Age* (London: Goodman, 2010). On the invention of early photography see, for instance, Jean-Louis Marignier, *Nicéphore Niépce (1765-1833). L'invention de la photographie* (Paris, Belin, 1999); Larry J. Schaaf and William Henry Fox Talbot, *Records of the dawn of photography: Talbot's notebooks P & Q* (Cambridge [England]: Cambridge University Press in cooperation with the National Museum of Photography, Film & Television, 1996) and Roger Taylor and Larry J. Schaaf, *Impressed by light: British photographs from paper negatives, 1840-1860* (New York: Metropolitan Museum of Art, 2007). This thesis, by revealing how science and technology were used to invent photography, originally contributes to Wilder's recent publication, which clarified how photography was used for "doing" science. See Kelley Wilder, *Photography and science* (London: Reaktion, 2009).

colour in photography and the research work of the ‘primitive’ inventors of photography in the nineteenth century. Using unpublished archival material, my research shows for the first time how an entire industry was set up during a period of the twentieth century, and who the human sources engaged in the research and development of new photographic processes really were. With this new knowledge in mind, we can better comprehend the nature of our own visual culture in the twentieth century, intrinsically linked to the existence of imperfect and ever improved photographic materials with unique characteristics. We can now acknowledge that photography taken as a whole was created by its first inventors of the nineteenth century, by the masters of the medium and many amateur photographers since 1839, but also by the cohorts of inventors and photochemists of the twentieth century inside and outside the Kodak universe.

The present thesis also sheds new light on some aspects of the history of technology. It questions the management of intellectual property regarding the continuous flows of scientific and technological knowledge produced by Eastman Kodak or by third parties. Complementing existing studies about government secrecy, my research contributes to the under-studied field of industrial secrecy, one aspect of intellectual property. It provides the practical terms of industrial secrecy within the research laboratories and the production departments, and its consequence for public photographic research.[164] But the thesis also refreshes studies about the history of the patent system, by firstly ascertaining that this bureaucratic system represented a major constraint for the photographic research. Secondly, the description of scientific collaboration between Kodak Limited and independent inventors clarified how scientific knowledge was progressively optimised literally from the lab bench to the issuance of a patent. This

[164] On industrial secrecy, see Brian Balmer, *Secrecy and science: a historical sociology of biological and chemical warfare* (Farnham: Ashgate, 2012). For an account of government secrecy, see Peter Galison, “Secrecy in Three Acts,” *Social Research* 77, no. 3 (2010): 941-74. See also the documentary film about the topic made by Peter Galison and Robb Moss, *Secrecy*, Bullfrog Films, 2008.

new outlook on the photographic patent complements existing attempts to inventory photographic knowledge from the international corpus of related patents.[165]

Finally, the thesis makes a significant contribution to industrial research studies, in particular with the delicate task of deciphering the nature of industrial secrecy at Eastman Kodak from the analysis of disparate corporate archives. This study shows that industrial research is not only a matter of statistical figures about budgets and staff, the critical question of return on investment and the possible milestones produced, but also that this discipline has everything to gain from taking into account the human factor and the career paths of researchers, the evolving organisation of the research structure and the circulation of scientific knowledge inside. Historians of industrial research should not overlook the study of daily work done in the laboratories, if the related archive exists, to be able to disclose whole sections of industrial history.[166]

---

[165] Regarding the use of the patent system in the photographic and movie industry, historians usually try to draw some conclusions about the medium through the establishment of directories or inventories related to a specific period or technology. See, for example, Janice G. Schimmelman, *American Photographic Patents 1840-1880: The Daguerreotype and Wet Plate Era* (Nevada city: Carl Mautz-Publishing, 2002) and Franz Schmitt, *Dictionnaire des brevets cinématographiques français : des origines à 1929* (Paris: Prodiex, 1996). In France, the online database created by Constantin Imbs regarding the corpus of French patent applications related to photographic technology between 1845 and 1913 is unfortunately no more available at http://brevetsphotographiques.fr. See Constantin Imbs, « Répercussions esthétiques attendues des différents procédés d'enregistrement photochimiques et de restitution de l'information photographique au XIXe siècle » (MA diss., Sorbonne (Paris-IV), 2004) and Constantin Imbs, « Classification des procédés photographiques du XIXe siècle (réalisée à partir des brevets pris en France) » (Unpublished paper, available at www.yumpu.com/fr/document/view/17037638/classification-des-procedes-brevets-photographiques, 2007).

[166] A priori the only study about the conduct of industrial research in the photographic sector is given by Bertrand Lavédrine and Jean-Paul Gandolfo, *The Lumière Autochrome: History, Technology, and Preservation* (Los Angeles: Getty Conservation Institute, 2013). For similar studies related to laboratories in other industries, see, for example, Marc J. de Vries, *80 Years of Research at the Philips Natuurkundig Laboratorium: (1914-1994): The Role of the Nat.Lab. at Philips* (Amsterdam: Pallas Publications, 2005). An account of histories of corporate laboratories made in the 1980s is given by Michael Aaron Dennis, “New Histories of Corporate Laboratories and the Social History of American Science,” *Social Studies of Science* 17, no. 3 (1987): 479-518.

1.3. Methodology of the research

The temporal context of the research is particular because Eastman Kodak was a very important company which was still active in 2016, although the number of employees was drastically reduced and its structure recently modified. Conducting qualitative research on the British and French communities of Kodak researchers would have been the ideal pretext to engage in an ethnographic study with them, in the style of Latour and Woolgar in 1979. Unfortunately, it is impossible because the time of scientific research at Eastman Kodak has passed. In Chalon-sur-Saône, France, the building of the *Centre de Recherches de Kodak Industries* is still in place but without any researchers in its deserted laboratories. In Cambridge, the Kodak European Research Labs was an ephemeral research structure that opened in 2006 and closed in 2009. But what Kodak Limited bequeathed to scholars was a huge heterogeneous archive at the British Library. The former employees of Kodak-Pathé managed to rescue similar corporate archives and artifacts in Chalon-sur-Saône. In this context, I decided to adopt a social historical research to study the activities of the Kodak European scientific community and to compare my research questions to the collected data and evidence from the archives. Digging into such documents from the past and progressively constructing some narratives about researchers active in the first half of the twentieth century has not to be seen as establishing a "congealed" history of Kodak research. After all, "such a narrative account, at its best, is flowing, revealing, vibrant, alive."[167]

1.3.1. Timeline of the research

This thesis is the result of thorough archival research during the three years of my PhD scholarship. It is worth clarifying the general timeline of the research to better point out the development of my ideas and the progressive drafting of the chapters. I started the bibliographical research and the reading of the secondary sources for the

[167] Bruce L. Berg and Howard Lune, *Qualitative Research Methods for the Social Sciences*, 8th ed. (Boston: Pearson, 2012), 305.

literature review at the end of 2011. At the same period, I was introduced to the Kodak Collection in the Special Collections at the Kimberlin Library, De Montfort University. I collected some data in this Collection during the year 2012 but I rapidly noted that the Kodak Collection's content was not exactly relevant to my research, although invaluable reports or monographs could be found there.[168] This archive was lacking some primary sources so I decided to focus on the Kodak Collection Archive at the British Library. I first visited this very important archive in terms of volume in January 2012 with Dr. Michael Pritchard, currently Director-General of The Royal Photographic Society, who was the first scholar to dig into the many boxes and who did the first inventory. At the time this inventory was at the stage of drafting but it helped me enough to identify documents and boxes directly connected with Kodak fundamental and industrial research. However, the archive's huge size did not assist the identification of the relevant primary sources to consult. The access to the Kodak Collection Archive in the reading rooms at the British Library was not possible before June 2012. So I started my first data collection in this exceptional industrial archive the same month with the help of John Falconer, Lead Curator Visual Arts at the British Library. From June 2012 to June 2014, I organized and realized 11 archival researches at the British Library.[169] The methodology I used to collect data in the Kodak Collection Archive is described in section 1.3.2.

In September 2012, I created ethics forms to be able to conduct some interviews of former Kodak researchers and managers.[170] However, at the same time, the situation changed due to new evidence in France proving that a scientific archive might exist at

---

[168] The Kodak Collection in the Special Collections at the Kimberlin Library represents a large part of the scientific library of the former Kodak Research Laboratories in England. It is made of the main periodicals since the beginning of photography, publications and monographs by Kodak researchers, some general publications in the science of photography and some unpublished reports from Kodak Limited. It constitutes an exceptional set to better understand how a Research Laboratory worked in the photographic industry in the twentieth century.

[169] For the year 2012, 4 data collections were made in June, September, October and November. In 2013, I made 5 data collections in January, February, June, September and November. In 2014, I finished with 2 data collections in January and June. Each stay represented from 2 to 5 days at the British Library.

[170] These documents were made of a research information sheet and of a consent form.

the former Kodak-Pathé industrial site. In April 2012, I first approached the Fondation Jérôme Seydoux-Pathé in Paris to consult the index notebook of Marcel Mayer, the works manager at Pathé in Joinville-le-Pont during the 1920s. During my visit, Stéphanie Salmon, director of historical collections, informed me about the recent creation of the association CECIL near Chalon-sur-Saône and the possible existence of unidentified Kodak-Pathé archives. During 2012, I established first contact with Jean-Pierre Martel, President of CECIL, and I planned my first visit to the Kodak-Pathé archive in March 2013.

This visit in the French archive modified the framework of my research. I found the almost complete set of research notebooks made by the Pathé photochemists from 1906 to 1927 and by the Kodak-Pathé researchers from 1928 to the 1960s. From this time onward I was able to consider a comparison between the English and French research reports made from 1929 on, but also to study the transfer of scientific knowledge between the three main Kodak Research Laboratories in Harrow, Vincennes and Rochester. I made a second visit to CECIL in November 2013 and for both visits, I was able to make the full reproduction of the documents consulted. In this way, only two visits were made in the Kodak-Pathé archive. As a consequence, I decided not to conduct some interviews and to spend more time on the analysis of the French archive, to complement and to improve chapters 2 and 3. Due to the additional archive material to collect and analyze, but also due to my supervisors' request to increase the scope of the literature review, my application to transfer from MPhil to Doctor of Philosophy was slightly delayed and finally obtained in February 2014. In parallel, I started the writing of the general draft of my thesis in January 2014, and I finished this first version of the dissertation in May 2015.

1.3.2. Methodology in practice

According to Danto, up to five categories of historical evidence can be collected to conduct historical research: primary sources, secondary sources, running records such as agency reports, and recollections (including autobiographies and oral history). The author also mentioned possible artifacts such as maps, objects or artwork.[171] I had at my disposal the British and French Kodak archives which constitute the primary sources available. These corporate and scientific archives are made up of correspondence, research reports, notebooks, legal documents and patent folders among other things. I also consulted a wide range of secondary sources directly or indirectly linked with the history of Eastman Kodak. I found some oral histories of former Kodak researchers that had already been transcribed at the end of the twentieth century, and several biographies and obituaries of Kodak research leaders. With this in mind, I decided to avoid a chronological narrative of a general history of Kodak Research but rather to favour a thematic scheme with chronological sections and case studies to answer the research questions. The data analysis was therefore concentrated on the information collected from the scientific Kodak archives and was compared with the data enclosed in several secondary sources on a regular basis. The data collected and analysed from the archives were a decisive asset in ascertaining how topics of research were selected, how inventions and scientific knowledge were progressively produced and how teamwork was planned amongst the laboratories of Rochester, Harrow and Vincennes.

At the start of my research, the possibility of conducting some interviews with former Kodak researchers in Britain and in France arose. With this prospect I constructed a consent form for interviewees addressing the necessary ethical issues related to this type of data collection. In parallel, I started to find some earlier interviews conducted in the 1970s and 1980s which gathered recollections from scientists who had partially worked at Eastman Kodak in the United States. Transcripts, abstracts and the interviews were found in the Chemical Heritage Foundation and on the Niels Bohr Library and Archives websites.[172] These findings included the transcript of an undated

[171] Elizabeth Ann Danto, *Historical Research* (New York: Oxford University Press, 2008), 5.

[172] See the Chemical Heritage Foundation website, Center for Oral History, accessed August 5, 2014, http://www.chemheritage.org/research/institute-for-research/oral-history-program/index.aspx; the Niels Bohr Library & Archives website, American Institute of Physics, Oral History Interviews, accessed August 5, 2014, https://www.aip.org/history-programs/niels-bohr-library/oral-histories.

interview with Walter Clark, first director of the Harrow Research Laboratory, about infrared aerial photography and another undated interview with Wesley T. Hanson, the director of Kodak Research at Rochester from 1972 to 1977, at the Clarence E. Larson Collection from the Engineering and Technology History Wiki.[173] I conducted a concise analysis of the interviews' content and this first glance demonstrated that while the active living period of the interviewees was relevant for my research, the information delivered was not of prime importance. Some recollection could only be sporadically connected to the research questions. As an example I enclose an extract of the interview made in 1983 of the astrophysicist Dr. Walter Roberts, who first worked at Eastman Kodak in the development department.

> Roberts:
>
> I was in the development department under a man named Fred M. Bishop. The development department was one of two parts of the research lab under Kenneth Mees. There was the pure research, and there was the development side. But I did, interestingly enough, have a lot of contact with Mees, who knew of my astronomical interests and so on, and a lot of close personal contact with Fred Bishop, who was a marvelous man. I was in a group that was really incredibly close and friendly. We were developing new products. We had to do two things.
>
> We had to develop new products for the company, and test them out, and we had to test the competition, so that Kodak knew what the other companies were doing. Occasionally we had to do very unusual things; for example, my boss in my first year at Kodak, had to re-design the optical system of the Bell and Howell projector, because it wouldn't project Kodachrome very well. It was such an inefficient optical system that the Kodachrome didn't show up well on the screen and Kodak was losing money, because people who had Bell and Howell projectors didn't like their pictures. So we redesigned the optical system, and gave the new design to Bell and Howell, and they went ahead and marketed it, and they still use that same condenser system that Kodak designed back then.
>
> DeVorkin:
>
> Was the sprocketing different?

[173] "An Interview with the Godfather of Modern IR Film", Willem-Jan Markerink personal website, accessed November 25, 2014, http://www.markering.org/WJM/HTML/wa_clark.htm; Engineering and Technology History Wiki (formerly IEEE Global History Network), Clarence E. Larson Collection, accessed August 10, 2015, http://ethw.org/Wesley_T._Hanson. Hanson's interview is undated and was made prior to 1987, the year of Hanson's death.

Roberts:

> No, the sprocketing was the same. I think the light taken through the gate, from the bulb to the gate, was inefficiently used, and they were getting only about 40% as much light as they could from the bulb through the film. It was just a matter of poor optical design, and Kodak had superb optical experts. So we redesigned the optical system for Bell and Howell, in order to sell more Kodachrome. At least that is how I remember it. Then a crazy guy came around with a camera that you could take pictures and develop them immediately, and we tested that camera and decided it was impractical. His name was Edwin Land![174]

As this extract indicates, interviews can provide valuable information.[175] But the interviewee cannot immerse himself in his own past again in the same way he experienced it. His memories depend on the interviewer's questions and on the capacity of his mind to remember. Through the interviewee, some specific facts will emerge from the past while others will not be mentioned without a particular prompt. Instead, the archival artifact is better dealing with the time of "science in the making". Ideas and thoughts are still clear in the scientists or managers' mind when they put them in a letter, be it in a research report or through a technical notice in a personal handbook. Having observed this, I decided not to conduct any additional interviews to complement my data collection. The fact that the possible interviewees would only have been able to provide about the period 1960-2000 was another reason. It would have been problematic to ensure continuity between the time period of the historical archive, principally the interwar years, and this period, 1960-2000, for the data analysis. Lastly, the discovery of the French Kodak-Pathé archive in 2013 and the subsequent data collection and analysis this represented provided another strong argument against the conducting of interviews.

With regard to the nature of the European Kodak archives, the heterogeneity of the materials was evident from the start of the qualitative data collection. The two Kodak

---

[174] Interview of Dr. Walter Roberts by David DeVorkin on 26th July 1983, Niels Bohr Library & Archives, American Institute of Physics, Oral History Interviews, accessed June 16th 2015, https://www.aip.org/history-programs/niels-bohr-library/oral-histories/28418-1.

[175] For instance, the extract indicates that Eastman Kodak was undertaking competitive intelligence.

archives could not be considered as a complete and exhaustive corpus. First of all, preservation conditions of the archives on both industrial sites before the donation of Kodak to the British Library and the CECIL association are not clear, and there are some indications that neither archive is entirely complete. Secondly, when a corporate division is either closed, dismantled or transferred, the fate of surviving corporate archives is a secondary concern. Furthermore, a proportion of these archives will be physically destroyed depending on their level of confidentiality and on the directives followed by the archivist, if any. At the British Library the Kodak Collection Archive was unclassified and frequently chronologically mixed. It was therefore impossible to consult the entire corpus of the archive about a specific topic, or to claim to do so.

In this context, it was not convenient to adopt a methodological approach based on a chronological and descriptive history of the research conducted in the Kodak laboratories over several decades. It was clear that the adoption of a linear model of the research process (involving a strong separation of the sampling, the data collection and the data analysis) was impossible. The nature of the Kodak archives has led me to favour the collection of topical data from which process and draw case studies, all related to the research questions. For that purpose, I have taken into account the Grounded Theory method used in the social sciences, which involves the finding of theory through the progressive analysis of data.[176] As I had no *a priori* assumptions on what exactly would be found in the collection of data, I concentrated my initial sampling on the framework of the research questions. Thus, several periods were studied: before the creation of the first Kodak Research Laboratory in 1912, during the 1930s principally with the Harrow research reports, and during the Second World War when research on colour photographic processes was predominant. I selected the scientists and managers to study according to their relevance to my research topics.[177]

[176] Barney G. Glaser and Anselm L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research* (Chicago: Aldine Pub. Co., 1967); Juliet M. Corbin and Anselm L. Strauss, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (Thousand Oaks: Sage Publications, 1998).

[177] Uwe Flick, *An Introduction to Qualitative Research*, 4th ed. (Los Angeles: SAGE, 2009), 91.

Following an initial analysis of the findings, I had to refine my sampling of the archive for the next process of data collection, before returning to each Kodak archive. For instance, the research notebooks of the French Kodak archive were only inventoried in October 2013, and it was difficult to speculate about what would be found in them before this necessary archive work was completed. At the British Library, as it was impossible to finance the large-scale reproduction of several years of Harrow research reports, I carried out the data analysis on the fly, speeding up the data collection process of Grounded Theory. This methodology helped me to broaden the scope of my research and not to focus on the English research reports only. I was able to consider Kodak Research as a whole, including the period of pre-industrial research in Harrow and in Vincennes with the competitor Pathé, and not only from 1912 and the creation of the Kodak Research Laboratory at Rochester. The case studies collected in relation to scientific collaboration provided some innovative conclusions about Kodak research, in particular the mixed use of “Closed and Open Innovation” by Kodak during the interwar years.

The use of Grounded Theory did not simplify in the research process, but one of the advantages of this approach is that the collection and the interpretation of the data are frequently close, and that the initial qualitative analysis is partially completed during the collecting process. The research process that I used can therefore be identified with a circular model, for which the starting point is the definition of preliminary assumptions, followed by the collection of a first data sampling, their interpretation and comparison, and as many other collections of data as necessary. That is to say, it is from this global corpus of data that the theory is expected to emerge and be formulated. As Flick mentioned, Grounded Theory research “allows the researcher not only to ask the following question repeatedly but also to answer it: How far do the methods, categories, and theories that are used do justice to the subject and the data ?”[178]

---

[178] Ibid., 92.

Chapter 2: Evolution of Research and Development at Eastman Kodak Company

2.1. Knowledge and secrecy about emulsion-making during the Interwar period

2.1.1. The secretive practices of film manufacturers

When studying research and development within the photographic industry, the work carried out on emulsion-making would appear to be a relevant indicator in the evolution of manufacturing innovations and related scientific discoveries about the behaviour of the photographic emulsion. However, inadequate secondary sources or detailed publications supplied by film manufacturers make this problematic. Very little has been written about the process, since photographic research was mostly confined to laboratories belonging to private industries and the necessity to keep key processes secret considerably restricted the exchange of knowledge in the public domain. The more the method behind film-making was dominated by the principle of secrecy, the less researchers studied the matter in the twentieth century, breaking with the tradition of the previous century.

Despite its limited quantity, however, literature about emulsion and film-making is generally identified and promoted by specialists, most of them involved in the photographic industry.[1] As no substantial external literature was produced concerning the daily activities of the Kodak Research Laboratories or those of competitors in the photographic industry, it is relevant to consult the rare literature devoted to the production of emulsion and film within the industry. Indeed, the use of trade secrets can indirectly provide some information on how the research was handled to produce

[1] See for example Dr. Wolfgang F. Berg, introduction to *The Photographic Emulsion*, by Burt H. Carroll, Donald Hubbard and Charles M. Kretschman (London: Focal Press, 1968), 7. Dr. Berg worked at Kodak Limited in Harrow from 1936 to 1961 as the director of the emulsion department.

knowledge and technical tools related to emulsion-making. Moreover, the study of the collaboration between national research laboratories and the research structures of film manufacturers provides complementary information regarding emulsion research.

During the Interwar period, one unique publication written by Edward John Wall in 1929 described some steps of the production of photographic emulsions. After *The Dictionary of Photography* (1889), *The History of Three-Color Photography* (1925) and *Photographic Facts and Formulas* (1924), Wall published in 1929 his *Photographic Emulsions.*[2] Although Wall started his career as a chemist in the plate manufacturing company B.J. Edwards & Co. in London, he was not directly connected with a film manufacturer during the Interwar period and thus *Photographic Emulsions* can be considered as an independent work about the science of making black and white film. In his preface, the author points out the rarity of literature in the field, recognising that there had been no work available about emulsion-making since William de W. Abney's *Photography with Emulsions* (1885) and Joseph M. Eder's *Photographie mit Bromsilber-Gelatine und Chlorsilber-Gelatine* (1903).[3] The main purpose of the book, as indicated by the author, was to provide enough technical information to enable the amateur to undertake research work on emulsion-making. According to Wall, the reason for the lack of data about the subject is simple.

> Practically all the knowledge is secreted in the great factories. The worker at this point stands practically in the position of the man who first discovered emulsion photography, and he must battle his way through and pull himself up until he has acquired a knowledge equal to what is known at the present day.[4]

Wall also clarifies that in his publication, "no trade secrets have been disclosed nor any confidences violated, even if such be in the writer's possession."[5] In a chapter about

---

[2] E. J. Wall, *Photographic Emulsions. Their Preparation and Coating on Glass, Celluloid and Paper, Experimentally and on the Large Scale* (Boston: American Photographic Publishing Co, 1929).

[3] Ibid., iv.

[4] Ibid., v.

[5] Ibid., iv.

the mixing of emulsions, while discussing the greater sensitivity of iodide of silver to red and orange than of bromide of silver, describing this property as a "trade secret never disclosed", Wall goes back to the problem of the exchange of knowledge since the rise of the photographic industry.[6]

> This trade or professional etiquette, which prevents the manufacturer from giving information as to his emulsions, is a serious stumbling block in the advance of our knowledge of the real whys and wherefores of emulsion making. In the early days, and it must not be overlooked that the gelatino-bromide emulsion was discovered by an amateur, the technical journals were filled with accounts of experiments in emulsion making; but since the commercial manufacture of plates an impenetrable wall of silence has shut down, that one might as well try to pierce as get through a modern safe with a knitting needle. This is, of course, explicable and understandable to some extent in view of commercial rivalry, but there can be no doubt that much valuable information might be given without violating professional secrecy.[7]

In the end, Wall dedicated almost four years to this research work and produced "over three thousand very carefully arranged and recorded emulsions […] and approximately five miles of paper", working day and night to this end.[8] The book looks more like a treatise of the nineteenth century, supplying techniques and formulas for many kinds of emulsions, describing the many steps of emulsion-making : the mixing, shredding and washing of the emulsion, the filtering and coating for glass plates, film or paper, and the drying. For the equipment used, although some semi-industrial machines are described such as the coating plates machine of J.H. Smith (see Illustration 1), most of the accessories are generally suited to the amateur photographer.

---

[6] Ibid., 43.

[7] Ibid., 43-44.

[8] Ibid., v.

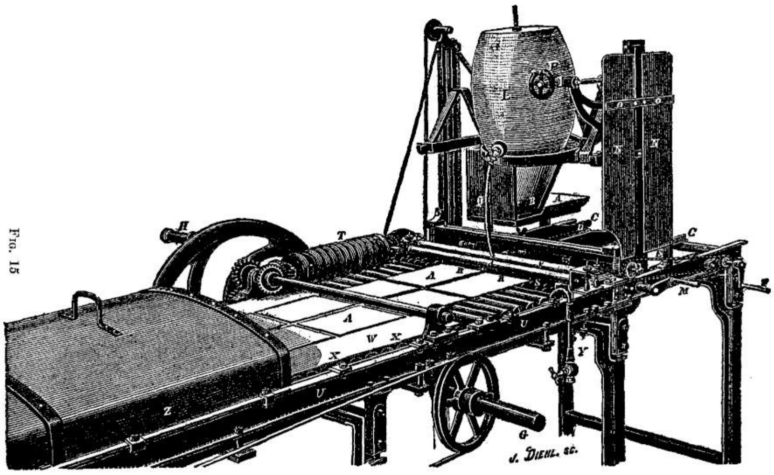


Illustration 1. The J. H. Smith's coating machine, to coat glass plates with photographic emulsion.[9]

At some point, Wall gives indications about his research work procedures. For example, in the paragraph about chloro-bromide and bromo-chloride film emulsions, the author describes some laboratory experiments he conducted to prove that the length of exposure with a constant developer bears no correlation with the colour of the image.

> […] a series of emulsions was made, starting with a pure chloride of silver and then with increasing percentages of bromide from five, ten, twenty, etc., to a pure bromide emulsion. The plates were exposed under a test plate of varying densities from 1 to 3.01, that gave exposures from 1 to 1024. The exposures were made to magnesium ribbon, a Nernst lamp and incandescent gas, and a constant developer metol-hydrochinon, was used.[10]

This empirical method of laboratory work, frequently used in photographic science, was also used at the same period in the Kodak Research Laboratories as it will be studied in section 3.2. However, the method used by one individual cannot be adapted to the work of a set of Research departments. In the same paragraph, Wall gives two

---

[9] Ibid., "Fig. 15", 169. I thank Kirk D. Keyes for the digital copy of Wall's publication available on his personal website at www.keyesphoto.com/index.html.

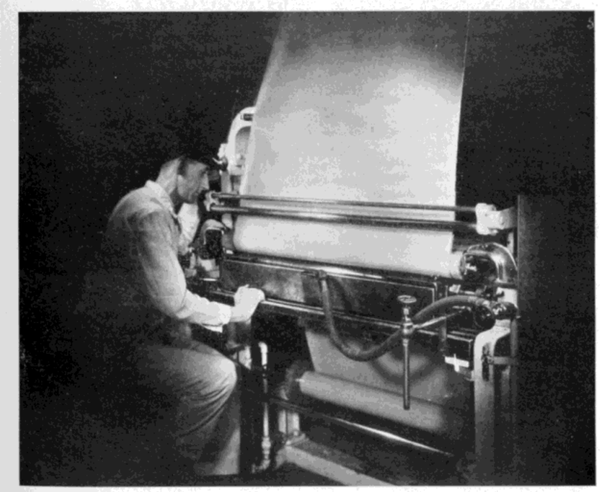
[10] Ibid., 95-96. This bureaucratic and descriptive discourse is similar with the one used in the Harrow research reports. See section 3.2.

formulas for Wellington & Ward Limited and Wratten and Wainwright emulsions. The author indicates that formulas are supplied because “they have been proved commercially to be reliable”, but it is not known if this indication was, at the time of writing, the delivery of a trade secret or if both manufacturers had already communicated the formulas.

Wall’s vast and independent research work must be understood as one of the last attempts to publish with objectivity some technical data about the science of emulsion-making. In *Photography* (1937), the Eastman Kodak director of research, Kenneth Mees adopts on the contrary a corporate discourse, a specific language which allows the author to convey enough descriptive information without any specific essential details or key technology from the company, a language referring to “the impenetrable wall of silence” as criticized by Wall. The purpose of *Photography* is intended to “provide a general review of the whole subject of photography written in a simple and popular style”[11], and although the author devotes the second chapter to the manufacture of photographic materials, the description of processes can be likened to scientific popularization.[12] Five illustrations of equipment used for the making of the film base, the emulsion or the photographic paper were included. These installations were probably those of Kodak Park at Rochester although it was not specified (see Illustration 2).

[11] C. E. Kenneth Mees, *Photography* (New York: The Macmillan Company, 1937), v.

[12] “The machines used in making film base are large and very complicated. They are of many forms: in one form, the surface of a big cylindrical wheel is covered with polished silver. As this wheel rotates very slowly, the solution is run on to it, and, by the time it has gone through one revolution, enough of the solvents have evaporated for the film to have formed so it can be stripped off as the wheel rotates and passed over other drums to dry.” Ibid., 40.



(*b*) Coating the film base with emulsion. (*p.* 44)

Illustration 2. The process of coating the emulsion on the film base, most probably at Eastman Kodak in Rochester.[13]

Some figures cited at the end of the chapter go some way to explaining why the disclosure of data about film making might act as a threat to the employment in the photographic industry. Mees indicated that 30,000 people were employed in the manufacture of photographic materials in various parts of the world in 1937. Too much competition could therefore have weakened this specialized industry. Other figures were supplied, such as the 500 tons of pure silver required per year, the 6000 tons of cotton needed to make the film base or the 3000 tons of prepared gelatin[14]. Mees was aware of the economic issues surrounding the photographic industry and related financial investments. It was therefore impossible to disclose sensitive data about emulsion-making to avoid industrial piracy and forgery.

Breaking with Mees' controlled discourse, the recollections of the photochemist Dr. Fritz Wentzel, published in 1960 by the American Museum of Photography with a foreword by its founder Louis Walton Sipley,[15] are more informative about the technical activities of the photographic sector. Wentzel, a chemist born in Berlin in

[13] Ibid., 41.

[14] Ibid., 48-49.

[15] For Sipley, see Larisa Dryansky , "Le musée George-Eastman", *Études photographiques* 21 (2007), accessed April 21, 2013, http://etudesphotographiques.revues.org/index1082.html.

1877, spent most of his professional career as a consultant for several photographic firms, and obtained a doctorate from the Technische Hochschule Charlottenburg in 1908, with a thesis about the *Contributions to the optical sensitization of silver chloride gelatin*.[16] He started working for the dry plate factory of Unger & Hoffmann in Dresden, “supervising the mixing of developers for sale, working on toning processes, etc.”[17], then for the larger Neue Photographische Gesellschaft near Berlin where the chemist Rudolf Fischer, inventor of the colour developing process in 1914, was working. For Wentzel, since knowledge of the emulsion-making was key to the industry, the policy of secrecy complicated the production of film.

> There was a certain type of man working in the production of photographic materials, the so-called emulsioneer, with often a doubtful background, but possessing some formulae which he had acquired and applied in his employment with more or less success. Secrecy was in full bloom, every new production manager, chemist or emulsioneer, had to start work all over again, because his predecessor had left nothing behind except some basic formulae without any records.[18]

Wentzel contrasts these basic methods of producing film in small plants with the methods of larger companies, who invested in research on emulsions “in well established laboratories”, highlighting the disappearance of these small photographic factories or their absorption by larger entities during the interwar period.

During this period, Wentzel also became acquainted with gelatin manufacturers in Germany, and occasionally obtained information about their manufacturing processes. He provided some details about the making of this critical component of photographic emulsion, however this is a general technical narrative not related to a particular

---

[16] Wentzel, *Memoirs of a Photochemist*, 39. The Technische Hochschule Charlottenburg, created in 1879, was one of the leading scientific universities from the German period 1871-1918. During his studies there, Wentzel was trained by renowned German photochemists such as Hermann Vogel, Carl Graebe, Adolf Miethe or Erich Stenger. In the 1930s, the first director of the Kodak Research Laboratory at Harrow Walter Clark was in contact with Erich Lehmann, a scholar from the same institution, regarding cine and photographic supports. See the analysis of the Harrow research reports in chapter 3.

[17] Wentzel, *Memoirs of a Photochemist*, 21.

[18] Ibid., 23.

manufacturer.[19] More interestingly, the author indicates that suspicion also existed between the customer and the manufacturer, requiring time-consuming trials of batches of gelatin.

> This always has been, and still is, done by sending samples to the customer who makes trials with his emulsion formulae with no knowledge of the past history of the gelatin. On the other hand, the gelatin producer is kept in ignorance, except in very vague and general terms, of the emulsion for which his gelatins will be used. This secrecy on both sides has been a serious handicap in the development of the manufacture of photographic gelatins from the practical point of view because there is still much to be learned […].[20]

Regarding gelatin, some of the mistakes and failures noted by Wentzel are also studied in the reports of the Kodak researchers at Harrow, such as the appearance of spots on the emulsion, or the non-uniformity of the production generating variation in the photographic sensitivity. Referring to the making of photographic emulsion itself, Wentzel is quite prolix, also supplying some references in footnote such as the *Photographic Emulsions* of Wall. The necessary equipment, a list of principal chemicals, conditions of operation and the process is detailed from the first mixing of the components to the coating and drying of the emulsion on film or paper.[21] The author does not indicate from which manufacturing companies he draws his technical information but one can speculate that most of the processes described were inspired from ANSCO or AGFA technology, as Wentzel's last position was at the Ansco paper plant from 1933 to his retirement in 1945, the American Ansco company having merged with Agfa in 1929.

Wentzel, a good friend of the photochemist and photo historian Erich Stenger, was interested in the history of photography too and established his own photographic library. Footnotes of his *Memoirs* are full of references to scientific journals and publications in the field of photography and, as Sipley supposed in his preface,

---

[19] Ibid., 41.

[20] Ibid., 42.

[21] Ibid., 77-80.

Wentzel's book has certainly been "of invaluable service" to students in photochemistry in the second half of the twentieth century.

This rare photochemist's account of the craft of emulsion-making echoes another publication written during the same period, about the making of nuclear emulsions, that is emulsions able to capture particles in the corresponding spectrum. The Canadian author of *Ionographie*[22], Pierre Demers, was studying chemistry and nuclear physics at the nuclear synthesis laboratory in Ivry, France, where he specialized in particle physics for which special nuclear emulsions were requested, in keeping with the recommendation of the scientists Frédéric Joliot-Curie and Hans von Halban. Demers initially tried to establish an industrial collaboration with a film manufacturer but, due to the lack of positive feedback, developed his own nuclear emulsions and soon became an independent emulsion expert[23]. Demers' research work was a long-term project, which probably started just after the Second World War.[24] Complete descriptions of the technology and procedures he developed for the making of these emulsions are included in his publication *Ionographie*, including the improvement of the "emulsion Eastman α" and the selection of a compatible gelatin.[25] For example, products from Difco Bacto and General Foods gave good results, but gelatins "Eastman Pigskin Purified", "Eastman Calfskin Purified" or a selection of Keystone gelatins from

[22] Pierre Demers, *Ionographie. Les Émulsions Nucléaires, Principes Et Applications* (Montréal: Presses Universitaires, 1958).

[23] « Ionographie et photographie utilisent des techniques étroitement apparentées, et j'ai entretenu sans relâche l'espoir d'établir une collaboration industrielle. Pendant un temps, j'ai eu des contacts avec Direct Film, étonnante création et étonnant succès d'un Montréalais d'adoption, Belge d'origine Adrien Cordelier. Mais la toute-puissance de l'omni-présente industrie de Rochester aux États-Unis, associée au secret des procédés de fabrication favorisée par la noirceur des chambres noires où l'on manipule le très sensible bromure d'argent, a eu raison et de Direct Film et de mes plans. » Demers, personal website, last modified 1998, accessed April 12, 2013, http://www.er.uqam.ca/nobel/c3410/BioChap2.html.

[24] Discussing the use of Ilford, Kodak Limited and Eastman Kodak nuclear emulsions in 1954, Delaware mentioned a paper from Demers dated 1947 and recognized his efforts to identify the physico-chemical composition of these emulsions and to provide other workable formulas of nuclear emulsions. See Joseph L. Delaware, "Tracks of nuclear particles in photographic emulsions" (MSc in Physics diss., United States Naval Postgraduate School Monterey, 1954), 10.

[25] Demers, *Ionographie*, 100.

American Agricultural Chemical Company created an abnormal fog on the film.[26] In a chapter devoted to *Kodak, Ilford, and the Photographic Panel*, Galison discusses in 1997 the contribution of Demers to the science of emulsion making[27]. He quotes a translated thought of Demers about the making of negative emulsions.

> "The fabrication of the fastest negative emulsions is surrounded by the greatest secrecy, a fact which is explained simultaneously by industrial necessity and by the nature itself of the techniques employed […]. These procedures are empirical, they hide tricks of the trade and craft recipes (*des tours de main et des recettes de métier*)." One can also add the end of the paragraph : "For these reasons, [these procedures] are difficult to protect with a patent ; it is easier not to make them known. Moreover, the analysis of the finished product shows little about the processes used."[28]

According to Demers, reverse engineering is useless in understanding the methodology used to produce photographic emulsions, and this "impenetrable wall of silence" provided the opportunity for an impressive research work into emulsion-making. Rather than keeping the precious resulting technology and know-how to himself, Demers decided to diffuse it through an exhaustive publication. In *Ionographie*, the author provides 21 complete formulas of nuclear emulsions according to three kinds of process: double spray processes with two burettes (p.105), double spray processes with two syringes (p.114) and processes using pumps (p.123). Demers does not hesitate to formulate advice to the photographic industry when he feels it necessary, such as the proposal to use continuous manufacturing processes for the numerous stages of emulsion-making instead of producing in batches. The mixing, the making of long noodles, the washing, the shredding or the maturation of the emulsion could be processed within this framework.[29] For Galison, Demers "was […] unique in both successfully making new, highly sensitive emulsions and applying them productively to physics problems."[30] However, his work remained a unique experience in independent

[26] Demers, *Ionographie*, 110.

[27] Galison, *Image and Logic : A Material Culture of Microphysics*, 186-196.

[28] Quotation in Galison, *Image and* Logic, 191. From Demers, *Ionographie*, 29.

[29] Demers, *Ionographie*, 124.

[30] Galison, *Image and Logic*, 194.

emulsion-making and ultimately, the outstanding emulsions made by Demers were not used by emulsion physicists, who preferred the larger grain of Kodak and Ilford products.[31] When interviewed in 1985 by Galison, Charles Waller, an emulsion expert from Ilford, continued to express reservations about discussing in detail the photographic processes used at Ilford after World War II.[32] Although the convention of the *silver curtain* was a Kodak tradition, it was also used by other film manufacturers.

Collected at the end of the 1980s in the company's only publication about its research activities, the accounts of researchers and managers at Eastman Kodak about emulsion-making do not depart from the rule of industrial secrecy.[33] Discussions of the milestones and technical achievements in the science of emulsion-making do not extend to the methodology used by the various teams of Kodak organic chemists and researchers. Although the practice of the *silver curtain* and its positive or negative influence is widely discussed.

This corporate policy was developed in 1931 when Kenneth Mees received the approval of the Kodak President William G. Stuber to create a new Emulsion Research Department, the purpose of which was to regroup the skills and knowledge devoted to the photographic emulsion which were widely dispersed within the Eastman Kodak structure. Cyril J. Staud, a promising organic chemist in the company since 1924, was appointed head of the Department. As his team needed some emulsion production formulas in order to make progress, a secrecy protocol was set out to avoid any knowledge leakage, even to the other divisions of the Kodak Research Laboratory.

> The formulas were sent by the manager of the Film Emulsion Division to the director of the Emulsion Research Division on a "need-to-know" basis, and stored in a safe in the director's office. When a researcher needed a formula, he would go to the office, be given the needed formula, and sit in that office while he

[31] Ibid., 196.

[32] Ibid., 191.

[33] *Journey : 75 Years of Kodak Research*.

> translated it from production jargon into emulsion research terminology and codes.[34]

These languages and coding tools were frequently personalised in the following years to increase security about emulsion knowledge, and the nickname of *silver curtain* was invented for this trade secret practice.

It is unclear whether the Film Emulsion Division managers hindered the transfer of emulsion technology to the new Research Department. It can however be noted that in its first years, it was frequently difficult for chemists to obtain the production emulsion formulas. During the necessary work for the completion of the Kodak publication, Jeffrey Sturchio and Arnold Thackray, two independent scholars from the Center for the History of Chemistry at the University of Pennysylvania, undertook a series of interviews with Kodak researchers and managers in the second part of the 1980s. When asked about the *silver curtain*, the chemist Daan Zwick, who was hired in 1944, recalled that the practice had negative consequences on the research work of chemists. Unaware of emulsions formulas, unexpected results often resulted in additional and time-consuming experiments. For Zwick, the director of the Film Emulsion Division at Kodak Park, Earl Arnold played a major role in knowledge retention practices. After Arnold's retirement in the 1960s, secrecy rules were relaxed and new procedures simplified the transmission of emulsion information.[35]

Sturchio and Thackray introduced the question of whether the *silver curtain* changed or influenced the Kodak research process. They gathered the opinions of several researchers, pointing out that they were quite divided depending on their access to the emulsion technology and formulas. However, the arguments in favour of a policy of secrecy were outweighed by the disadvantages noted by researchers. According to Elliot Stauffer, a former director of the Emulsion Research Division, the *silver curtain* was the vector for the introduction of scientific technologies into Kodak manufacture facilities, as some scientists of this division created a development group within the

[34] Ibid., 39.

[35] Ibid., 41.

Film Emulsion Division. One should point out that this technology transfer was unilateral, and that it did not involve in the research process. On the contrary, most "outsiders"[36] to the *silver curtain* were discouraged when looking for sensitive knowledge about emulsion-making and gave up any research directly linked to these data. For Leo J. Thomas, director of the Kodak Research Laboratory from 1977 to 1985, the *silver curtain* "was a device that may have had some rational existence back in the 1920s, but by the 1960s it was an absolutely inexcusable device, and it covered more ignorance than you could possibly believe".[37]

More recently, the technical information collected by Robert L. Shanebrook from 2007 to 2010 about the production of film at Kodak Park demonstrates that even in the last decade the use of the *silver curtain* was still active, at least within the Film Manufacturing Division.[38] The author was able to depict the various steps of the production of colour film in particular because he was a product-line manager at Eastman Kodak before he retired in 2003. He confirms that the *silver curtain* was still in use as there is no documentation of the complete photographic film-making process, and most of the procedures and chemicals remain codified.

> Coding of process and material names is practiced. Early in the exploration of a material or process it is referred to by its scientific or commercial name. If use of the material or process is promising, a code is assigned. When used in manufacturing, it is assigned an alpha-numeric code. The same material at different dilutions may have totally different codes. (5)

Shanebrook stresses that the procedures used to mix the various chemical compounds of the photographic emulsion are also protected by the *silver curtain*. If some reverse engineering methods can determine which compounds were used for a specific film, it cannot reveal how these chemicals were mixed and in which order.

---

[36] In this particular context, the outsiders are researchers and managers working at Eastman Kodak but not in the Emulsion Research Division.

[37] Ibid., 42.

[38] Shanebrook, *Making Kodak Film*, 5.

It appears from these readings that the trade secret of emulsion science and technology seems principally to take place downstream from the research work, and that it concerns mostly the production procedures or the application of new technologies to the manufacturing workflow. The fact that the activity of researchers was disrupted by a lack of cooperation from the engineers and chemists working in the manufacturing plants, does not really clarify how these researchers were supposed to conduct their work on experimental emulsions or new dye testing to improve current films. For Wall or Demers, the initial problem was even simpler; they had to start from scratch with no chance of cooperation and knowledge transfer. But independent photochemists were not the only scientists to suffer from the tradition of trade secrets in the photographic industry. In order to fully understand the problems faced by public sector researchers, it is necessary to clarify the lack of collaboration between public research laboratories or institutions and industrial laboratories in the private sector.

2.1.2. National laboratories versus industrial research

Government awareness of the lack of knowledge in scientific fields that were necessary to the development of industry at the beginning of the twentieth century led to the creation of several national laboratories. These institutions launched all-around research in a wide spectrum of technological and scientific fields, but the connecting thread of the work was the establishment of a global standardization to help industries to improve their production. Following this aim, the National Physical Laboratory was created by the British government in 1900 and the National Bureau of Standards in 1901 by an Act of Congress of the United States. The French *Bureau International des Poids et Mesures* was created earlier in 1875, during the International Convention du Mètre in Paris. In Germany, the Physikalisch-Technische Bundesanstalt was created in 1887 by Werner Siemens, head of the Berlin electrical firm Siemens &

Halske "to promote the advancement of science and, thereby, also the technology closely bound to it."[39]

In photographic research, the National Bureau of Standards (NBS) played a key role during the Interwar period and its scientists, among them Burt Haring Carroll and Donald Hubbard, known as Carroll and Hubbard, directly addressed the use of trade secrets within the photographic industry. Their research started in 1920 when the spectroscopy laboratory of the NBS requested infrared sensitive emulsions. Commercial film was not sensitive enough, the support in cellulose nitrate was dangerous and it shrunk too much.[40] Initially, two NBS scientists, Raymond Davis and Francis Marion Walters conducted a general sensitometric survey of 90 photographic films and plates manufactured in the United States, with the aim of measuring "speed, development, colour sensitiveness, filter factors, and scale."[41]

As Davis and Walters had no data about the chemical compounds and the processes used for the production of American films and plates, they did this survey using the methods of a testing laboratory, describing in their report the process of doing the tests and the instrumentation used such as the sector disk type sensitometer, the Martens photometer used for measuring the density or the thermostat for developing test plates. Davis and Walters' initial survey led to the general study of photographic emulsion, and the spectroscopist Dr. W. F. Meggers of the NBS managed to obtain some pilot plant machinery for making emulsions from Germany. When this equipment was installed in the basement of the Chemistry Building of the NBS and an Emulsion Laboratory created in 1922, Carroll and Walters were given the assignment to increase knowledge about photographic emulsion through the production of small-

[39] Sean F. Johnston, *A history of light and colour measurement: science in the shadows* (Bristol: Institute of Physics Publishing, 2001), 96.

[40] Rexmond C. Cochrane, *Measures for Progress; a History of the National Bureau of Standards* (Washington: National Bureau of Standards, U.S. Dept. of Commerce, 1966), 344.

[41] Raymond Davis and Francis M. Walters, "Sensitometry of photographic emulsions and a survey of the characteristics of plates and films of American manufacture," *Scientific Papers of the Bureau of Standards* 18, no. 439 (1922): 2.

scale batches of film.[42] They obtained significant results in 1926, when Carroll and Hubbard produced around 400 batches of emulsion and two years later, when they managed to control the photosensitivity of the emulsion and published their first paper.[43] According to Cochrane, in 1933 and after the publication of seventeen reports, emulsions produced by the two chemists were superior in terms of sensitivity and graininess to the best commercially available films. But "disclosure by the Bureau of the method of their preparation threatened to make public vital trade secrets", and the author pointed to the context of the great depression to explain why advisory committees surveying the research work of the NBS divisions decided to terminate the Emulsion Project, "in the interest of economy".[44]

Mees and his team of researchers from the Kodak Research Laboratory no doubt studied with care the various publications of the photographic division of the NBS. Although there is no evidence of any pressure or lobbying of American institutions or governments by Eastman Kodak at that time, the fact that the published work of Carroll and Hubbard posed a threat to Kodak products is clear. The film manufacturer further benefitted from Carroll's skills when it managed to hire him in 1934, while Hubbard stayed at the NBS. In 1968, most of Carroll and Hubbard's research papers were reprinted. In the publication's introduction, the writer Dr. W. F. Berg, a former scientist of Kodak Limited's Research Laboratories, who had succeeded Professor Eggert as the Director of the Photographic Institute of the *Eidgenossische Technische Hochschule* at Zurich at that time, stated that "the value of the series of papers produced during the years 1927 to 1934 is undisputed to this day, and they are widely quoted; indeed they should be regarded as classics."[45]

---

[42] Cochrane, *Measures for Progress*, 344. Carroll, Hubbard and Kretchmann, *The photographic emulsion*, 7.

[43] Burt H. Carroll and Donald Hubbard, "Sensitization of photographic emulsions by colloidal materials," *Bureau of Standards Journal of Research* 1, no.4 (1928): 565.

[44] Cochrane, *Measures for Progress*, 345.

[45] Berg, introduction to *The photographic emulsion*, by Carroll, Hubbard and Kretchmann, 7.

In England, new co-operative research associations emerged from the First World War in 1918, to help the British industry increase its capacity for innovation and production in the face of international competition. A new Department of Scientific and Industrial Research was created in the same year by governmental authorities, to assume responsibility for the National Physical Laboratory.[46] For Varcoe, the war brought "home to many manufacturers the necessity of continuous research in order to bring about a systematic improvement in the methods of production and in the quality of goods produced."[47] Among them was the British Photographic Research Association (BPRA), one of the first to have been formed in 1918, along with the British Scientific Instrument Research Association and the British Wool Research Association. The aim of the BPRA was principally to carry out pure research in photography and photochemistry and, in a sense, it joined the mission of the Emulsion Laboratory of the National Bureau of Standards by starting research in various fields of photographic science such as colloidal chemistry or chemical properties of gelatin.

The first laboratory of the BPRA was situated in the chemistry building of University College and Walter Clark, a young undergraduate, frequently met with its director Dr. R. E. Slade and his associates. He was so interested in the photographic process that soon after completing his studies, he took a position in the BPRA, the association having been transferred in the meantime to the Institute of Chemistry at Russell Square in London. Clark worked for the BPRA for five years, carrying out research with F. C. Toy and S. O. Rawling mostly on the theory of photographic development and the latent image. On the basis of his work at the BPRA he published two theses and obtained a Master of Science and his doctorate. In his recollections Clark mentioned a fruitful spirit of competition with various Kodak photochemists: "We had a splendid five years jousting with Svedberg of Sweden and with Sheppard, Trivelli, Silberstein,

[46] Russell Moseley, "The origins and early years of the National Physical Laboratory. A chapter in the pre-history of British science policy," *Minerva* 16, no. 2 (1978): 249.

[47] Ivan Varcoe, "Co-operative research associations in British industry, 1918-34," *Minerva* 19, no. 3 (1981): 434.

Loveland and others of Rochester."[48] For financial reasons, he left the BPRA to take a position of deputy librarian at the Science Museum in London. However, he was still active in the photographic research field and the Seventh International Congress in Photography in London in 1928 provided him with the opportunity to meet Mees. The director of Eastman Kodak Research was perfectly aware of Clark's photographic work through his publications as well as his correspondence with Sheppard and Trivelli.[49] Adopting the method that George Eastman used in 1912 for his own recruitment, a convinced Mees strove to hire the skilled Clark.

> So I went up to see Dr. Mees who said: "Clark, I have followed your work with interest. I want to start a research laboratory for Kodak in England. Would you like to run it for me?". I said "Yes". "Good", Mees said, "You must come to Rochester and see how we do it there.[50]

Therefore, the threat that the National Bureau of Standards, and the BPRA to a lesser extent, represented to the photographic industry was greatly reduced by the recruiter's talents of Mees. Both the narratives of the photographic research at the NBS and that of the BPRA demonstrate the failure of constructive and scientific collaborations between public research institutions and private film manufacturers. Technological and scientific knowledge was produced unilaterally, and it appears that the photographic industry remained constantly suspicious towards the two national laboratories. During this period however, two factors can be defined as zones of knowledge exchange about photographic emulsion. Firstly, the intellectual and scientific rivalry between European and American photochemists, stirred up by the many publications on each side. Secondly, the organisation of several International Photography Congresses in Europe during the Interwar, where chemists and theorists from France, Germany, England and the United States in particular, met and exchanged their discoveries concerning photographic processes and improvements in

---

[48] "The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album" (unpublished report, Harrow Research Laboratory, Harrow, 1977), 9. Available at De Montfort University, Kimberlin Library, KC 338.4777 HAR.

[49] *Journey : 75 Years of Kodak Research, 143.*

[50] "The Harrow Research Laboratory," 10.

film production. The proceedings of these congresses were usually published thereby increasing knowledge about photographic science and growing into the research libraries of many photographic research laboratories.[51]

[51] See for example the proceedings of the Eighth International Congress of photography held in Dresden in 1931, in John Eggert and Arpad von Biehler, eds., *Bericht über den VIII internationalen Kongress für Wissenschaftsliche und Angewandte Photografie, Dresden 1931* (Leipzig: Barth, 1932). This publication includes a panoramic group portrait with all the participants and their relatives.

2.2. Basic and Industrial Research at Kodak before 1912

In the first section, an insight has been gained into the mechanisms of the research and production within the film industry, starting from the observation of a general use of secretive practices about manufacturing technologies and introducing the activities of national laboratories working without industrial support. In the present section I will indicate how technological research was performed at Eastman Kodak before the existence of the Research Laboratory in 1912. I will argue that unlike traditional views about the so-called breaking point caused by modern industrial research in the first half of the twentieth century, the scientific way of doing research at Eastman Kodak started well before the creation of the Research Laboratory. To this purpose, some secondary sources will be used. The British and French Kodak archives will also be used to introduce some unpublished data about the process of innovation in the company at the end of the nineteenth century.

First of all, how do we qualify industrial research in the context of the research activity? Basic, fundamental, scientific or pure research seems to follow another goal. It represents research work produced when experimenting theory or attempting to discover new knowledge but without any commercial plan about its application. The strategy used in industrial research is slightly different: the goal is to make new products emerge from newly developed knowledge, invention or technological processes. In this way, the research process can be seen as biased or oriented from the beginning. At the turn of the twentieth century, the opinion of the scientific community about industrial research was commonly negative, compared with the pure objectivity of academic research. Therefore, the first years of the Kodak Research Laboratory in which fundamental research was emphasized can be seen as an attempt to highlight the value of the research work within the framework of the new structure.

2.2.1 The development of scientific research at Eastman Kodak 1891-1912

Before 1912, the research activities of Eastman Kodak were especially oriented towards solving manufacturing issues and controlling the quality of raw materials. Existing laboratories were frequently located in production facilities. To qualify the nature of the research work at Eastman Kodak during this period, it is necessary to understand the notion of "master emulsion maker"[52] with the evocation of a case of counterfeiting George Eastman had to solve in the 1890s. At that time, technological knowledge was not secured enough as a company asset, yet within the photographic industry skilled chemists were hired for their experience and knowledge. However, should they resign from a film and plate manufacturer, they left with their formulas and the company had to start from scratch again with another photochemist. With regard to Eastman Kodak, this section demonstrates that the shift from the model of the independent master emulsion maker to the model of the industrial research laboratory happened progressively from the 1890s to 1912, and did not suddenly emerge in 1912 with the creation of the research Laboratory at Rochester.

Jenkins (1975), Brayer (1996) and more recently Catherine Fisk (2009) have all studied the case of the photochemist Henri Reichenbach, the perfect example of a master emulsion maker. Dr. Samuel A. Lattimore, the head of the chemistry department at the University of Rochester, recommended Reichenbach to George Eastman who hired the young expert in 1886 as a chemist, together with the analytical chemist S. Carl Passavant to assist him. At that time Eastman was still fully involved in the process of innovation and was aware of each stage of the production of his photosensitive products. Reichenbach's mission was partly to release Eastman from laboratory work by undertaking experiments as necessary with a specific budget for research.[53] The paper used for photographic support in the Eastman-Walker Roll Holder did not render

[52] Jenkins, *Images and Enterprise : Technology and the American Photographic Industry, 1839 to 1925*, 223.

[53] Brayer, *George Eastman*, 49.

the picture sharp enough and the young Eastman knew in 1886 that a new base had to be invented with the same physico-chemical properties as celluloid. Working in close cooperation, both men managed to develop in 1889 a formula for a photographic transparent support similar to celluloid, a material whose manufacturing method was patent protected by the Celluloid Manufacturing Company. This transparent film was produced by dissolving nitrocellulose in wood alcohol, strengthened with camphor acting as a solvent and further optimized with fusel oil and amyl acetate to retain the camphor in solution when the film was drying.[54] When launched in 1890 the new film was a commercial success, even if some technological issues in its manufacturing requested further optimization. At the end of 1891, as Eastman reported to Walker he was working as the director of an invisible experimental laboratory, trying to solve the problem of static discharges from the film in cold weather.

> One day, reflecting upon the theory that the discharge was caused by two surfaces, one of which was positive and the other negative, it occurred to me that if one of the surfaces was metallic there could be no generation. The idea of making one of the surfaces metallic naturally followed. […] I finally decided that every metallic particle in the emulsion must be insulated by the surrounding gelatine. […] I then naturally thought of the soluble salts and knowing that nitrates would not interfere with the emulsion, I decided to try them first. I directed Reichenbach to try the first experiment with Ammonium Nitrate, but he tried it with Potassium Nitrate, and found it worked perfectly.[55]

This teamwork with his chief chemist ended when Eastman discovered in January 1892 that Reichenbach had betrayed him in using the developed technology of transparent film to create a new film making company, along with the other chemist Passavant and the sales director Gustav Milburn, another of Eastman's employee. The three "conspirators" were immediately dismissed and their loss led to a difficult situation for the young company. Eastman had neglected the protection of the intellectual property of his company in patenting the new transparent film under the name of Reichenbach in recognition of his decisive research work. The American patent n°417,202 for the "manufacture of flexible photographic films" was finally issued and granted to

---

[54] Ibid., 69. Jenkins, *Images and Enterprise*, 131.

[55] Ackerman, *George Eastman*, 68. Also quoted in Jenkins, *Images and Enterprise*, 132-133.

Reichenbach on 10 December 1889, with Eastman as the first witness. At the same time, the Patent Office denied the application of Hannibal Goodwin for an equivalent technology of film-making arguing that the delivered information was not accurate enough.[56]

At the end of November 1890, Reichenbach and Passavant improved the manufacturing process. In their application they claimed as their invention the "improvement in the art of forming flexible film-supports, which consists in adding a distillate obtained from zinc chloride and fusel-oil to a fluid solution of nitro-cellulose and camphor and subsequently depositing and spreading such solution upon a rigid supporting-surface and drying it."[57]

Fisk points out that the Reichenbach case is a good example of "the development of the law of corporate ownership of workplace knowledge"[58]. The case Eastman Co. v. Reichenbach was handled in 1892 and the New York Supreme Court judged that the owner of all the processes and formulae produced by Reichenbach and Passavant was the company of George Eastman because the two chemists had been hired to perform chemical research. It was clear in their contract and they knew the value of the technological knowledge produced for the company which they had kept secret up to this time.[59]

This judicial story illustrates that intellectual property progressively shifted from the genius independent engineer, chemist or physicist to corporate ownership. But George Eastman needed to develop the method of securing technical knowledge as a company asset. He had several tools such as trade secrets, noncompetition clauses, or horizontal integration to reach this goal. I argue later in this chapter that producing innovation in

---

[56] Brayer, *George Eastman*, 70.

[57] Henry M. Reichenbach and Samuel Carl Passavant, "Manufacture of flexible photographic films" (US Patent 370,790 filed November 8, 1890 and issued September 1, 1891).

[58] Fisk, *Working Knowledge*, 188.

[59] Ibid., 190.

the framework of an official Research Laboratory was one of the strategies for the company to secure and obtain the ownership of all the inventions.

In the British Kodak archive, some documents refer to Reichenbach and allow the description of pre-industrial research at the Kodak Harrow Works. They stress that some fundamental research work was also undertaken in Harrow well before the creation of the Research Laboratory at Rochester in 1912 and the Harrow Research Laboratory in 1928. Surprisingly, the study of these documents reveals that the fundamental research involved a scientific collaboration with independent chemists. F. W. Thomas Krohn, the Works chemist of Kodak Limited at Harrow from 1891 to 1901, was sent to Rochester from March to July 1891 to "get a good insight into the work over there"[60]. In other words, he had to learn basic principles of emulsion-making at Kodak Park. The Harrow Works were not finished at that time and George Eastman himself suggested this journey. In Rochester, Krohn worked under the supervision of Henri Reichenbach, who was now in charge of the whole manufacturing process and he was very impressed by the chemist's skills.

> The second thing I learned, watching Reichenbach, was that genius is, as has been truly said, the infinite capacity for taking pains. Week in and week out, Sunday included, he was at that time, here, there and everywhere supervising and pushing along the work. He and others made a bad mistake afterwards, but one has to give him his due.[61]

During these weeks of apprenticeship, Krohn took a lot of technical notes including the description of the manufacture of transparent film and formulas, all the more since he had no experience in the photographic industry, having previously worked as a chemist in the laboratory of the brewery Warwicks & Richardsons. The draft agreement between The Eastman Photographic Materials Co. Limited and Krohn for his engagement in connection with the Harrow factory stresses the great importance of

---

[60] F. W. Thomas Krohn, "Early Kodak Days," unpublished manuscript, first typescript, 1932, ref. A1397, box 116, Kodak Collection Archive, British Library (hereafter cited as KCA-BL), 2. Krohn wrote his recollections from his career in 1932 on the request of Mr. Bent and the manuscript was found in January 1955 by Franck B. Phillips.

[61] Krohn, "Early Kodak Days," 6-7.

keeping the production in good working order rather than undertaking experiments to develop innovative products.

> Mr. Krohn's duties will be to improve and perfect the present processes and apparatus of the Company, and to devise and perfect new and important systems of manufacture, and it is very important that he should be firmly bound to this Company in such a way that any discoveries that he may make in connection with photographic art shall be communicated by him to this Company and shall be our property, and that he shall take out no patents in his own name or in the name of the Company connected with photography without permission.[62]

The possibility that Krohn might make some inventions during his routine work was therefore seen more as a threat than a benefit, "in virtue of his superior chemical knowledge".[63] But the new chemist, who came back to England and started to work at Harrow in August 1891, was in no way as ambitious and unscrupulous as the unruly Reichenbach.

Krohn's *Early Kodak Days* is important because it provides, on the one hand, information about applied research in the Harrow Works and on the other hand, the nature of the fundamental research made by the British photochemist at Kodak Limited. The analysis of the manuscript reveals evidence of scientific collaboration between Eastman Kodak, Kodak Limited, independent photochemists and instrumentation makers. Krohn illustrated in his diary the many difficulties of the production of base and emulsion at Harrow during the last decade of the nineteenth century, and he also detailed his own attempts to use the preliminary research of Hurter and Driffield and the primitive densitometers available at that time, to measure the parameters of the emulsion and its speed (see Illustration 3). Krohn was aware of the photographic literature of his time and he discovered in 1894 the paper of Hurter and Driffield pointing out the mathematical relationship between the exposure and the density of the developed photographic material.[64] They had produced the first

---

[62] William H. Walker, draft arrangement between The Eastman Photographic Materials Co. Ltd. and F. W. Thomas Krohn, 10th February 1891, ref. A1396, box116, KCA-BL, 1.

[63] Ibid., 1.

[64] Ferdinand Hurter and Vero Charles Driffield, "Photochemical Investigations and a New Method of Determination of the Sensitiveness of Photographic Plates," *Journal of the Society of Chemical Industry*

principles of densitometry and sensitometry. In his manuscript, Krohn discusses the benefits of the Hurter and Driffield work for the emulsion-maker.

> I became convinced in time that as a practical speed indication for ordinary camera use the H & D figures were not much more useful than the other speed indication methods then in vogue. […] I also became more and more convinced that the chief use of H & D work was to give the emulsion maker information about the characteristics of his emulsion and was only secondarily of use as a speed marking method. I felt too that the lighting and development conditions would have to be very fully studied and rigidly specified before we could begin to mark our materials with H & D numbers.[65]

Krohn was in touch with the few actors of this young photographic science: the dry plate manufacturer and supplier of densitometry equipment Marion and Company's, John Sterry[66], an independent photographer trying to improve Hurter and Driffield's methods, as well as the two English chemists. The first exposure apparatus of the Harrow Works was a densitometer made by Marion and Company's, probably developed by the company's technical manager Alexander Cowan, according to Krohn. The source of illumination, at first a standard candle, did not satisfactorily characterize the orthochromatic and the latter panchromatic emulsions.[67]

9, no. 5 (1890): 455-469. According to Mees, this paper was the basis of sensitometry. See C. E. Kenneth Mees, "L. A. Jones and his work on photographic sensitometry," *Image. Journal of Photography of the George Eastman House* 3, no. 5 (1954): 35.

[65] Krohn, *Early Kodak Days*, 26.

[66] Concerning the link between Sterry, Hurter and Driffield and Marion and Company's, see Ron Callender, "Hurter, Ferdinand (1844–1898) and Driffield, Vero Charles (1848–1915)," in *Encyclopedia of Nineteenth-Century Photography* 1, ed. John Hannavy (New York : Routledge, 2008), 733.

[67] "In the new laboratory I set up a 10 candle standard pentane lamp and a sector exposure apparatus which was made for us by Munroe and a more elaborate and better finished densitometer of the H&D type fitted with a Schmidt and Häutsch light balancing eye-piece." Krohn, *Early Kodak Days*, 29-30.

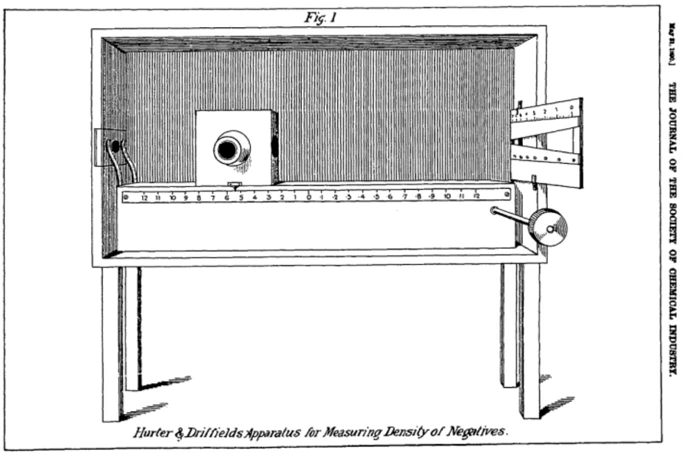


Illustration 3. Primitive densitometer made by Hurter and Driffield at the end of the 1880s.[68]

When John Sterry published a paper about the organic and inorganic latent image and the mechanism of the development at the Royal Photographic Society in 1898, Krohn started a short correspondence with him. The Kodak Collection archive includes a few of Sterry's letters to Krohn about the characterization of H & D speed for high speed plates when high densities are reached, the suggestion to conduct trials to test speed, or the problem of testing mixed emulsion.[69]

Several letters dating from 1898 to 1899 between Krohn and Darragh De Lancey, Works manager of Kodak Park, reveal that Krohn collaborated with Rochester to convince them adopt some Hurter and Driffield equipment to improve emulsion formulas, at De Lancey's request. The method of the two British chemists was objectively discussed and its potential underlined.

> At the same time I felt from the very first what you express in one of your letters that here was promise of a really scientific method for studying emulsions and that it only required patience & perseverance to understand how to apply the method

[68] Hurter and Driffield, "Photochemical investigations," fig. 1, n.p.

[69] Sterry to Krohn, 14 April 1898, 30 April 1898, 31 May 1898, ref. A1450, box 121, KCA-BL.

> for the purpose of discovering the true laws which govern the speed of emulsions, the laws of exposure, the laws of development and many other questions.[70]

In the same letter, Krohn reported to De Lancey that he had met Driffield to get additional information about his method, and that Driffield apologized for the delay in responding to De Lancey due to Hurter's sudden death of in 1898. In his answer to Krohn, De Lancey emphasizes the benefit of what can be named as scientific collaboration.

> I hope to have Mr. Harris, our chemist, prepare a statement of what we have been able to accomplish so far and will send it to you shortly together with his reply to what you have been told us in your letter. I think that a full interchange of ideas and experiments on such matters will only result in great benefit to the Company, and you may be sure that we appreciate the care and the trouble to which you went in giving us such a full account of your own work.[71]

Later in the same year, Krohn installed a photometer and an exposure machine at the Harrow Works and sent the same equipment to Kodak Park in Rochester, continuing to instruct De Lancey and his technical team about the best method for using this equipment and giving in particular the formula of the H & D standard pyro soda developer.[72]

This first cooperation between independent researchers and several Kodak representatives from two continents represents an important turn in innovation. Krohn's recollections, which Kodak staff themselves only discovered in 1955 through his manuscript, demonstrate that the new strategy of the Research Laboratory did not suddenly emerge in 1912. On the contrary, they reveal that the previous laboratory work at Kodak was not just about solving production issues. Fortunately, Krohn's bureaucratic behaviour, that emerges from his writings, urged him to write down his ideas and concepts. His eye for detail, as anecdotal as scientific, helps us to comprehend his time at Kodak Limited. In 1901, he resigned from his position to join

---

[70] Krohn to De Lancey, 30 April 1898, ref. A1398, box 116, KCA-BL.

[71] De Lancey to Krohn, 11 May 1898, ref. A1398, box 116, KCA-BL.

[72] Krohn to De Lancey, n.d., 7 pages, ref. A1398, box 116, KCA-BL.

two cousins in a family business, and took care of transferring most of his photochemical knowledge and know-how to his successor.

> I at once took steps to ensure, as far as I possibly could, that all the experience I had gained should be put on record, so that as far as I could foresee there should be no break in the continuity of manufacture. E. Robins and I spent many hours collecting and collating notes, I dictating and he taking down all notes, formulae and instructions I could think of which might be of use to my successor.[73]

This conscientious behaviour was rewarded during the First World War as George Eastman agreed to supply Krohn with surfaced papers for the Seltona paper he was then manufacturing. Finally, Krohn was re-hired at Kodak Limited at an unknown date and retired in 1932. However, Krohn's last notebook reveals that he was still working for the company after his retirement probably in his personal laboratory. He was for instance sending samples of Victoria blue dyes in 1935 to Harrow, revising the colour-film costs in 1936 or suggesting a method to suppress the appearance of bubbles during the coating of acetone-acetate dopes. In a report entitled *Colour Films*, he provided the complete procedure of the film making, from the dope making to the coatings, with indication about the drying and temperature needed.[74]

The section above introduced Reichenbach's research works in the 1890s, Krohn's training at Rochester in 1891 and the scientific collaboration he developed in-house and with independent photochemists at Harrow. Now we are going to identify similar evidence of applied and fundamental research at Eastman Kodak in the United States. At Kodak Park in Rochester, the leaning toward pre-industrial research was also growing in the first years of the twentieth century. In 1890 Eastman set up a new organisation called the Experimental and Testing Laboratory. Harriet Gallup, an MIT chemist and Franck Lovejoy, an MIT engineer, were hired in the mid-1890s and started to work in this Laboratory to make some routine quality control on raw materials.[75]

---

[73] Krohn, *Early Kodak Days*, 32.

[74] F. W. Thomas Krohn (attributed to), "Colour Film Formulas," personal notebook, ref. A1261, box 89, KCA-BL.

[75] Sturchio, "Experimenting with Research," 6.

They also performed some concise studies on the production of chemicals used in the process of film making as well as on the nitrate film support and its possible substitutes. They managed to make the nitrate film stronger, more resilient and less liable to shrinkage by substituting a mixture of carbon-tetra-chloride and grain alcohol for fusel oil and camphor.[76] In 1906, a pharmaceutical chemist David E. Reid was hired under the supervision of Lovejoy in the Experimental and Testing Laboratory with the initial mission of starting an experimental production of raw photographic paper with a staff of eight people. In the same year, George Eastman was informed by the General Paper Company, his Belgian supplier of raw paper material, that Pathé Frères among other companies in Europe had undertaken research on a new nonflammable cine film made of acetate cellulose. Work on the same topic was finally assigned to Reid as well.[77] The standard celluloid cine film made of nitrocellulose was easy to produce at low cost for the Eastman Company, and the many stages of the production process had been long since mastered. But the necessity of developing a new film base was growing as celluloid film remained dangerous due to its flammability. After one year of research, Reid's positive results allowed the start of production tests and a satisfying acetate support for film was developed in the spring 1908. The new safety film was launched on the market the same year, but due to its relative weakness compared with nitrate film, this innovation remained a commercial failure despite some technical improvements and two years of marketing. The nonflammable film was thinner and less tough than nitrocellulose film and it tore faster in the sprockets of the cine projectors. These negative feedbacks from the market proved that the new base was not matured enough and that it requested further research and development work.

The method of research used by Reid for the development of the new base is not known, but one can speculate that experimentation played a large part in the process, through the analyses and the progressive improvements of experimental bases. The estimation of the Laboratory's organisation is also challenging. It did not end with the

[76] Wyatt Brummitt, "The Story of Kodak," section I, "George Eastman, of Kodak," unpublished typescript, 1959, ref. A260, box 13, KCA-BL, 136-137.

[77] Jenkins, *Images and Enterprise*, 289 and 302.

creation of the Research Laboratory in 1912 and Reid remained at its head for many more years. The staff grew to forty-five employees, and they were in charge of the routine production issues and of some product developments. However, the coordination between the laboratory and the production departments was not efficient and the research staff was not trained enough.[78] The Kodak historian Wyatt Brummitt mentioned Reid's assignment about the production of photographic paper and provided some indication about the research work inside the laboratory.

> Reid started from scratch, trying to determine which paper ingredients or pulps were most compatible with sensitized silver salts. His experiments led to the making of small batches of paper, according to new specifications, by the American Playing Card Company and, to investigations abroad. For the time-being, Kodak continued to obtain its raw stock from the Rives-Steinbach people and from the Schoeller mills in Germany.[79]

It is not confirmed whether this empirical method of research was also used for the development of the new cellulose acetate nonflammable film or not. Jenkins provided some indirect information about the research for the new support: the solvents had to be carefully selected to produce an acetate film as transparent as requested and some modifications of the process were necessary to avoid the infringements of some American and European patents[80]. Above all, the supply of acetic anhydride, a key chemical compound for the new film given its use in the synthesis of cellulose acetate, was problematic. In 1908 no one was able to supply the requested quantities for Kodak Park. So George Eastman asked his scientific expert in Europe Joseph Thacher Clarke to look for a skilled chemist in England to run a plant to produce the acetic anhydride. But it was finally possible to draw up a contract at the end of 1908 with the *Verein für Chemische Industrie*, the Association for the Chemical Industry in Frankfurt for 1200 tons of such a chemical in monthly shipments of 50 tons[81].

---

[78] Jenkins, *ibid.*, 302.

[79] Brummitt, "George Eastman, of Kodak," 127-128.

[80] Jenkins, *Images and Enterprise*, 289.

[81] "In view of the fact that 50 tons were about equal to the then total world production of acetic anhydride per year, the contract was slightly sensational". Brummitt, "George Eastman, of Kodak," 150.

2.2.2 Research work on film support at Pathé Frères 1909-1912

In France, the wealth of research work and production know-how at Pathé benefited Eastman Kodak, when the American company bought its French competitor in 1927. From this time onwards, the innovation made within both companies was mutual. As the recently discovered French Kodak archive at Chalon-sur-Saône reveals the research work during the 1910s for an equivalent nonflammable film in the research notebooks of photochemists, working at that time in Vincennes, France, it is appropriate to mention now how such laboratory work was performed at one of the Kodak's main competitors.

At the end of 1909, Pathé tested the new nonflammable film Reid had developed at Eastman Kodak but reported that it was not satisfactory as it broke during the process of perforation.[82] Some Pathé research notebooks reveal that in the autumn 1910 the experimentation on collodion and acetate raw material was assigned to the photochemist Clément Lair. He initially used Mr. Rivière's formula and looked for a modification of the acetylation process.[83] At the same time, he sought technical information in the patents of the American chemist George Miles in particular. Lair confessed that his methodology was in fact based on the absence of any scientific procedure.

> The tests we have undertaken this week have been done without method, it is more a sequence of experimentation, with the goal of producing a film base with the requested thickness.[84]

This description might indicate that he was using a trial-and-error method for his laboratory work. Indeed, Lair experimented with the many processes at his disposal through the existing patents or through the technical knowledge gathered from

---

[82] Carlos Bustamante, "AGFA, Kullmann, Singer & Co. and Early Cine-film Stock," *Film History* 20, no. 1 (2008): 62.

[83] Lair, « Rapport de Mr. Lair, du 5 octobre 1910 », research notebooks, 1907-1910, ref.33484, Kodak-Pathé Archive, Association CECIL (hereafter cited as CECIL).

[84] « Les essais que nous avons fait cette semaine ont été faits sans méthode, c'est plutôt une série de tâtonnements, dans le but d'arriver à obtenir une pellicule d'épaisseur voulue. » Lair, Rapport du 12 octobre 1910, CECIL, 1.

specific collaboration. Imitating the process of Mr. Rivière, Lair tried the process of Lederer as well (*Rapport du 19 octobre 1910*), but it was not satisfying as the acetate produced was not soluble in acetone and water, and the solubility of the acetate was a pre-requisite chemical behaviour. In fact, the dissolution of the acetate in the acetone together with additional chemicals produced the nitrocellulose collodion material. As this material was the main component for the making of traditional cine film base, its production had a great industrial and economic interest.[85] Lair was producing more and more experimental acetates, going sometimes back to processes already tested but with a change in the formula. He was also comparing the mechanical and chemical behaviour of the acetate available from a few European suppliers in Europe, and his own acetates. In December, Lair had produced 107 experimental acetates of which 95 were satisfactory for the research (*Rapport du 28 décembre 1910*). As Lair clarified in one report, the number of tests was due to the method of preparing a batch of acetate materials for which some components and quantities were constant and only one quantity of chemical varied (*Rapport du 27 octobre 1910*). In this way it was possible to estimate the influence of the unique variable of the experiment. In the same report the chemist indicated that the experimentation on acetates was over but it is unknown if the decision came from him or if he was told to stop. Anyway Lair's remark confirms that he used a trial-and-error method for the development of these 107 cellulose acetate supports.

The innovation of the nonflammable film at Pathé has to be understood as a long-term research work, which was extended up to the end of the 1920s. In addition to the fundamental research on the acetate base, Pathé management favoured the development of technical collaboration with raw material suppliers while dismissing a strategy of vertical integration for this innovative film base. During the same year 1910, Lair was investigating the supply of raw material such as the acetic anhydride

[85] About the nature and manufacturing of photographic and cine flexible supports from the 1880s to the 1920s, see Jean-Marie Michel, *Contribution à l'Histoire Industrielle des Polymères en France*, chapter A-1351 « Pellicules-Photographie-Cinématographie » (Paris: Société Chimique de France, 2012), accessed February 10, 2012, http://www.societechimiquedefrance.fr/IMG/pdf/a_1_351_000.vfx2_sav.pdf.

and was testing new formulas to reduce the production costs. For instance, the synthesis of acetate with acetic acid, cellulose and sulfuric acid but without acetic anhydride gave no positive result as the acetate produced was inadequate (*Rapport du 23 novembre 1910*, 12). In France, Lair contacted the suppliers Oudé, Ognat et Cie, Favel, Desfours or Latierce. The price from the supplier Desfours for 100 kgs of acetic anhydride for a minimum of quantity of 5 tons was 315 francs. At that time, these companies were mostly buying the acetic anhydride in Germany, so Lair went directly there, probably at the request of Charles Pathé. Like Thacher Clarke two years before, he met the directors of the *Verein für Chemische Industrie* in Frankfurt and obtained the price of 9 francs per kilogram for the supply of cellulose acetate. Near Dresden, he met the director Mr. Fuhrlainder of the *Chemische Fabrik von Hayden*, the Chemical Factory, to discuss the supply of sulfuryl chlorure and acetic anhydride. The price of the latter was cheaper than the price of the French suppliers: 215 francs for 100 kgs (*Rapport sur notre voyage en Allemagne, du 13 au 21 décembre 1910*). Concerning the buying of acetate as a finished product, Lair had already tested some samples: the supplier Favel sold him in November a batch of the acetate made by the *Verein für Chemische Industrie* but the product was not very satisfactory. He suggested then either to collaborate with the German to modify the production process of the acetate, or to buy the acetic anhydride from them and keep on experimenting with the production of acetate directly in Vincennes (*Rapport du 1er Décembre 1910*). During his experiments, he also tested the acetate from the Bayer industry and from the Guiterman company. The product made by Bayer was called *Cellit* and very likely in 1908 Thacher Clarke reported to Eastman that the Bayer plant near Cologne had been extended to produce the new cellulose acetate, and that Pathé among others was interested in the *Cellit.*[86] Lair's last reports show that he went back to the *Chemische Fabrik von Hayden* in Dresden in February 1911 to try to improve the acetylation process with the German chemists.[87] In the summer 1912, he reported his journey in

[86] Brummitt, "George Eastman, of Kodak," 148.

[87] Lair, « Rapport sur notre visite du service de fabrication d'acétate de cellulose de la maison de Heyden, de Dresde », 28 février 1911, CECIL.

the United States and his meeting with a few suppliers of acetone and cellulose acetate. One of them, represented by Dr Little and the film manufacturer Fire Proof Co. at Rochester, produced a very good acetate but at an expensive price, as it was not producing the acetic anhydride itself. Lair tried to find a solution in a hypothetical collaboration.

> I think it is worth for us connecting Hayden, in Dresden, with this company, the first having the means of succeed and the second having a good process of production. They certainly could manage to produce at an affordable cost an interesting product.[88]

When the first Kodak Research Laboratory was being constructed in the summer 1912, it is obvious that the capacity of producing cellulose acetate was still experimental at Pathé and that the laboratory work expressed in the form of chemical formulas could not yet be transferred to the production departments in the Vincennes Works. It is challenging to characterize the organisation of the emulsion laboratory of the French film manufacturer, and the research work of each chemist seemed to be quite independent following the assignment of a specific task. However, the all-around methods and the rigorous experimentation used reveal a high level of expertise in the context of the production of scientific knowledge. Consequently, Pathé was undoubtedly a major competitor and a threat for Eastman Kodak to the European market when it was decided to open the new Research Laboratory in Rochester.

In conclusion, the analysis of the American, British and French situation of pre-industrial research at Kodak and Pathé before 1912 shows an in-between phase of research, neither individual nor structured, in a research laboratory, as it was after 1912. For Reid and Lair, this research was caused by the need for a new film base to replace the flammable nitrocellulose support. While maintaining sometimes technical and scientific collaboration with independent chemists or suppliers, Krohn, Reid and Lair were conducting relatively independent research in their own organisation. Thus

---

[88] « *Je pense qu'il y aurait intérêt pour nous à faire entrer en relations Heyden, de Dresde, avec cette Compagnie, les uns possédant les moyens de réussir et les autres ayant un bon procédé de fabrication. Ils arriveraient probablement à fabriquer à bon compte un produit intéressant.* » Lair, « Rapport du 5 juillet 1912. Voyage en Amérique », 2.

scientific knowledge was scattered among isolated chemists from photographic industries, patent literature and chemical manufacturing suppliers. A new solution had to be found to centralised this knowledge and to promote innovation.

2.3. Creation of the Kodak Research Laboratory in 1912

I have pointed out in the preceding section that the "innovation turn" at Eastman Kodak did not appear suddenly in 1912 but that the change from the model of the independent master emulsion maker to the more protective model of the industrial research laboratory happened progressively from the end of the nineteenth century to 1912. Competition in the synthesis of a new nonflammable film by many European actors also threatened the market shares of Eastman Kodak. Pathé, among others, was investigating a great deal in laboratory activities hoping to innovate and produce the new acetate film which would satisfy the movie industry worldwide.

In Germany, it is also worth noting that the *Actien-Gesellschaft für Anilin-Fabrikation* (AGFA)[89] re-started the production of cine nitrate film in 1908 and also built a new film factory in April 1909 in Greppin near Bitterfeld, dedicated to the production of cellulose acetate.[90] Thacher Clarke warned Eastman of the impressive plant[91] and Erik Rassmussen, another Eastman's agent, tried to get into it in February 1909 but could only take some photographs of the building and send them to Rochester.[92] As the Kodak acetate film invented by Reid was not entirely satisfactory, and provoked by the competition surrounding this product, Eastman needed to take action in terms of his "innovation strategy". Furthermore, the making of a photographic colour process seemed to be out of reach, and the Lumière Autochrome process unsurpassable. In order to understand how Eastman made the transition I will first describe the creation of the Research Laboratory.

As the findings of the preceding section revealed, this process did not suddenly start during a business trip in Europe made by Eastman in 1911. Indeed, some scholars point

---

[89] Corporation for Aniline Production.

[90] Bustamante, "AGFA, Kullmann, Singer & Co. and Early Cine-film Stock," 63.

[91] Brummitt, "George Eastman of Kodak," 158.

[92] Bustamante, "AGFA, Kullmann, Singer & Co. and Early Cine-film Stock," 63.

to a fairly well-known anecdote of Eastman's visit to the Bayer chemical plant in Elberfeld in Germany in the winter of 1911. Brummitt in his unpublished *Story of Kodak* depicted the scene.

> In Elberfeld, in Germany, Eastman and his party were entertained at a formal luncheon by Dr. Duisberg of the Bayer Co. […].
>
> During the luncheon, Dr. Duisberg remarked, quite casually, that the Bayer organization found it necessary to have a research staff of several hundred chemists. "And how many do you have, Mr. Eastman ?
>
> Eastman's answer was a little evasive. What could he say, without losing face completely ? But he was stirred to action. Legend has it that he exploded to Clarke, "I won't be talked to that way !" At any rate, he formed an idea on which he proposed fast action.[93]

Ackerman, Eastman's first biographer, did not mention the dinner and is rather brief about the new Research Laboratory.[94] In 1975 Jenkins cited Brummitt and discussed the source of the information, as Brummitt did not provide any references. Jenkins concluded that a stop in Elberfeld would have been feasible as Eastman undertook "an extensive continental tour" in January 1912 in Europe.[95] However, he also mentioned that he found further corroboration of the story in the interview of Kenneth Mees by Johansson and Allardt on 24 April 1952. 10 years later, Sturchio confirmed in a footnote that the famous anecdote was taken from that Mees interview, kept in the archive of the first director of the Research Laboratory.

> […] Duisberg turned to Eastman and said "We have 700 chemists in our organization. How many have you got ?" Kodak had closer to seven than 700, and Eastman did not answer Duisberg directly. Shortly after this encounter, Eastman told Joseph Thacher Clarke, his technical intelligencer in London, that he refused to "be talked to in that way. I'm going to have a research laboratory, too !" Eastman asked Clarke to recommend someone to organize and direct the projected laboratory, and Clarke suggested Kenneth Mees.[96]

---

[93] Brummitt, "George Eastman of Kodak," 182.

[94] Ackerman, *George Eastman*.

[95] Jenkins, *Images and Enterprise*, 305-306.

[96] Sturchio, "Experimenting with Research," 6-7. See also *Journey: 75 years of Kodak Research*, 5.

For this reason, the same Mees would stress later, Eastman's early motivation was to have a Research Laboratory "for the sake of prestige". The fact that this would allow Kodak scientists to publish the results of their scientific work provides additional evidence of this hypothesis.[97]

A meeting with Mees, at that time the young managing director of Wratten & Wainwright in Croydon, a modest firm manufacturing panchromatic plates, colour filters and safelights, was finally arranged with George Eastman in January 1912. Eastman visited the small factory quickly, being especially interested in the production of Wratten light filters. On the evening, he called Mees back and offered him the founding, organisation and direction of a new Research Laboratory in the heart of Kodak Park in Rochester, New York. It was not the first time that Eastman had met Mees; during a professional trip for the American Bank Note Company in the United States in 1909, the British specialist of photographic chemistry had showed the same approach towards George Eastman in writing directly to him, requesting a visit of Kodak Park. The two men met for the first time, and Mees visited the industrial plant of Kodak Park with its manager James H. Haste.[98] He was certainly impressed by the size of the production facilities but it is not known if he tried to apply any of the production knowledge he acquired on his return at the factory of Wratten & Wainwright.

In response to Eastman's offer, Mees consulted his relatives and friends and finally accepted the new and promising position at Rochester, provided that Eastman took over Wratten & Wainwright and its production too.[99] Mees even refused Eastman's

[97] Thomas H. James, *A Biography-Autobiography of Charles Edward Kenneth Mees, Pioneer of Industrial Research* (Rochester, N.Y.: Photographic Research Laboratories, Eastman Kodak Co., 1990), 50.

[98] Mees, *An Address to the senior staff of the Kodak Research Laboratories*, 22-23.

[99] According to Mees' notes studied by T. H. James, the idea of requesting the purchase of Wratten and Wainwright was suggested by the Wratten father and son. They were only willing to let Mees go with Eastman Kodak if the American company would take over their business as well (see James, *A Biography-Autobiography,* 48). The fact that Mees answered to Eastman he would accept his offer only if he would purchase Wratten and Wainwright is therefore the second stage of Mees's thought about the job proposal. See James, *A Biography-Autobiography,* 48. This version is corroborated in Mees, *From Dry Plates to Ektachrome Film*, 42.

first financial offer and requested double the amount, and this was finally accepted. Indeed, the deal was to hire the expert of photochemistry and colour photography as well as acquire a renowned factory of panchromatic plates and colour filters, and the additional opportunity to transfer technology was something that Eastman could not refuse. Finally, in April 1912, Mees went to Rochester to start the building of the laboratory. He also had his own doubts about his new position and duties, and the prospect of leaving London for Rochester was not a pleasant one. He asked himself if he was he the right man for the various responsibilities to come. As Mees wrote, "I told to Mr. Eastman, "I'm too young', and he said: "That is a trouble that will get a little better every day." [100] This anecdote shows that Eastman put forward Mees' scientific background rather than his rather limited experience.

At this stage, it is relevant to point out the scientific and corporate background of Mees at Wratten & Wainwright, because it clarifies Eastman's decision to hire a young man with both managerial and scientific skills. Between 1904 and 1907, Mees and his classmate and friend Samuel Sheppard published eleven papers, which formed the basis for their doctorates and for the well-known book *Investigations on the theory of the photographic process* in 1907. The "revelation" of Sheppard and Mees's passion for photochemistry was the discovery before 1903 of the research work of Hurter and Driffield about the sensitiveness of photographic plates. It is not known if the two young chemists met either Driffield or Krohn from Kodak Limited as there is no evidence of a possible collaboration in the archives. But it is certified that Sheppard and Mees used the work of Hurter and Driffield as a basis for their own research, trying to improve on their experimental methods[101]. Thacher Clarke and Eastman knew the growing ability of Mees in photochemistry through his publications, and when the young chemist took the position of managing director at Wratten & Wainwright in 1906, he soon started to improve the current production of plates and to develop new products. Mees had access to the sensitizing dyes produced by Hoechst Farbwerke in

[100] James, *A Biography-Autobiography,* 50-52.

[101] Mees, *An Address to the senior staff of the Kodak Research Laboratories*, 13.

Germany, such as the Orthochrome T or the Pinacyanol. He succeeded in developing an innovative process of making plates involving the new German dyes, by incorporating the dye in the emulsion before coating on the glass: the new plates were marketed as "Wratten Panchromatic Plates".[102] Mees also developed three well-known light filters, the Wratten K filters, from a new German dye called "Filter yellow K". He was collecting more and more dyes, and built a wedge spectrograph to be able to photograph the absorption spectra of all of them. When Eastman discovered the result of this work published in *An Atlas of Absorption Spectra* in 1909, he certainly understood that Mees was a seductive expert of coloured filters and thus of additive colour processes. The book was revised by Dr. E. Koenig of Hoechst and one notes that Mees mentions the "Research Laboratory of Wratten & Wainwright".[103] This laboratory was quite small with some measuring instruments at the factory in Croydon, as can be seen on Illustration 4.

[102] James, *A Biography-Autobiography,* 37-38. See also Walter Clark, "Charles Edward Kenneth Mees. 1882-1960," *Biographical Memoirs of Fellows of the Royal Society* 7 (1961): 178.

[103] C.E. Kenneth Mees, *An Atlas of Absorption Spectra* (London: Longmans, Green, 1909), 1.

Illustration 4. Kenneth Mees (left) in the laboratory of Wratten & Wainwright, Croydon, using a home-made diffraction spectroscope in 1908.[104]

During the same period, Mees was also doing some consulting work and took some advice on methods of industrial research from two of his friends who were directing a research laboratory, William Rintoul at Nobel Explosives Limited and William Whitney at General Electric. In 1910, an important English dry plate factory suffering from the competition from Kodak Limited offered to purchase Wratten & Wainwright, interested by the technical knowledge of the production of panchromatic plates and proposing to Mees a position of technical director of the factory. The understanding with the director of the unidentified company was difficult and the offer was finally declined.[105] It is not known if Eastman or Thacher Clarke heard about the possible agreement however one can speculate that Eastman was conscious that Mees's scientific aura would attract some companies in the field.

It should also be stressed that the small scale of Wratten provided the opportunity for Mees to experiment with various activities for the company, from research work to salesmanship, and to always keep in mind later at Kodak that scientific research needs

[104] Mees, *From Dry Plates to Ektachrome Film*, 34.

[105] James, *A Biography-Autobiography*, 46. The English dry plate factory could be Ilford Limited but the author did not mention its identity.

at least sometimes to deal with profitable results. And for Eastman, finding a skilled manager to establish a Research Laboratory also provided a new solution to control the production of knowledge with Mees directing a team of researchers, casting the individual's role within the overall framework of the laboratory's mission.[106] Therefore tacit or explicit knowledge, as defined by Polanyi,[107] remained embedded in the company's assets, following a model of "Closed Innovation".

For Mees, research activities were also seen as an opportunity for publication despite the constraints of the industrial context. Thus, before accepting the new position he also negotiated with Eastman to secure his approval for the publication of "everything that we do that is scientific".[108] The generous Eastman also agreed to allow the new research structure enough time to start producing important and marketable inventions. The expected returns on investment from the Kodak Research Laboratory therefore followed a long-term strategy. As requested by Mees, the main goal of the laboratory was not to solve manufacturing issues but to study the unsolved aspects of the photographic process.

> It was understood that the laboratory was to be essentially devoted to basic research on photographic science but would not, at first, at any rate, deal with manufacturing processes or with new products, though obviously new discoveries in science might easily lead to new photographic products.[109]

At this point, I am going to resume the study of the reasons of the creation of the Kodak Research Laboratory. The argument of the attack of Bayer's executives as the release mechanism of a new strategy of research and innovation was almost always

---

[106] Sturchio, "Experimenting with Research," 12.

[107] Michael Polanyi, *The tacit dimension* (Garden City, New York: Doubleday, 1966). "The knowledge associated with innovations can be classified as tacit or explicit. This distinction, first suggested by Polanyi (1966), assumes that knowledge is either transmittable in formal, systematic language (explicit knowledge) or has a personal quality, making it hard to formalize and communicate (tacit knowledge)." Philipp Herzog, *Open and Closed Innovation : Different Cultures for Different Strategies* (Wiesbaden: Gabler, 2011), 52.

[108] Mees, *An Address to the Senior Staff of the Kodak Research Laboratories*, 30.

[109] Ibid., 42.

used by historians inside and outside the Kodak Company. But the same scholars and others also stress the rise of industrial research, at the beginning of the twentieth century. In the United States, the biggest companies like Eastman Kodak, General Electric (GE), AT&T, General Motors and DuPont had enough capital resources to invest in applied research and managers to structure it, in parallel with the various problems of production facilities.[110] But, if at least 39 American companies had their own industrial laboratory by 1900, they were usually devoted to the testing of new products, processes, and quality control of chemicals and raw material. On the contrary, the rationale of innovative research was the discovery of new scientific principles upon which to base industrial development.[111] This new vision was initially developed in leading German chemical companies at the end of the nineteenth century, such as Bayer ; the purpose was to introduce "basic", or "fundamental" research into the industrial laboratory. As John J. Beer concludes in 1958 in a paper about the Bayer company and the German dyestuffs industry, "it can be said […] that the industrial chemical research laboratories of Germany in the decade prior to the First World War were already highly institutionalized and closely resembled the commercial research laboratories of our own way."[112] For Eastman Kodak, introducing fundamental research into an industrial laboratory was just what was needed to solve the acetate film base problem in particular.

In the second half of the twentieth century, other historians pointed out new interpretations of the development and use of industrial research. For Chandler and Galambos, research was an asset to corporate strategy, a resource amongst other resources, such as the will to increase the production capacity. For Jenkins and Reich, industrial research was used as a weapon to strengthen market position and to protect against competitors. And for Wise and Leslie, the success of the modern structure of

[110] Sturchio, "Experimenting with Research," 2.

[111] *Journey: 75 years of Kodak Research*, 2.

[112] John J. Beer, "Coal Tar Dye Manufacture and the Origins of the Modern Industrial Research Laboratory," *Isis* 49, no. 2 (1958): 131.

research depended to a great extent on the personality of the research directors[113]. The shift toward new research corporations producing knowledge and inventions weakened the traditional model of independent inventor in the beginning of the twentieth century, as stressed by the historian Thomas P. Hughes.[114]

Sturchio pointed out another reason for the creation of the Kodak Research Laboratory in 1912. Reducing the argument of colour photography still being invented, he highlighted the "rise in antitrust sentiment on both the state and national levels." This new way of promoting research within the industrial laboratory represented an opportunity for Eastman to comply with a good public policy should horizontal integrations no longer be allowed.[115] On the contrary, Jenkins and later Brayer pointed out the various unsuccessful technical attempts of Eastman to develop a marketable colour photographic process. Analysis of Eastman's correspondence showed that his concern about colour started no later than in 1904 when Thacher Clarke was asked to seek new processes in Europe. Some examples of scientific collaborations started with independent inventors: in 1904 John K. Powrie and Florence Warner worked for a few months in the chemical laboratory of Kodak Park, trying to improve their screen colour process but technical results remained unsatisfactory. In 1910, the chemist Carl Späth was working at Harrow with Thacher Clarke on his two-colour dichromated gelatin screen process, for which Eastman Kodak had optioned patents. Späth was later taken to Rochester to continue his experiments but, like many other experimental additive

---

[113] Alfred D. Chandler, *The visible Hand: the Managerial Revolution in American Business* (Cambridge, Mass.: Belknap Press, 1977); Louis Galambos, "The American Economy and the Reorganization of the Sources of Knowledge," in *The Organization of Knowledge in America, 1860-1920*, ed. Alexandra Oleson and John Voss (Baltimore: Johns Hopkins University Press, 1979); Jenkins, *Images and Enterprise*; Leonard S. Reich, *The making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (Cambridge [Cambridgeshire]: Cambridge University Press, 1985); George Wise, *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research* (New York: Columbia University Press, 1985); Stuart W. Leslie, *Boss Kettering: Wizard of General Motors* (New York: Columbia University Press, 1983). References from Sturchio, "Experimenting with Research," 3.

[114] Thomas Parke Hughes, *American genesis: a century of invention and technological enthusiasm, 1870-1970* (Chicago: University of Chicago Press, 2004), 138-9. Reference from Hintz, "The Post-Heroic Generation," 734.

[115] Sturchio, "Experimenting with Research," 8-9. The strategy of horizontal integration is typically used when a company purchases a competitor in the same business.

colour processes of that time, the complexity of the manufacturing, development and projection was too high to reach a viable and marketable standard. So before Mees's era, Eastman already favoured internal research in establishing a prototype colour laboratory under the supervision of the MIT graduate Emerson Packard. The mission of Packard was to develop a filter screen process from the research of Powrie and Warner, without infringing Lumière's autochrome. It appears that the experimental laboratory did not produce any noticeable innovation and this structure did not survive the new Research laboratory in 1912.[116]

[116] Jenkins, *Images and Enterprise*, 303. Brayer, *George Eastman*, 218-221.

2.4. Basic and industrial Research under the management of Kenneth Mees 1912-1955

This final section of chapter 2 deals with the development of the Research Laboratory in terms of figures and the strategy used by Mees to hire the most skilled scientists. It also identifies the nature of the research organisation he progressively set up during the first years. Fortunately for Eastman, the young Mees did not become a victim on the RMS Titanic, which sank the month of his round trips to Rochester in April 1912.[117] At Kodak Park, one challenge for Mees was his inexperience in working with engineers to build and design the new laboratory, requesting the demolition of the old emulsion building 3 at the centre of the industrial plant. However, this was also the chance for him to arrange the laboratory according to his vision of how photographic research ought to be conducted. The basement of the new laboratory was dedicated to the manufacturing of experimental emulsions and small-scale emulsions for coating films, plates or papers. Wratten panchromatic plates were also produced in this basement. Mees placed the research library dedicated to photography, chemistry, physics and engineering on the ground floor. The scientific departments were situated on the first and second floors, including offices and a conference room. Finally, the photographic studios and the projection room occupied the third floor. Mees, encouraged by the resources of the large company, created as many scientific departments as necessary, in particular to better understand how the photographic process works.

> In a new laboratory supported by the Kodak Company, I could organize an attack on all divisions of the problems presented by the science of photography, and by that time I knew enough about industrial research to believe that work on a large scale on the basic science of photography would justify itself commercially.[118]

The staff of the Research Laboratory grew rapidly, as stated in Table 1.

[117] During the shipwreck Mees was travelling back to England on the RMS Caronia: "On the morning of April 15, the steward woke me with the news that the Titanic had sunk about 700 miles from us. We had turned back to go to her aid, but at that distance could do nothing, and the Carpathia of the same line was very much nearer." Mees, in James, *A Biography-Autobiography*, 60.

[118] Mees, *From Dry Plates to Ektachrome Film*, 42.

Year	Annual expenditure ($)	Staff	Floor area (sq. ft)
1913[119]	53,787	20	-
1915[120]	126,745	40	24,500
Early 1920[121]	-	70[122]	-
1920[123]	338,680	88	29,500
1921[124]	-	105[125]	-
1925[126]	397,449	92	39,600
1930	618,503	159	48,700
1935	952,397	210	140,100
1940	1,923,223	392	205,600
1945	2,457, 463	413	207,100
1955[127]	-	1175[128]	318,700

Table 1. The growth of the Research Laboratory in Rochester in terms of annual expenditure, staff and size.[129]

---

[119] Ibid., 49-50.

[120] C.E. Kenneth Mees, "The Kodak Research Laboratories," *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 192, no. 1031 (1948): 467.

[121] Alfred D. Flinn, A. J. Porskievies and Ruth Cobb, "Research Laboratories in Industrial Establishments of the United States of America. A Classified List with some Information about Staff, Work and Equipment," *Bulletin of the National Research Council* 1, part. 2, no. 2 (March 1920): 67.

[122] Ibidem. The repartition is the following: 40 chemists, physicists and photographic experts and 30 assistants.

[123] Mees, "The Kodak Research Laboratories," 467.

[124] Alfred D. Flinn and Ruth Cobb, "Research Laboratories in Industrial Establishments of the United States. Including Consulting Research Laboratories," *Bulletin of the National Research Council* 3, part. 1, no. 16 (December 1921): 31.

[125] Ibidem. The repartition is the following: 45 chemists, physicists and photographic experts and 60 assistants.

[126] Mees, "The Kodak Research Laboratories," 467. It concerns the years from 1925 to 1945 (included).

[127] Mees, *From Dry Plates to Ektachrome Film*, 293.

[128] Ibidem. With the following repartition in America: 734 at Kodak Park in Rochester, 355 at Tennessee Eastman Division in Kingsport, 34 at Texas Eastman Division in Longview and 52 at the Distillation Products Industries Division in Rochester.

[129] Some figures are partially mentioned in James, *A Biography-Autobiography*, 71; Walter David Lewis, "The development of Industrial Research in America to 1920" (research report, Hagley Museum and

One of Mees' major qualities was his managerial ability to set up an efficient team of researchers by hiring talented scientific profiles by using his networks and circles. Whilst still a student in London, he started networking at the Croydon Camera Club in 1901 and at the Royal Photographic Society in 1904, establishing new contacts and being elected to the Council of the second institution in 1907.[130] At Wratten and Wainwright, he was in contact with other business leaders and photochemists, as previously explained. A recent study of Emanuel Goldberg by Michael Buckland pointed out Mees's way of sustaining friendships with a positive self-interest.[131] Goldberg, a Russian-born physicist and photochemist was the founder of Zeiss Ikon Company in Dresden. He met Sheppard and Mees in London in 1904 and Goldberg and Mees established a long-term friendship. He then went back to the Ostwald's Institute in Leipzig, Germany to work with Robert Luther and Arthur Slator on his doctoral dissertation about the photochemical reaction. Having worked in the Technical University of Berlin with the photochemist Adolf Miethe, Goldberg took up in 1907 a teaching position in the department of Photography at the Leipzig academy. In 1911, Mees tried to increase the research capacities of Wratten and Wainwright by hiring Goldberg to work with him in London. The Leipzig academy was apparently informed about the British proposal and a counteroffer was made with a salary increase and a promotion to the rank of Professor in the same year. Goldberg finally declined Mees' offer, but the wise British man replied in a way that kept an option open to the skilled Goldberg in the future.

> Should at any time in the future our financial position be such that we could afford to make an offer commensurate with the position which you will then have obtained, and should you at that time feel that the burden of official life was heavy

Library, Wilmington, Delaware, 1962), 138; Sturchio, "Experimenting with Research," 25. Holland indicated a staff of 183 researchers as of April 1928 but this number seems rather excessive compared with the 159 researchers listed in 1930. See Maurice Holland and Henry F. Pringle, *Industrial Explorers* (New York: Harper & Bros, 1928), 238.

130 James, *A Biography-Autobiography*, 20-22.

131 Buckland, *Emanuel Goldberg and His Knowledge Machine*, 68-69.

> and that you would prefer a change, we may perhaps be able to re-open the subject.[132]

In February 1912, Goldberg was informed in a letter from Mees about the new deal with Eastman Kodak. He was very surprised and congratulated his friend, joking about the possible reaction of André Callier, the Belgian physicist and a mutual friend of the two men.[133] Goldberg was interested too: "if you ever need an assistant there, please think of me. Perhaps there will be a possibility later on to work together".[134] Mees took his chance and invited Goldberg to work with him at Rochester. However, the young Leipzig professor hesitated for a long time before finally declining the promising offer for family reasons and because he was enjoying his new life in Germany at that time. Following the outbreak of the First World War, Mees invited Goldberg once again to work in the Kodak research Laboratory, but Goldberg was not allowed to move to America as he was considered a Russian citizen.[135] The same disappointment occurred when Mees tried to hire the dye chemist at Hoechst Dr. E. Koenig, as can be found in his notes.[136] These two failures ascertain, in any case, that Mees used a wise hiring strategy, mixing appeals to his social and professional networks and rather opportunistic approaches built on favourable political contexts, to approach the relevant applicant at the right moment.

In this way, Mees used his professional and social networks to build the most strategic team for the Research Laboratory. Some people were taken from the British staff of Wratten such as the emulsion-maker James K. Baker and John G. Capstaff, a young

---

[132] Ibid., 43.

[133] Mees knew Callier since at least 1909. In one of his treatises about photography, he wrote: "To M. André Callier, a Belgian worker, who is both a first-rate landscape photographer and a scientific investigator of great knowledge, I am indebted for the framework of this chapter, and for many of the points with which I deal, as well as for the Alpine photographs which he allowed me to reproduce." See Kenneth Mees and A. J. Newton, The Photography of Coloured Objects (New York: Tennant & Ward, 1909), 49.

[134] Ibid., 45.

[135] Ibid., 68-69.

[136] James, *A Biography-Autobiography*, 65. In 1909, Dr. Koenig revised Mees' publication *An Atlas of Absorption Spectra*.

man just hired in 1912 to make the Wratten filters. Unsurprisingly, Mees offered a position to his friend Samuel E. Sheppard who had planned to obtain a degree in biochemistry in the field of agriculture. Sheppard accepted the job, as did John I. Crabtree, another young Englishman and student in chemistry. In America, Mees drew from the scientific resources of the National Bureau of Standards and hired three promising scientists: Perley G. Nutting and L.A. Jones, who were working in optics and Alonzo S. McDaniel, who was an inorganic chemist.[137]

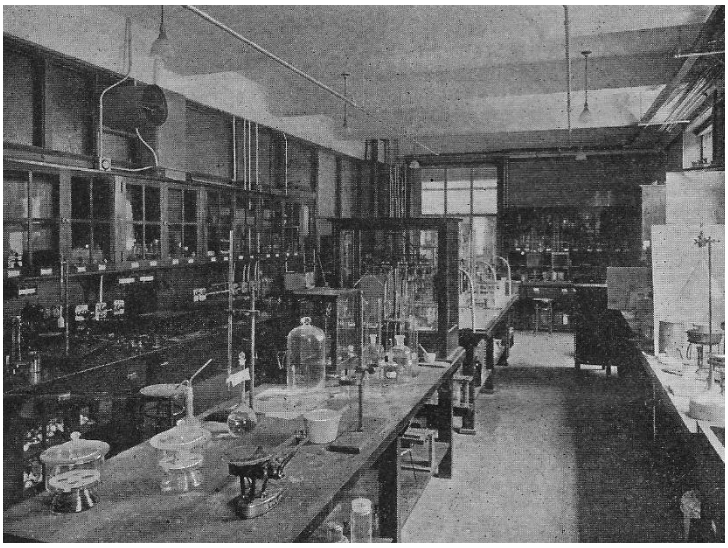


Illustration 5. The physico-chemical laboratory in the Kodak Research Laboratory at Rochester in 1913.[138]

Following Mees's intuition in the development of the Research Laboratory but also responding to the growing needs of the researchers in their daily activities, the number of scientific departments grew in the first decade of the new research structure (see Illustration 5). The chemist Harry LeBreton Gray, former superintendant of the Emulsion Coating Department at Kodak Park, joined the Research Laboratory in 1914 to create and head the organic chemistry department. He was soon seconded by Hans Thacher Clarke, the son of Joseph Thacher Clarke, the same year. Later in 1917, it was

[137] *Journey: 75 years of Kodak research*, 11-14.

[138] From "A New Laboratory for Research in Optics and Photography," *Scientific American Supplement* 76, no. 1960 (July 26, 1913): 56.

decided to create a department of microscopy and photomicroscopy and Adrian Peter Trivelli, a Dutch photochemist was hired to head the new department. This way of developing the Laboratory indicates that Mees's inexperience was mitigated by his empirical sense of research. The inevitable hazards he encountered in his function made him progress and he took quick actions when necessary to improve the structure of the new Laboratory.

Mees also developed a successful social network within the American industry. In December 1914, Mees, his friends Willis R. Whitney of General Electric Laboratories, Raymond F. Bacon of the Mellon Institute, Milton C. Whitaker of Columbia University and William H. Walker of MIT investigated the creation of a special subcommittee on industrial research during a meeting of the American Association for the Advancement of Science. The new think-tank raised the matter of the organisation of industrial research and the necessity of promoting cooperation between industrial research laboratories and research institutes.[139] The subcommittee may have influenced the creation of the National Research Council by the American Congress in 1916 as well as the need to develop new technologies for the purposes of the First World War. In 1918 a campaign was launched to increase public understanding of industrial research and an advisory group was set up with some American business leaders among whom George Eastman, Edwin W. Rice of General Electric, Theodore N. Vail of A.T. & T. and Pierre S. du Pont. These presidents of large-scale companies stressed the importance of basic research compared to applied research. Science should be applied to every branch of industry.[140] In a publication of the National Research Council, George Eastman provided his own views about the organisation of an industrial research laboratory, pointing out the significance of the creation and distribution of scientific,

---

[139] Lewis, "The development of Industrial Research in America to 1920," 147.

[140] Ibid., 148. See also the emergence of the engineer to organize science to industry in the 1910s, in David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Knopf, 1977).

technical and commercial knowledge in all departments. For Eastman, the benefits of such a structure could also "irradiate" up to final customers.

> By the very nature of its work an industrial research laboratory must become a focus and center of the technical knowledge of the industry. In our schemes for industrial development, therefore, we must direct our aim so that the laboratories established for research may create and systematize the technical knowledge relating to the industries with which they are associated, so that from the laboratories this knowledge may permeate all branches and sections of business life, […] insisting on products of higher quality and simultaneously educating customers to make the best use of the products which are supplied to them.[141]

Eastman had been convinced by Mees and his management philosophy for the Research Laboratory. From 1913 onwards, Mees developed his vision of the young structure and took an enthusiastic interest in the organisation of the scientific research. He first published a paper in *Science* about the subject in 1916.[142] Mees stated the limits of the self-made man period, Eastman's era before 1900.[143] He also defined the nature of this new type of laboratory.

> It means a large, elaborately equipped, and heavily staffed laboratory engaged largely on work which for many years will be unremunerative and which, for a considerable time after its foundation, will obtain no results at all which can be applied by the manufacturer.[144]

Thus, while the research laboratory provided a structured organisation of in-house researchers, the notion of economic risk was still not excluded from the research process, due to the "unremunerative" nature of fundamental research. Mees also thought about the boundaries between the research laboratory and the manufacturing

[141] George Eastman, "Concerning the importance of industrial research," *Bulletin of the National Research Council* 1, part. 1, no. 1 (October 1919): 18.

[142] C. E. Kenneth Mees, "The Organization of Industrial Scientific Research," *Science* 43, no. 1118 (1916): 763-773.

[143] "[…] with the increasing complexity of industry and the parallel increase in the amount of technical and scientific information necessitating increasing specialization, the work of investigation and development which used to be performed by an individual has been delegated to special departments of the organisation, one example of which is the modern industrial research laboratory." Ibid., 764.

[144] Ibid., 766.

divisions. Researchers could not handle all the technical issues of the manufacturing departments, thus a necessary separation was needed between them.

In a second paper published in *Science* in 1917, Mees took on the organisation of research work, and developed his theory of the "convergent laboratory" and the "divergent laboratory," the first being a structure for which "problems investigated are all connected with one common subject" and the second being a structure for which "the problems are of many kinds, having no connecting bond of interest."[145] The example used for the convergent laboratory was the Eastman Kodak Company. "The purpose of this laboratory is the investigation of the scientific foundations of photography and its applications, everything relating to photography in all its branches and applications being of interest."[146] Using graphics, Mees showed how the distinct sciences of photography (physics, chemistry, photography) are interrelated around a common "core" called photographic theory and practical photography (see Figure 2). As the scientific field of a photographic expert partially overlaps the other fields, Mees proved that in his organisation of a research laboratory scientific knowledge could be transferred between researchers working on different fields. It is precisely this use of knowledge transfer between the three Kodak Research Laboratories that is confirmed and highlighted in chapter 3 of this thesis with the study of the research reports' exchange.

[145] C. E. Kenneth Mees, "The Production of Scientific Knowledge," *Science* 46, no. 1196 (1917): 520-521.

[146] Ibid., 522.

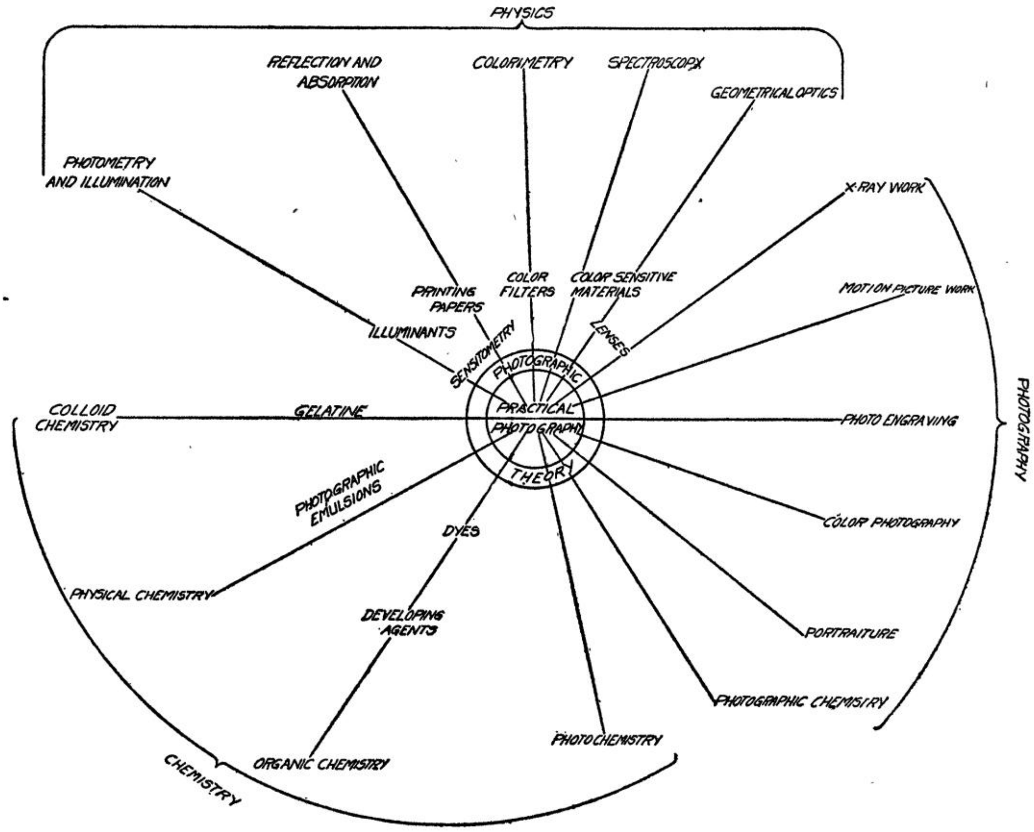


Figure 2. Sections of a research laboratory for the study of photographic problems as organized by Kenneth Mees.[147]

Contents of both papers were used in 1920 by Mees to publish a monograph as the relation of science to industry was prominent after the end of the War.[148] The book was intended to help people in industry when thinking about the creation of a research laboratory in terms of budget, recruitment and return on investment. Mees also studied the relationship between the research laboratory and the industrial organisation, the direction of the work and the design of the building for a specific industry. Sturchio pointed out that Mees emphasized cooperation and teamwork. As the time of photographic pioneers and individual geniuses was over, the research laboratory could now rely on well trained but standardised scientists, able to solve

[147] Ibid., 523.

[148] C. E. Kenneth Mees, *The Organization of Industrial Scientific Research* (New York: McGraw-Hill Book Co., 1920).

research problems through interdisciplinary cooperation.[149] In this way, Mees developed a process of invention by management, for which the origin of invention had shifted from individuals to the managed team.[150]

In his quest for an ideal organisation of industrial research, Mees also used the experience of his friends W.R. Whitney at the General Electric Research Laboratory and W. Rintoul at the Nobel Explosives Research Laboratory. The former notably warning "against the things you shouldn't do, particularly that you shouldn't try and run the laboratory - that you should leave the men to run the laboratory and just see that nobody interfered with them."[151] Conversely, the organisation promoted by Rintoul was more traditional and structured and Mees, during his career at Eastman Kodak was always looking for a way between these two theories of managing a research laboratory, between the "over-organised" and the "under-organised" structure. In 1935, he confessed during a talk, that in his opinion the choice between the two attitudes was not the most important.

> In some laboratories, the direction and the organization is extremely centralized, so that every problem is followed by a group of higher executives, and the most rigid analysis is kept of all expenditures. In other laboratories, the organization is so loose that it scarcely has any form at all; the individual worker has great latitude, and long distant planning is almost absent. As far as I can see, it doesn't matter which method you use provided the men are equally competent. As you will see later, my own method is of the "formless" variety rather than a centralized plant.[152]

It appears from the archives analysed for this thesis that the "formless" method referred to by Mees, was more a well-ordered freedom in conducting research. The choice of research topics was flexible and not restricted by the director Mees, but

---

[149] Sturchio, "Experimenting with Research," 11-12.

[150] Recently, Brown stressed the rise of management and science as organisational tools during the first quarter of the twentieth century in American commerce and industry. See Elspeth H. Brown, *The corporate eye: photography and the rationalization of American commercial culture, 1884-1929* (Baltimore: Johns Hopkins University Press, 2005).

[151] Mees, *An Address to the Senior Staff of the Kodak Research Laboratories,* 28.

[152] C. E. Kenneth Mees, "Research and Business with Some Observations on Color Photography," *Vital Speeches of the Day* 2, no. 4 (November 1935), 117.

routine activities were closely supervised. Furthermore, Mees remained a decision-maker and gathered all the data produced by the Research Laboratories, which is the characteristic of a centralized organization.

From Rintoul and Whitney, Mees also learned the best way to circulate technical and scientific knowledge among the researchers - he instigated the conference system. This "knowledge transfer" tool consisted in morning conferences held weekly in each problem area and involved researchers from several departments provided that they were working on the same specific subject. The growth of the Research Laboratory led to additional conferences being developed. "There were weekly meetings of laboratory departments heads, weekly division meetings (often involving as many as 150-200 people), and periodic conferences of the research directors with senior research associates and laboratory heads."[153]

It is worth noting that, despite all this new strategy in the development of innovation in-house and the great hopes for scientific discoveries and inventions to result from the work at the Kodak research Laboratory, Mees never forgot to keep a vigilant eye on potential independent or internal inventors. This is confirmed by Maurice Holland, director of the division of Engineering and Industrial Research at the National Research Council, who interviewed Mees at the end of the 1920s for a publication and stressed the importance of the inventor's place in Mees' view. At the end of the chapter about Mees, Holland quoted the director of Kodak Research, who was regarded as an "industrial explorer" among other leaders.

> "I have not", he explains, "the slightest trace of the inventor in my make-up. The inventor is a valuable man in any research organization. He may be hard to get along with. He may even be ignorant, because it is difficult for the inventive mind to absorb facts. But he's essential. He finds a path around or across when the research man has been stopped. He may fool around for years without getting

[153] Sturchio, "Experimenting with Research," 15. The author received some information about the conference system from John R. Thirtle, the former Technical Assistant to the Director of the Color Photography Division of the Kodak Research Laboratory.

> anywhere. But he’s essential. When you get your hands on an inventor, freeze onto him !”[154]

As this thesis clarifies in chapter 4, Mees’ clear vision of independent inventors’ potential would result in crucial scientific collaborations with the independent photochemists Mannes, Godoswky, Martinez and Schinzel.

2.5. Conclusion of Chapter 2

Placing fundamental and applied research in the photographic industry within the framework of intellectual property in chapter 2, I was able to argue for the central role of industrial secrecy in the production and manufacture of photographic and cinematographic film from the end of the nineteenth century. The industrial secrecy, nicknamed the “silver curtain” by the Kodak researchers, was a powerful constraint to innovation in the first half of the twentieth century. Emulsion research was principally impacted because industrial secrecy was usually deployed as a defensive weapon around the production departments. Indeed, the stages of photographic and cine film production and the application of new technologies to the manufacturing workflow were mostly affected by this constraint. Industrial secrecy therefore produced a lack of in-house cooperation between engineers and chemists working in the manufacturing plants, and scientists in the research laboratories. In these conditions, it was sometimes difficult to develop experimental emulsions or to test new dyes to improve current films. Outside the firm, industrial secrecy prevented scientific knowledge about emulsion making from being diffused within the international community of scientists in the field of photography. The independent photochemists Wall and Demers complained about this restriction of technical and scientific knowledge-sharing and had to start the development of emulsions from scratch with no chance of cooperation and transfer of knowledge. Demers developed a small-scaled industry on his own,

[154] Quotation from Mees, in *Industrial Explorers*, Holland and Pringle, 238-239.

which was dedicated to the production of special emulsions used by nuclear physicists. Unlike the tradition of the photographic industry, he published all his findings, methodology and know-how in an exhaustive book.

I also argued that the predominance of industrial secrecy progressively reduced public research activities in the science of photography. After the First World War, the National Bureau of Standards (NBS) in the United States of America and the British Photographic Research Association (BPRA) were forced to study film emulsions without clear information from their manufacturers about their nature. Both narratives of the photographic research at the NBS and at the BPRA also show the failure of constructive and scientific collaborations between public research institutions and private film manufacturers. Technological and scientific knowledge was shared unilaterally and the photographic industry remained suspicious towards the two national laboratories. During the same period however, two traditions stimulated zones of knowledge exchange about photographic emulsion and experimental colour processes. Firstly, the intellectual and scientific rivalry between European and American photochemists, provoked numerous publications from both sides. The second tradition, which is linked to the first one, was the organisation of several International Congresses of Photography in Europe during the Interwar period from which a photographic scientific community progressively emerged. Chemists and physicists from France, Germany, England and the United States in particular met and exchanged their discoveries concerning the photographic process and improvements in film making. The proceedings of these congresses were usually published thereby increasing knowledge about photographic science, and steadily growing into the specialised libraries found at many photographic research laboratories.

In chapter 2, I also clarified the fact that contrary to traditional views about the so-called breaking point between the old technical laboratory and the cutting-edge industrial research laboratory in the first half of the twentieth century, the method of doing scientific research at Eastman Kodak started well before the creation of the Research Laboratory in 1912. Nonetheless, research activities were principally devoted to the resolution of manufacturing issues and the quality control of raw materials. The reduced staff in the industrial laboratory was managed by the "master emulsion maker" who controlled the complete manufacturing processes of the company. At Rochester, this situation led to the betrayal of the photochemist Reichenbach. In England, his counterpart Krohn, hired in 1891, had nevertheless had time to benefit from Reichenbach's extensive experience and the ensuing transfer of technological knowledge during a stay at Kodak Park. The agreement between Krohn and Kodak Limited was rigorous with respect to the intellectual property of any possible discoveries made in Harrow by the new photochemist. Krohn's manuscript revealed that he undertook a long-term scientific collaboration with leading scholars in the science of photography. He developed the method of Hurter and Driffield to determine the speed of the emulsions and transferred it to Rochester at the request of the general manager De Lancey. This first cooperation between independent researchers and Kodak representatives from two continents represented an important innovation turn. During the same period, the *Experimental and Testing Laboratory* at Kodak Park in Rochester foreshadowed the upcoming Research Laboratory. Important studies were made there on colour photography, photographic paper manufacturing or nonflammable film base. I argue that all these small facts constituted the beginnings of the need for an industrial Research Laboratory in George Eastman's mind, but also among the staff of Kodak managers and photochemists. The creation of the first Kodak Research Laboratory in 1912 represented, in part, the outcome of these common reflections.

In parallel, Pathé, Eastman Kodak's main competitor, instituted scientific procedures and modern experimental work in its industrial laboratory at Vincennes in France. Thorough scientific investigations were made into the production of a nonflammable support in cellulose acetate. Chemical raw materials were sourced directly from German and American suppliers to reduce manufacturing costs. The research methods used by the French photochemists revealed a high level of expertise in the production of scientific knowledge. Consequently, Pathé was undoubtedly a major though not unique threat for the European market of Eastman Kodak in the first decade of the twentieth century. In particular, competition over the synthesis of a new nonflammable film by several European actors threatened the market shares of Eastman Kodak.

Another section of chapter 2 also pointed out that the creation of the Kodak Research Laboratory in 1912 took place for a variety of reasons. With respect to intellectual property management, it was necessary for Eastman Kodak to secure and obtain the ownership of all the inventions produced within the controlled in-house organisation which the Research Laboratory represented. In terms of historical context, George Eastman followed the trends in industrial research development from the end of the nineteenth century, inspired by the model of the German chemical industry. Pertaining to Kodak marketing strategy, the Research Laboratory was also used "for the sake of prestige" as confirmed by the liberty of researchers to publish their scientific results. With regard to photographic technology, the quest for a marketable colour photographic process was an important reason to increase the research capacities of the firm as well. The political context played an important part too. At a time during which antitrust policies were growing in the US, creating a research laboratory was a solution to innovate in-house and to avoid the use of horizontal integrations. In the same part of Chapter 2, it has also been stressed that the success of the new Laboratory highly depended on the managerial and organisational skills of its director. To that purpose, Mees's recruitment was crucial, as he was an expert in colour photography and connected with European partners and suppliers. Eastman made an excellent choice in the personality of Mees, and the British scientist was partially responsible of the long-termed development and future commercial successes of the Research Laboratories.

Mees's inexperience in the organisation of a research laboratory was fruitful because he started from scratch without prior assumptions. He reasoned scientifically and even developed a methodology of the organisation of industrial research. He had to design everything from the laboratory's building to the departments and their fields of study. It means that Kodak Research as a new institution in 1912 was organised scientifically by an expert in photographic science and that fundamental research in particular was oriented towards applied research. The laboratory’s staff grew progressively as Mees hired the best men for the job, selecting them amongst his former colleagues at Wratten & Wainwright, the National Bureau of Standards and his acquaintances (agreement with Sheppard, failure with Goldberg). Mees created an in-house scientific community devoted to the understanding of the photographic process. However, during the first years of the Research Laboratory at Rochester, Mees never considered the technological skills of Kodak Limited as an opportunity for Research and Development internationalisation. The first scientists scattered throughout the many scientific departments of the Research Laboratory at Kodak Park had to prove themselves first. As regards management, Mees was given favourable conditions by Eastman for the laboratory’s development: a satisfactory budget for the first years, the opportunity to publish scientific results and a greater focus on basic research during the laboratory’s first years. It is clear that Eastman took an important risk in financing Mees’s Research Laboratory, as the production of scientific knowledge promoted by the new director would not necessarily result in later marketable inventions. For Eastman, the long-term and uncertain development of Kodak Research represented a “risky strategy in terms of return on investment”.

Chapter 3: Kodak Research in Europe: origins, organisation and methods

Since 1912, the Kodak Research Laboratory at Rochester had been increasing its understanding of the photographic process, while continuing to solve the occasional production issues. In the middle of the 1920s, a business opportunity in Europe caused a definitive change of the Kodak Research organisation, through the purchase of the French competitor Pathé-Cinéma. This horizontal integration strengthened Eastman's establishment in Europe and led to the opening of the British and French Kodak Research Laboratories.

The first section of the chapter answers a question that could appear insignificant: why did Kodak decide to duplicate the Rochester Research Laboratory at the turn of 1928 by forming two additional laboratories in relation with Kodak Limited and Kodak-Pathé? Indeed, the Rochester Research Laboratory had substantial scientific results and the number of scientists it employed was growing year after year. In England, the Harrow Works were at that time an important film and paper manufacturing plant with a limited testing laboratory mostly used for the production processes. In France, the recent merger with the former customer and competitor Pathé-Cinéma was the opportunity to significantly increase film production capability without the need for building a new physical plant. However, recently discovered research reports of the Pathé Company show that the creation of a French Research Laboratory from the former Pathé structure was strategic due to the quality of the technical and scientific work of the French researchers. The new European laboratories were an attempt to "open" the "Closed Innovation" produced in the Rochester Research Laboratory to new scientific stimuli, new inventors or new competitive technologies. While performing their own research work inside the laboratory, these structures also acted as innovation clusters operating in several European countries and promoting networking and the exchange of knowledge. The technological context of research on colour processes also has to be taken into account. The Rochester Research Laboratory collaborated for several years with the two chemists Mannes and Godowsky without clear and viable results, except the announcement of a two-colour subtractive process. The fact that Kenneth Mees decided to use the expertise in colour technology and chemistry of his colleagues at Harrow by opening an additional Research Laboratory is thus also quite strategic.

To prove this, in the second part of the chapter I analyse one of the most important primary sources of the Kodak Collection archives in Europe: the research reports. They relate to the technical and scientific knowledge produced through the routine work of the researchers in the two laboratories. The research reports belong to the few primary sources available to answer my research question, in addition to the notebooks of the scientists, the varied correspondence, the patent work, some unpublished reports about Kodak Research and the oral histories of former researchers. This "older type of document" as Peter Galison names them, compared to late twentieth-century experiments of large-scale organisations give more direct access to the laboratory work.[1] The research reports, which are a "public" source in-house, are particularly pertinent because they provide the operating procedure and the results obtained from, for instance, a chemical experiment of which no traces now exist. The fact that each report follows a logical and scientific rationale helps in deciphering its meaning and import in the specific field studied.

A research report is somewhat similar to a *micro-thesis* introducing a research problem. It includes a main body of experimental work and an analysis of the data collected in a conclusion and summary. The scientist's reasoning is generally included within the text and the report is therefore more intelligible to non-expert researchers than, for example, a published scientific paper. To approach these sources, because the large quantity of research reports does not allow a complete study of the corpus in the framework of this thesis, I used a computer assisted qualitative data analysis software (CAQDAS) technique to process the list of collected report titles. Use of a

[1] Galison, *How Experiments End*, x.

recent tool, the tag or word cloud, visually indicates whether or not some specific research topics might emerge for a specific period. Then the study goes through the content of a sampling of research reports and examines similitudes and differences between British and some French reports, including research about collaboration and communication between the three Research Laboratories. This section also clarifies the sociological aspect of the research reports, asking what their contribution to knowledge production might be and establishing "the social processes that convert the fallible individual research report (or rather, collections of such reports) into scientific knowledge".[2] The purpose of the research report is principally to increase the level of knowledge in a specific field as well as to serve as a decision-making tool to guide management towards the best innovation strategy. In a teamwork structure, the research report has to be read by as many scientists and collaborators as possible to gradually construct scientific facts and to promote the exchange and transfer of knowledge. To achieve this goal, it has to be widely spread into the various departments of the Research Laboratory. Its role is thus central to communication amongst the Kodak Laboratories.

The third section of the chapter is the study of another important primary source to estimate the contribution of the European Research Laboratories to Kodak innovation. Indeed, the notebooks of some researchers can be considered as the first artifacts produced from their experimental work and reasoning in the laboratory. One might assume that these artifacts are private sources or objects unintended for communication to other scientists within the corporate network, however the convention of drawing up an index at the end of the notebook in the film manufacturing industry tends to demonstrate the opposite. The notebook in the first instance a research tool for its own writer, but it was probably intended for the closed research community as well. The fact that we still find such notebooks in the archives of Pathé or Kodak Limited acts as further evidence. Kodak management decided to

[2] Ackermann, *Data, Instruments, and Theory: A Dialectical Approach to Understanding Science*, 115. See also the notion of the research report as the "product of a completed scientific investigation" in Ravetz, *Scientific Knowledge and its Social Problems*, 182-184.

keep them and this decision shows their importance. A study of the consulted notebooks ascertains which data relate to the production of photographic products and which data concern more specifically the research process. The authors under study hold various professional positions and this characteristic emphasizes the disparate nature of industrial research, including both fundamental and applied research activities. Marcel Mayer, the first author, was the works manager at Pathé in Joinville-le-Pont, France. The second set of notebooks was filled in over a period of time by Charles T. Robinson, a production manager who worked at the same plant for Pathé and then for Kodak Limited. Using English as well as French in his notebooks, Robinson can be seen as a social link between the British and French photographic industry and provides an example of transfer of technical and scientific knowledge. The notebooks indicate the importance of teamwork and collaboration in the scientific structure. For instance, the notebooks of Franck B. Philips, a physicist, illustrate that the British researcher was frequently sent to Rochester to work with his American colleagues, among them Mannes and Godowsky, on the improvement or development of processes and manufacturing procedures. In the last section I consider a set of notebooks belonging to F.W. Thomas Krohn, the first photochemist at the Kodak Harrow factory whose work appeared in chapter 2. Krohn used his notebooks to keep formulas and recipes but also as a cognitive tool, to archive his thoughts about the development or improvement of photochemical processes.

Together the setting up of British and French research laboratories, the official research reports sent between those research laboratories, and the individual research scientist’s research notebooks, combine to show the rise of Kodak Research in the 1930s through the internationalization of its structure. Additionally, they provide an understanding of the methods of fundamental and applied research used and of both the standard and the occasional scientific topics investigated by British and French researchers. Finally, they show important findings and make clear the nature of the innovation performed in the three Research Laboratories.

3.1. Creation of the Kodak Research Laboratories in 1928 at Harrow and Vincennes

The history of the European Kodak Research Laboratories remains largely untold despite its significance for the history of twentieth-century photography. For the 75th anniversary of Kodak Research, Eastman Kodak published a book to celebrate the many scientific and technological turning points produced by the researchers of the Kodak Research Laboratory at Rochester. Surprisingly, only one page in 155 was used to introduce the other Kodak research Laboratories at the end of the volume, despite of the amount of scientific work and innovation produced at Harrow and Chalon-sur-Saône.[3] By 1988, the British laboratory in Harrow and the French laboratory in Chalon-sur-Saône were listed, but also the German and Japanese laboratories located respectively in Stuttgart and Tokyo. Very little is known about these last two laboratories and it is not the purpose of my research to investigate them further here.[4] Kodak's own extremely short introduction of the overseas laboratories not only demonstrates a broader problem of a lack of publications about them, but also that from inside of the company that Kodak Research history was biased towards the American side of the research work.

This bias also occurred in 1961, when Mees published an abridged history of the work done so far in the Kodak Research Laboratories.[5] Only the twenty-third (and last) chapter discussed all the Kodak Research Laboratories as they were in 1955, with the main part devoted to the Rochester laboratory.[6] The British and the French Research

[3] See "International Aspects of Kodak Research" in *Journey: 75 Years of Kodak Research*, 141.

[4] The German laboratory was formed by the purchase by Eastman Kodak of the August Nagel Camera Works in 1931. The Kodak Japan Research & Development (KJRD) facility was created in Tokyo in the 1980s and a team of approximately 100 researchers were working there in 1988.

[5] Mees, *From dry plates to Ektachrome film*.

[6] Two small laboratories were listed among others, the tropical research laboratory in Panama with a staff of 11 and the research laboratory of Kodak Australasia in Abbotsford, Victoria in Australia with a total staff of 69 on which historical and scientific information is also missing.

Laboratories received only a condensed paragraph. Consequently, to better ascertain the development of the European Kodak research structure at the end of the 1920s I draw information from several sources such as unpublished Kodak histories, reports and recollections of Kodak staff. With the help of this data I first discuss the creation of a Research Laboratory at Harrow in 1928. The purchase of Pathé-Cinéma and the organisation of the new Kodak-Pathé Research Laboratory will be analysed in a second stage.

3.1.1. The origins of the Harrow Research Laboratory

Kenneth Mees' hiring of the British photochemist Walter Clark in 1928 to create and manage a new Research Laboratory at the Harrow plant has been studied in the previous chapter. What was the raison d'être of this new research structure? In 1977 Dr. G.I.P. Levenson, head of the processing technology division, provided the following anecdote about Mees' new initiative.

> I have heard it said – and the story is true in character if not in detail – that, on a visit to the Harrow factory, Dr. Mees asked were the reports from his Rochester Research Laboratory were filed. It was discovered that the reports were lodged, unseen, at the head office in Kingsway in central London. Dr. Mees thereupon decided to have a Research Laboratory at Harrow as, at the least, a fertile point of reception for Research reports from Rochester.[7]

However, spreading the scientific knowledge contained in the Rochester research reports was not the only reason for the creation of the Research Laboratory at Harrow. It was a logical necessity to provide the output of scientific and technological research to the British photochemists and production managers of Kodak Limited, because one part of the Research work directly addressed the solution of production department issues. But during the 1920s, the Harrow Works faced a number of important production changes and modernizations, and the final creation of the Research Laboratory fitted within the framework of the new organisation. In 1919, it was

[7] "The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album," 8.

decided to permanently produce 35mm cine-positive film at Harrow, resulting in the formation of a Cine Film Department in 1921, as well as an Emulsion Department in 1922 for which a new building was erected. A Film Coating Department was finally created after 1928. In 1924, a new Cine Kodak processing section was set up in the Harrow Building 10 of the Developing and Processing Department.[8] This improved structure of the production might have been partially initiated by Kenneth Mees even if no clear evidence has been found in the Kodak archives. Indeed, George Eastman sent Mees in July 1923 to England to replace Francis C. Mattison, the Managing Director of Kodak Limited, who stepped down due to ill health. This meant that the Research Laboratory in Rochester was without his renowned director for almost a year, until September 1924, when Mees finally returned. Mees had by that time run the research work of the company for 10 years. In the words of Eastman, this British stay was an opportunity for an up to date view of the foreign needs of the business. At Rochester, Mees' colleague Dr. Sheppard replaced him temporarily and reported to his friend frequently, in addition to his usual duties directing the Physical Chemistry Department.[9]

During his work in Harrow, Mees was disappointed by the absence of a Research Laboratory despite the presence of the classic Works laboratory performing testing and analysis of raw materials. All finished products, the papers and the cine-positive film that were produced at Harrow were subject to testing. T. Wells, the "testing boy" who had been trained by the photochemist Krohn at the end of the nineteenth century was in charge of all the testing activities, which were conducted in several locations between the Harrow Works and the Kingsway head office.[10] The potential benefits of internationalising photographic research, as has been recently stressed by Sally M.

[8] Margaret D. Gauntlett, "A History of Kodak Limited" (unpublished report, Kodak Limited, Harrow, 1978), 34-40. Available at De Montfort University, Kimberlin Library, KC 338.4777/GAU.

[9] Ibid., 32. See also James, *A Biography-Autobiography of Charles Edward Kenneth Mees*, 91-94.

[10] Gauntlett, "A History of Kodak Limited", 107.

Horrocks, might have pushed Mees to open a research facility in England.[11] To increase the sensitivity of black and white photographic emulsion, in particular to enlarge its sensitivity to the entire visible spectrum, the film manufacturers had used the chemical process of optical sensitising since the end of the nineteenth century. This phenomenon was discovered in 1873 by Dr. H.W. Vogel, who increased the sensitivity of a plate by the addition of dyes. Research in organic chemistry grew progressively in the quest for new dyes. For instance, erythrosine increased the sensitivity of the film for the green region and was used to produce orthochromatic emulsions, and isocyanine dyes were used to sensitise the yellow and orange spectrum. Mees studied and used two such dyes, Pinacyanol and Pinachrome, in 1906 to manufacture the Wratten and Wainwright panchromatic plates. It is worth pointing out here that Mees was one of the few photochemists at Eastman Kodak to understand the mechanisms of optical sensitising.[12] In 1928, Dr. Frances Hamer and Olaf Bloch, two chemists of Ilford Limited, published a series of papers about improved synthesis of carbocyanines dyes and about 15 classes of modified cyanine dyes and their relative photographic sensitivities. It was soon evident to the Kodak researchers in Rochester that these new optical sensitisers were far better sensitising dyes than the chemical compounds Eastman Kodak has been using. On being confronted with this milestone in photochemistry, Mees reacted quickly and assigned Leslie G. Brooker, a young chemist at Rochester, the individual task of synthesising sensitising dyes starting from the work of Hamer and Bloch. The challenge was to produce new sensitising dyes to be able to increase the sensitivity of photographic emulsions. Brooker made important progress in the collect and synthesis of sensitising dyes, and the research work on the topic was increased tenfold when Walter Clark succeeded in recruiting Dr. Hamer in 1930 to the detriment of Ilford Limited.[13] Thus the new British Research Laboratory presented the opportunity to gain oversight of technological advances in England and Europe in spite

[11] See Horrocks, “The Internationalization of Science in a Commercial Context: Research and Development by Overseas Multinationals in Britain before the Mid-1970s,” 237.

[12] See for instance Kenneth Mees, “Sensitizing Dyes and their Use in Scientific Photography,” Nature 137, no. 3470 (1936): 726-730.

[13] Mees, *From dry Plates to Ektachrome Film*, chapter 9, 119-131.

of the fact that this kind of research structure was still rare in the British industry, as pointed out in 1962 by the second director of the Harrow Research Laboratory E.R. Davies.[14]

The opportunity for gaining a technological edge was not, however the only reason for the creation of the Harrow Research Laboratory. Economic and corporate factors also frame its creation. The European structure of Eastman Kodak would change significantly at the end of the 1920s. At Harrow, the photochemist Krohn returned to Kodak Limited in 1927 to take over the direction of the Collodion Department in the factory's first pre-cast concrete building, in charge of the production of the new print-out paper Kodatone. More important, George Eastman and Charles Pathé decided during the years 1926-1927 on a mutual merger to create the new Kodak-Pathé subsidiary (section 3.1.2). Eastman resigned in 1925 from the position of Joint Managing Director of Kodak Limited but was still active in important company decision-making. In 1927 Charles Z. Case, the successor of Mattison as Managing Director of Kodak Limited, was approached by Dr. Fritz Blüthgen of the Glanzstoff Fabriken A.G., a German textile manufacturer. Glanzstoff had created a photographic subsidiary named Glanzfilm to compete with A.G.F.A. and dealt with Pathé Frères concerning the building of a new film manufacturing plant at Cöpenick near Berlin.[15] Blüthgen suggested to Charles Case that Eastman Kodak purchase the entire Cöpenick plant as Glanzstoff and A.G.F.A. had resolved their differences meanwhile. Finally, Eastman decided to accept the proposal and the Cöpenick plant became a part of the reshaped German subsidiary Kodak A.G., then the responsibility of Kodak Limited.[16] As the study of the Harrow Research reports in section 3.2.3 shows, an important part of the Cöpenick production was analysed by the staff of the Harrow Research Laboratory

---

[14] "In 1928 industrial research laboratories were comparatively rare and our industry was among the few to carry out research on any scale." Davies, "Reports of Meetings. Scientific and Technical Group's Second After-Dinner Lecture - 15 February 1962," 255.

[15] The spelling "Cöpenick" was used by the British Kodak researchers in their reports (very rarely "Copenick"). This spelling is used in all this thesis. In German, the former spelling of the Berlin's district "Cöpenick" was replaced with "Köpenick" after the Second World War.

[16] Gauntlett, "A History of Kodak Limited", 45.

in its first years. All in all, the European structure of Eastman Kodak was greatly changed from 1928 on with increased capacity for film production, making the need for at least one research laboratory in Europe quite logical. As Mees was in London in 1928 for the Seventh International Congress of Photography, he could take advantage of his journey to look for a talented British photochemist.

The first years of the Harrow Research Laboratory were almost a duplication of the Rochester Laboratory, although on a smaller scale. The allocated budget was reduced, as seen in Table 2, and the initial staff of four graduate researchers was first installed in the "Goodwill to All", an old public-house and the first location for the Research Laboratory. Mees informed Walter Clark about his research *credo*: "Your time will be divided between pure research, industrial research relative to factory problems, and research connected with development work."[17] Clark was initially supposed to provide the Harrow production personnel with the scientific work and innovation of the Rochester Research Laboratory as well as of the photographic community. But the British researchers soon started to work on their own investigations, producing the first research reports at the beginning of 1929. Clark, helped by the experienced assistant Works Manager E.A. Robins, selected a staff of researchers: a microscopist, a physicist, a physical chemist, some photochemists and their assistants. Clark also established a small research library in the same building, with scientific and photographic books and periodicals.

---

[17] "The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album," 12.

Year	Annual expenditure (£)	Qualified staff	Floor area (sq. ft)
1930	7,000	7	-
1935	16,000	22	-
1938	32,000	31	-
1941	61,000	53	-
1945	120,000	54	-

Table 2. Kodak Limited R&D expenditure and staff.[18]

In 1931, as Dr. Hamer was hired away from the Ilford Research Laboratories, a building was erected at Harrow to house the new Organic Research Department. In his recollections, Clark confessed than during his supervision at Harrow from 1929 to 1931, about 180 reports were produced but nothing was done on photographic theory. One of the reasons advanced for this was the preponderance of some things, namely factory problems, the need of development studies and the practice of photography.[19] Another reason is certainly that the scientists had at the outset no access to the secrets of emulsion making, which were kept by the production staff. When E.R. Davies took his position of second director of research in 1931, he found this situation deeply unproductive and managed to change the policy of secrecy, after which emulsion research was finally permitted in a special place within the laboratory.[20] When studying the development of the British subsidiary of Eastman Kodak, it is therefore possible to see a pronounced rationale and continuity in Kodak policies about the innovation and the structure of research and development within the Anglo-Saxon framework. The chemist Krohn was hired by Eastman and sent to

[18] Edgerton and Horrocks, "British Industrial Research and Development before 1945," 233.

[19] "The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album," 15.

[20] Edgerton, "Industrial Research in the British Photographic Industry, 1879-1939," 122. About the laboratory's growth, Edgerton indicated page 121 that the staff in 1935 was 50 with 15 to 20 graduates in number and 200 in 1945 (the source was Kodak Limited).

Rochester in 1891 to "find out how things were done", Mees was recruited by Eastman in 1912 and sent to Kodak Park under the same conditions, and finally Mees hired Clark in 1928 and replicated the same corporate ritual. The long residency at Rochester during which the novice watched how production managers and research scientists were performing their tasks represented an initiatory journey for which the origin of the technical and scientific knowledge was always the American core and know-how of Eastman Kodak. With the purchase of the French competitor and film manufacturer Pathé-Cinéma, this situation changed radically. This time, the French had their own source of technical knowledge and the challenge is now to clarify to what extent this knowledge was known by George Eastman and his British staff.

3.1.2. The old tradition of photographic research at Pathé

The capacity of scientific and industrial research in the 1910s at Pathé has been studied in the previous chapter in section 2.2.2, through the analysis of several French research reports about the synthesis of a new nonflammable film. However, before this research period Charles Pathé, the founder and owner of the French Company, had already decided to investigate the production of his own nitrocellulose cine film in Europe. In 1906 he purchased the declining cine film manufacturing facilities of the European Blair Camera Company in Foots Cray, brought the production fittings up to date and sent French technicians there to be trained.[21] From a political point of view, Pathé was able to launch the production of film at Vincennes in 1909 thanks to the experimental work performed at Foots Cray. When Eastman was informed of this "conspiracy", in February 1909 he decided to stop all shipping of Kodak cine film to one of his best customers. This situation was unsolved for several years. From a technological point of view, the British "experimental plant" at Foots Cray constitutes an important innovation stage for Pathé and a starting point for a rational organisation of industrial research. As the analysis of the Kodak-Pathé archive clarifies, during June

[21] Georges Sadoul, *Histoire du Cinéma Mondial: des Origines à nos Jours* (Paris: Flammarion, 1949), 55.

to December 1906, the technical manager Léopold Löbel and his assistant Mr. Loeuillet sent weekly reports to Charles Pathé about the modernisation of the Blair plant and the first experiments of film production. A technological collaboration was set up between the British and French teams, the transfer of knowledge being bilateral. The Blair emulsion coating machine was still in use but another machine was purchased from Scott and two Friedheim & Scott film cutting machines. In June 1906 Löbel was in Foots Cray with the French photochemist Georges Zelger to organise teamwork with the British photochemist Bonwitt.[22] A laboratory was installed for the chemists to conduct "scientific testing" and "to control and improve our emulsions".[23] Bonwitt started with Dawson's emulsion formula and soon improved it. In mid-September, the new installations were completed and the experimental work could start. The first "emulsion 501" was produced in October and controlled at Vincennes but it was fogged, not contrasty enough and too sensitive. At the end of the same month, the first emulsion to be equivalent in quality to the Eastman emulsion was the number 519 and in the first week of December 1906 the perforating machine processed about 4 percent of Blair emulsion along with 96 percent of the Eastman emulsion.[24]

Therefore, the later research work undertaken by the French chemists from the Blair experience on the synthesis of photographic base and emulsion was logical. This initial work and the industrial research that followed were necessary to free themselves from the threat of Eastman Kodak, who was at the time the only reliable cine film supplier in the world. The French research reports kept by the association Cecil in Chalon-sur-Saône in France clearly demonstrate that scientific research was performed on a

[22] "Monsieur Bonwitt" was probably the emulsion maker for the Blair Company before the merger with Pathé.

[23] "Nous avons fait installer dans ces nouvelles pièces un bureau pour les chimistes ainsi qu'un petit laboratoire où ils pourront faire des essais scientifiques pour contrôler et perfectionner nos émulsions." Mr. Löbel, "Commentaires faits à la suite d'un voyage à Foots Cray", Vincennes, 26 Juin 1906, n.p., ref. 33014, CECIL.

[24] The first week of December 1906 11569 meters of Blair emulsion and 274800 meters of Eastman emulsion were perforated. See Loeuillet, "Rapport du 8 décembre 1906", ref. 33014, n.p., CECIL. The following reports of the same reference number also used to produce this summary are : "Rapport sur l'usine de « Foots-Cray », " Joinville, 18 septembre 1906 ; "Essais des émulsions Blair envoyées la semaine dernière" ; "Rapport du 8 au 13 octobre 1906" ; "Rapport du 29 octobre au 3 novembre 1906".

constant basis up to the end of the 1920s with all the attributes of a Research organisation: laboratories to perform the routine work, a team of skilled photochemists, the keeping of research reports classified by author, the most important of these being duplicated in a general “livre de fabrication”. The scientific know-how produced by the French photochemists was the result of this long-term industrial research and an attractive asset for a competitor in the same industry.

The possibility that Charles Pathé wanted to sell his photographic business to George Eastman is one of the potential causes that led to the purchase of Pathé-Cinéma by Eastman Kodak in 1927. One argument to support this hypothesis is Pathé’s 1926 publication about the making of cine film stock in the Vincennes Works and the development and printing division at Joinville-le-Pont.[25] The book was written by Louis Didiée, a technical manager at Pathé-Cinéma, and contains detailed information about the many processes of support and emulsion making, the testing and analysis activities of the Works laboratory and some sensitometric data about Pathé emulsions. The book is also illustrated with many photographs of the production facilities as if a virtual visit of the Works was offered to the reader. A short comment is added about the “Scientific Research Laboratory”, depicted as the place were studies and experiments are performed to increase knowledge about colloid chemical properties in particular.[26] The impression of a technological showcase conveyed by the book indicates that the research activities of Pathé-Cinéma were clearly known by its competitors including Eastman Kodak. Shortly after the merger was finalised, Mees stressed the necessity of teamwork between the British and the French researchers. Clark wrote that “on June 13 [1928], Dr. Mees told me in a letter from France that Marcel Abribat would be in charge of a « Photographic experimental laboratory at Vincennes and will thus be your collaborator in France. » ”[27] This extract shows that Mees had travelled to France and had visited the Vincennes Works. He was then able to evaluate the level of research

[25] Didiée, *Le Film Vierge Pathé : Manuel de Développement et de Tirage*.

[26] Ibid., “Le Laboratoire de Recherches Scientifiques,” 11.

[27] “The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album,” 12.

work that had been done there and that could be done in the future, as well as the financial means used up to now.

Dr. Marcel Abribat was indeed the man to take over the Kodak-Pathé research and to maintain the constant activity of the research work. But he did not belong to the old team of Pathé researchers. The new director of the Kodak-Pathé research laboratories had already worked for the French subsidiary of Eastman Kodak, the *Société Anonyme Française Kodak* (Kodak S.A.F.) established in Paris in 1897, as a "technical consultant" as Mees indicated in 1961.[28] Abribat gained his PhD in chemistry in 1922[29] and was first employed by Kodak S.A.F. in the same year, but resigned one year later.[30] When Mees finished his mission at the head of Kodak Limited in 1924, he met Abribat and hired him again on behalf of Kodak S.A.F. on 15 September before to return back to Rochester. Abribat is certainly the writer or at least the translator of the *Bulletin radiographique*, a technical brochure about Eastman Kodak X-Ray films which was first published in France in January 1927. The *Bulletin* was supposed to provide technical information on Kodak products to doctors using radiography and their staff. In the introduction of the first issue, the existence of the Kodak Research Laboratory is mentioned, as well as the possibility for customers to visit the "testing laboratory" of Kodak S.A.F. at Paris.[31] In the fifth issue of the *Bulletin* in September 1927, the merger of Kodak S.A.F. with the film production activities of the company Pathé-Cinéma was announced. The marketing discourse of the short communication stressed that the

---

[28] Mees, *From dry plates to Ektachrome film*, 300.

[29] Marcel Abribat, « Etudes électrochimiques sur la cyanamide et la dicyanodiamide » (PhD diss., Université de Toulouse, 1922). Accessed December 10, 2014, http://www.sudoc.fr/089219260.

[30] Sauteron, *Une si jolie usine: Kodak-Pathé Vincennes*, 59. Sauteron also recounted an anecdot about Abribat in the same place but one can only name it a "legend" as his sources cannot be verified. In 1926 Mees would have asked Abribat on George Eastman behalf to make some industrial espionage at the Vincennes Works to guess which chemicals were used to produce the Pathé nonflammable film.

[31] Kodak S.A., *Bulletin radiographique*, no. 1 (Lausanne, January 1927), 3. No. 2, 3, 5 and 6 are published by Kodak S.A.F. and no. 4 by Kodak Ltd (from Bruxelles). From no. 7 on, the publisher is Kodak-Pathé S.A.F. The issues consulted at the Bibliothèque nationale de France were from no. 1 to 11 (November 1928).

availability of the existing products of Eastman products would be maintained and that the synergy of the merger would provide new technical milestones.[32]

How Abribat was received at the head of the Kodak-Pathé Research Laboratories is unknown. He was certainly French, but came from the Charles Pathé's biggest competitor. As most of the chemists and scientists received their directives from Charles Pathé and reported directly to him, the threat from the competitors might have been seen as a visceral struggle from their side as well. Until now, available sources have not clarified the first months of the Research Laboratories at Vincennes, either about the organisation of staff, or also about the change in the structure of several scientific departments.[33] However, the discovery of the Kodak-Pathé hierarchical-type organisation charts for the years 1929, 1937 and 1951 in the French Kodak-Pathé archive clarified the progressive development of the French Research Laboratories around Abribat (see Figure 3).[34] Such a chart shows the structure of a company's organisation but also the relationship of one department to another. Unlike the situation of the Harrow Research Laboratory starting from nothing and requesting a new building and new scientists, the French researchers already had their facilities and working methods. Compared to the organisational structure of the Research Laboratory at Rochester, the French research and development activity took more time to structure itself hierarchically as it seems that there was no equivalent position of director of research at the time of Pathé.

[32] « Ceci doit vous faire entrevoir l'extension que la Société Kodak-Pathé se prépare à donner au commerce cinématographique, photographique et à la radiographie, et à l'aide puissante qu'elle ne manquera pas de fournir aux nombreux clients qui voudront bien la suivre dans la voie du progrès et lui accorder leur entière confiance. » Kodak-Pathé S.A.F., *Bulletin radiographique*, no. 5 (Paris, September 1927), 3.

[33] For instance, Horrocks only specified in her paper that a French counterpart opened at Vincennes in 1928 with no additional information. See Horrocks, "The Internationalization of Science in a Commercial Context: Research and Development by Overseas Multinationals in Britain before the Mid-1970s," 237.

[34] I am indebted to Jean-Pierre Martel, President of the CECIL association in Chalon-sur-Saône, for providing me with the reproduction of the three organization charts in 2015.

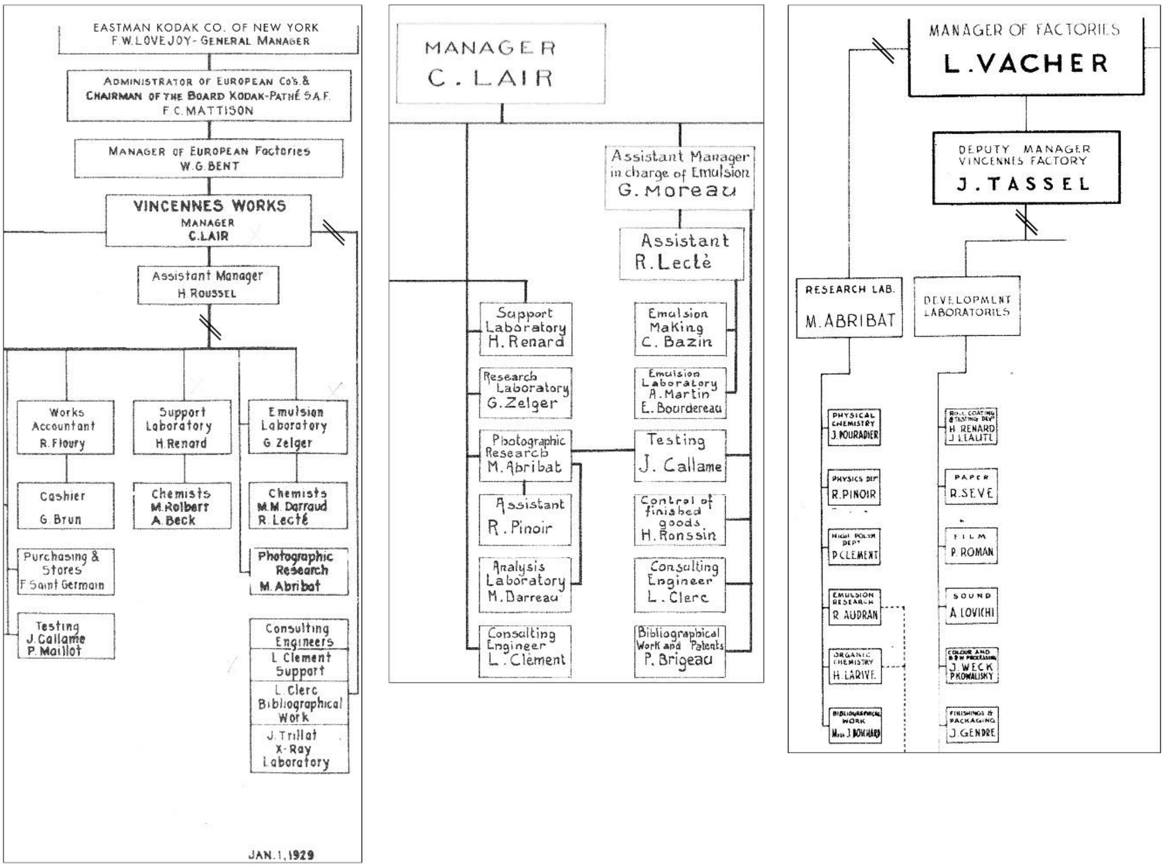


Figure 3. Extracts from the Kodak-Pathé organisation charts for the years 1929, 1937 and 1951 (from left to right).[35]

In 1929, Abribat was dealing with photographic research but his position was more isolated. Georges Zelger of the emulsion laboratory, H. Renard of the support laboratory or the consulting engineers Louis Clément and Louis Clerc reported directly to the general manager or assistant manager and not to Abribat. In 1937 the situation had changed. Abribat's position became central in the column of the organisation chart related to industrial research. He was assisted by R. Pinoir and one chemical analyst reported to him. Abribat also had direct connections to Zelger, Renard and Clément, while all reported to the general manager Clément Lair or to his assistant

[35] The complete Kodak-Pathé organisation charts for the years 1929, 1937 and 1951 can be found in the annexes at the end of the thesis. For a better reading, the chart's widths for the year 1927 and 1951 have been reduced in figure 10. A double stroke in diagonal means that the lines joining two names were longer and have been reduced.

Alfred Landucci. After the Second World War and at least in 1951, the hierarchy was clarified. Abribat was the director of the Research Laboratories, managing several departments such as the physical chemistry, physics or emulsion research departments.

Going back to the period shortly after the merger, what also appears is that a certain attitude of wait-and-see policy prevailed at Rochester but also at Harrow and London to clarify what role the highly skilled team of French researchers at Vincennes could play to benefit the Eastman Kodak Company. It is nevertheless possible to ascertain that it was initially requested that the Kodak-Pathé researchers follow the publication practices of the Rochester Research Laboratory. On July 1927 the first issue of the *Bulletin bibliographique mensuel* was published by Kodak-Pathé.[36] This monthly publication was the French translation of the *Monthly Abstract Bulletin* edited by the American Kodak Laboratory. The first French issue corresponded to the American bulletin no. 6 volume 13 published in June 1927. The French copies contained a short summary below each reference and the bulletin was segmented into several chapters about photography, physics, chemistry and new patents in particular. As of issue no. 6 a list of the authors was added at the end of the volume, making it easier to find out which researcher or inventor was working on what topic. This publication was the first attempt to make worldwide photographic knowledge circulate among the new tripartite entity of the Kodak Research Laboratories.

The Bibliothèque nationale de France owns some issues of the *Bulletin bibliographique mensuel* up to March 1930, but it is unclear whether the small journal was published later than that date. Another French quarterly publication of the Kodak-Pathé laboratories could be the successor of the *Bulletin*: in January 1942 the first issue of the *Résumés des travaux des laboratoires Kodak* was published (see Illustration 6). However, this corporate publication only dealt with the scientific work of the American, British and French Kodak laboratories with no mention of the photographic

[36] Kodak-Pathé S.A.F., *Bulletin bibliographique mensuel Kodak-Pathé*, no. 1 (Paris, July 1927).

research and new patents outside the company. In the first issues the table of contents included nine chapters and four additional chapters from the second volume, respectively : physics, X-ray photography, colour photography, colour photography and film-making.[37] This spreading of scientific knowledge outside the laboratory mirrored the activity in 1913, when Kenneth Mees decided with Eastman's approval to publish the *Abridged scientific publications from the research laboratory of the Eastman Kodak Company* on an annual basis. The best papers of the Kodak researchers were selected to be part of the Kodak scientific journal.[38] This policy was clarified in the introduction of the first issue in 1913.

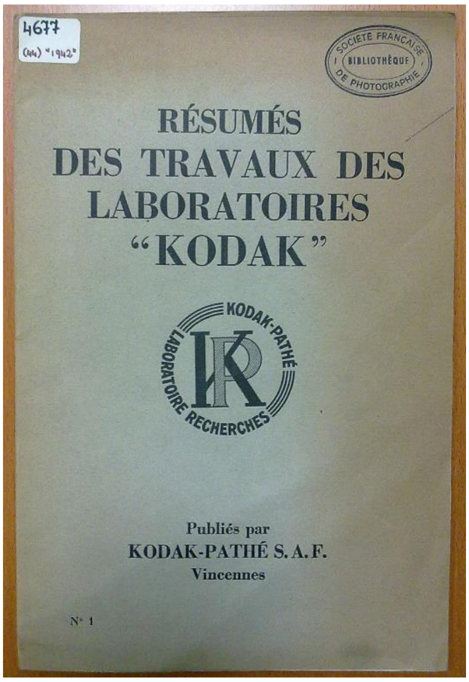
> The more important scientific results of general interest that have been obtained have been published in various scientific journals. Some of these are not available to many who wish these results and hence an abstract journal is being published which shall contain all of the more important results of each paper.[39]

Therefore, in the first issue of the French *Résumés*, one could find a paper of Abribat alongside with papers of L.A. Jones and Neslon from Kodak Rochester, Webb and Selwyn from Kodak Harrow for instance.

[37] The first nine topics are: sensitive layers, latent image, photographic techniques, scientific and technical applications, optics, physical chemistry, photochemistry, miscellaneous. The publication of the *Résumés* was reduced during the Second World War from December 1943 (no. 6) with no issue in 1944 and only 2 issues in 1945 (no. 7 & 8). The quarterly publication restarted in January 1946 (no. 9) up to, at least, 1969 (vol. 4, no. 20). In France, some incomplete sets of the *Résumés* can be found at the Société Française de Photographie (1942, 1943, 1951, 1952 and 1968) and at the Bibliothèque Nationale de France (classification marks AD-307-4 and 8-JO-2799).

[38] For Mees's opinion about the publication of research papers, see also Kenneth Mees, "The Publication of Papers from Research Institutions", *Science* 70, no. 1821 (1929): 502.

[39] Eastman Kodak Company, Research Laboratories, *Abridged Scientific Publications from the Kodak Research Laboratories* 1 (Rochester, N.Y., 1913-1914), Introductory note.



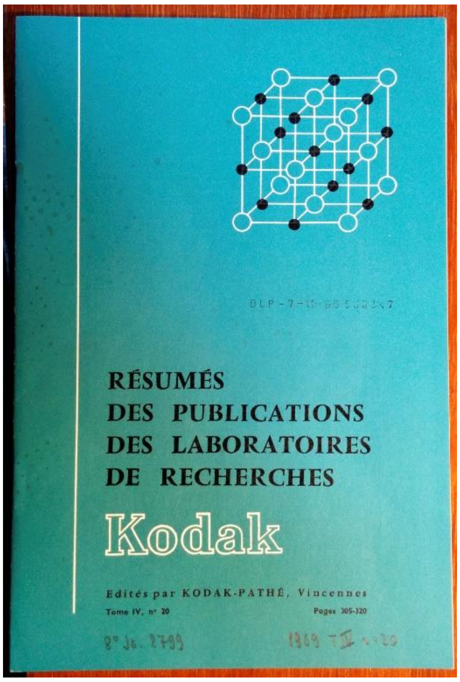


Illustration 6. First issue (vol. 1, no. 1, 1942) and last issue found (vol. 4, no. 20, 1969) of the French *Résumés* published by Kodak-Pathé.

The quality of Kodak research after 1928 in the United States, in England and in France could thus be demonstrated with the help of such publications, a tool of external communication which had to be handled with care to avoid the unwanted sharing of proprietary know-how and scientific knowledge. However, a list of scientific papers that were approved by the Eastman Kodak managing staff for publication several months after the research period cannot reflect the reality of the routine work undertaken and the selected organisation in the three Kodak Research Laboratories. In general, the papers first needed approval for publication and then were published in specialized journals. In a second step, the most important papers were selected and published in the *Résumés* or in the *Abridged scientific publications* a year or more later. It is clear that the information contained in these papers was sufficiently disconnected from the more secretive research work undertaken in the Kodak Research Laboratories. The threat that the competition could use scientific data from these articles remained extremely small. A deeper study and analysis of the scientific knowledge within the *Résumés* or the *Abridged scientific publications* is therefore not relevant to ascertain how industrial research was conducted in the Kodak European laboratories. In the next section, I use new historical material to answer the research question of the nature of the research work undertaken in the Kodak Research Laboratories, and of the "innovation models" used to this end. Here I stop using Kodak histories and scientific publications from Kodak and start analysing some of the research reports produced in the Harrow Research Laboratory as of 1929, as this very important primary source survived the dismantling of the Kodak British research structure at the beginning of the twenty-first century. The fact that these reports were not supposed to be shared and read outside the Kodak internal network is the key element to understanding why they are of crucial importance in our study. Their structure, their raison d'être and their classification without any subsequent selection or censorship work provide critical information. In effect, unlike Kodak publications, the research reports and their content reveal more complete research activities of the Harrow Research Laboratory, and not a subjective selection of the best papers excluding most of the routine work that the company needed to hide. In this way, thanks to this corpus of complete research reports, the following study is able to give a sense of the heterogeneous nature of the everyday research work, and by doing so the full organisational methods used to innovate at Kodak Limited.

3.2. Internal communication and Production of Knowledge

3.2.1. The nature of the Harrow Research Reports and their qualitative analysis

During the initial research within the draft inventory of the Kodak Collection archive held at the British Library in London, one of the most significant discoveries was the presence of the full set of Harrow Research Reports. Among many Kodak artifacts such as correspondence folders, sets of photographs or unpublished reports was this series of homogeneous volumes in relatively good condition. To understand them as research resources, it is necessary to extract some basic information from these documents.

The reference A2897 of the Kodak Collection archive represents 99 bound volumes of research reports, all issued by the Harrow Research Laboratory from 1929 to 1964. The set of volumes is complete and also includes the period during the Second World War. The volumes are physically similar and homogeneous possibly because the assembling of existing reports was done long after their writing and during a global operation of archiving the scientific knowledge of Kodak Limited.[40] The first volumes are not classified by year and the archivist seems to have gathered the reports on the basis of quantity. The first volume contains reports from H.1 to H.100P but the second volume is smaller, containing only reports H.101C to H.125P, due to the inclusion of sensitometric charts or technical drawings printed on relatively thick photographic paper.

Each research report has some specific markings that follow a classification system. The existence of this system of archiving also indicates that it might be the work of a single archivist at one moment in time. By checking the first volume of the Harrow Research Reports, one can read that the archivist created an index including, for each report, a classification number "H.xxx", the date of the report, the title of the report and the author or team of authors. The classification coding using H for Harrow correlates with similar coding of some French reports at Kodak-Pathé: some of them are stamped from 1928 on with the English mention "REPORT N°V.xxx", V for the location Vincennes. For Harrow, the first 4 volumes use an additional code of one letter following the classification number and provide the general category of investigation.[41] Each report includes a printed cover consisting of a form with the following data.

---

[40] The reports themselves are originals and most of the time signed by their author(s).

[41] The following letters were used: C, P, G, D, B and O. I found no mention of the significance of these letters but it is possible to suggest C for chemistry and P for production. The "G" reports concern mostly competitive innovation or technological partnership, while the "D" reports seem to follow no logical

Classification **[…]**
Problem No. **[…]**

REPORT ON
[…]

By […]

[Date]

RESEARCH LABORATORY
KODAK LTD.
Wealdstone, Middx.

The writer filled in the requested data usually by typing it on the printed form. On the back of this cover, there was the following printed form:

Copies of this Report have been sent to

Name	**Address**	**Date**
MR. BENT		
DR. MEES		
MR. LAIR		
[…]		

For most of the reports only the first column "name" is filled. The "classification" at the top right relates to the additional coding letter and is rarely specified. The problem number is sometimes indicated but this is not a rule. The decision to organise the printed cover in this way gives us many indications about the function of the research report. Firstly, it is made to collect and to archive the technical and scientific knowledge produced within the Harrow Research Laboratory.[42] Indeed the research

classification. B was used only once (H.126B, "Diffusing glass for enlarging", 29/05/1930) as well as O (H.185O, "Investigation of the dyes from Isochrome film", 21/07/1931).

[42] The question of bureaucratic practices and the significance for historians of science of archive materials such as reports was raised by Becker and Clark in 2001. In particular they pointed out how the modern plain style of scientific writing progressively created a new bureaucratic style adopted by the scientific community during the nineteenth century. See Peter Becker and William Clark, introduction to

report ends up being converted into, and producing scientific knowledge, as already pointed out by Ravetz.[43] Secondly, it is made to be kept by the scientist and also to be read by a restricted and defined number of managers who are therefore informed of the research undertaken. It is possible, therefore, to find out which individuals have been allowed to read the document. Consequently, the research report or scientific paper, with its logical structure as clarified by Knorr-Cetina,[44] is a vector of transfer knowledge within the internal framework of the Kodak research organisation, and the sharing of this knowledge can be mapped.

As many reports are sent to American and French managers and researchers, this bureaucratic tool allows scientific communication and cooperation between the three Kodak Research Laboratories. The structure of this research tool allowed those at Kodak Limited to provide the necessary data to understand the rationale of the experimentation and of the researcher, the method used, the data collected and the conclusion drawn. The report includes sometimes several scientific inscriptions such as numbers, diagrams, sensitometric curves or technical drawings. What the research report does not contain are the handwritten notes and drafts, if any, produced by the researcher while conducting his experiments in the laboratory. However, it does not mean that negative results are not included in the clean copy of the report. Negative results are kept together with conclusive results and the analysis of the whole allows the researcher to draw his own conclusion.

The problem with this source is the vast scope of topics. A methodical and reasoned analysis of the corpus would not be possible in the confines of this thesis. To illustrate this problem one can consider the first research report ever produced by the Harrow Research Laboratory. It was made by Walter Clark and Edwin E. Jelley, dated 12 January 1929 and entitled the *Investigation of removal of dye from red-backed and*

Little Tools of Knowledge: Historical Essays on Academic and Bureaucratic Practices, ed. Peter Becker and William Clark (Ann Arbor, Mich.: University of Michigan Press, 2001), 16-17.

[43] Ravetz, *Scientific Knowledge and its Social Problems*, 182-184.

[44] Knorr-Cetina, *The Manufacture of Knowledge : An Essay on the Constructivist and Contextual Nature of Science*, 114-135.

green-backed Cine Kodak film.[45] It concerns the opposition from the German competitor Agfa to a patent application of Kodak Limited in Germany.

> The Agfa company have opposed the application for a German patent for backed film on the grounds that the claims made in the application are too wide in their scope, in that they specify that the backing may be used on roll-film in general, and that the dyes are removed by any ordinary developing or fixing bath, but are not removed by water. Agfa submitted their opposition to the German patent office, who sent a copy, together with specimens of film prepared and treated by Agfa, to the patent department of Kodak Limited.

In the conclusion, the authors discuss the admissibility of the Agfa's opposition depending of the kind of film, safety film and dye-backed Ciné-Kodak film. They conclude that for both films the claim was justifiable and that the information provided in their patent application was insufficient. This research report relates therefore to the patent and trademark department of Kodak Limited but, as some experiments were necessary on some Agfa films, the opinion of the Harrow Research Laboratory was sought. Within the archiving structure set up for the notebooks, it is not impossible to link a sequence of research reports together as for instance the second one relates to the aluminium material used for the Kodak cameras and the third is about chemical experimentation with gelatine and baryta emulsion.

To overcome this linear classification of the reports, I gathered all the research reports' titles from the start of the laboratory to the end of the year 1935 to perform a statistical analysis of the principal words or tags used. The purpose is to use a Computer-Assisted Qualitative Data Analysis Software (CAQDAS) approach to obtain a preliminary glimpse into the many topics studied by the British Kodak researchers from the H.2C to the H.350 research report. The goal of this technique is also to ascertain whether or not it will generate some technical trends as the results of the software analysis cannot be anticipated. Many CAQDAS tools exist, within some of which there are several possibilities for processing data (Nvivo, QDA Miner, Atlas.Ti etc.). For this

[45] The number of the report is H.2C and one can wonder why it is not counted as the H.1. However for the first volume an important number of reports although counted are labelled as "Not available at Harrow" (23) or "Not issued" (28). Consequently the first volume contains only 49 true reports instead of 100. For the later volumes the two mentions appear rarely.

initial analysis I decided to focus on the generation of tag cloud or word cloud. This technique provides a visual representation of the most prominent terms used within a text by producing a hierarchical order with font size or colour. I decided to use two different software programmes, the freeware application *Wordle* available online[46] (see Figure 4) and the tag cloud from a trial version of the commercial programme Nvivo 10 (see Figure 5). To clarify this initial analysis, I restricted the number of words to 25. Words are classified according to the font size; the more frequent the word, the bigger the font size. Therefore, each software provides an image of the most significant terms (within the 25 word restriction) used in black font, larger or smaller depending on their frequency within the list of titles.

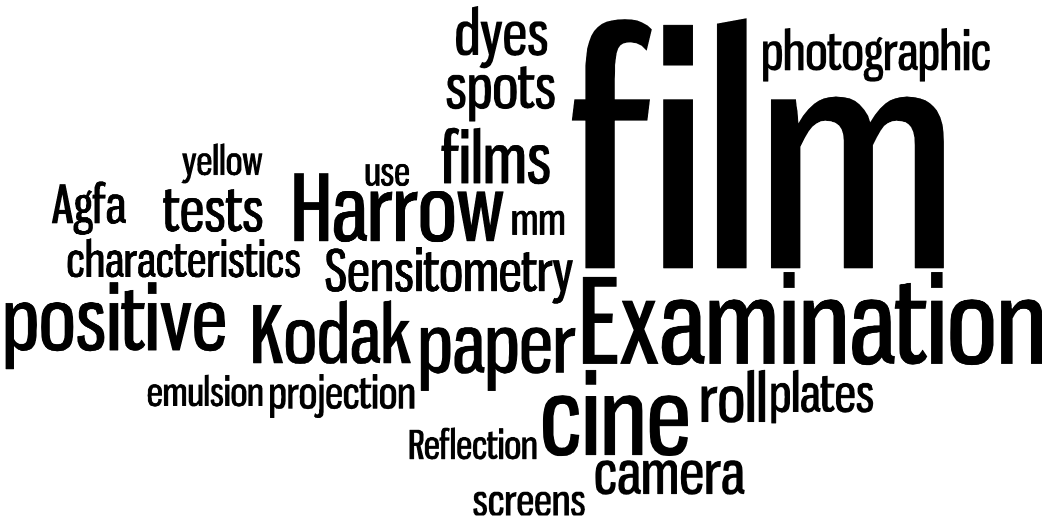


Figure 4. Tag cloud generated with *Wordle* from the list of Harrow research reports' titles.[47]

[46] This application can be reached at www.wordle.net and has been developed by Jonathan Feinberg. The applet uses some algorithms belonging to IBM and some source code source from an open-source project. According to the author, the content provided by the user is neither copied nor stored on a server online.

[47] The following settings were used in *Wordle:* maximum words: 25, common English words removed, horizontal layout with rounder edges, colour: black & white.

Compared with *Wordle*, Nvivo10 can run a word frequency query which provides a summary tab of a specific source, including the length of each word, its count and a weighted percentage. Unlike *Wordle*, Nvivo10 can export this list into an Excel file, as shown in Table 3, allowing a further processing of the statistical figures if necessary. An option allows the user to process the list by grouping related words together. The word cloud visualisation in the specific tab is relatively basic, as it is only possible to change the layout within 25 locked styles with a constant number of 100 words. But this quantity of words can be reduced at the start of the word frequency query. For my research I restricted the quantity to 25 words and I chose a black and white horizontal style to allow comparison with the visualisation generated from *Wordle*.

Figure 5. Tag cloud generated with Nvivo10 from the list of Harrow research reports' titles.[48]

[48] The following settings were used in Nvivo10*:* maximum words: 25, common English words removed, black & white horizontal layout.

Word	Length	Count	Weighted Percentage (%)	Similar Words
film	4	97	4,57	film, films
tests	5	47	2,21	test, testing, tests
cine	4	37	1,74	Cine
examination	11	30	1,41	Examination
paper	5	24	1,13	paper, papers
positive	8	22	1,04	position, positive
dyes	4	21	0,99	dye, dyes
harrow	6	21	0,99	Harrow
camera	6	19	0,89	camera, cameras
kodak	5	19	0,89	Kodak
roll	4	19	0,89	roll, rolls
measurements	12	18	0,85	measured, measurement, measurements, measuring
plates	6	17	0,80	plate, plates
reflection	10	17	0,80	Reflection
use	3	17	0,80	use, used
emulsion	8	16	0,75	emulsion, emulsions
process	7	15	0,71	process, processed, processes, processing
spots	5	15	0,71	Spots
screens	7	15	0,71	screen, screens
photographic	12	14	0,66	photographic, photographs
characteristics	15	13	0,61	characteristic, characteristics
colour	6	13	0,61	colour, coloured, colouring, colours
developed	9	13	0,61	developed, developer, developers, developing, development
investigation	13	13	0,61	investigation, investigations
prints	6	13	0,61	print, printing, prints

Table 3. Summary tab with related words grouped together from Nvivo10.[49]

A comparison between the generated tag clouds shows that the visual result is clearer using *Wordle* than using Nvivo10, as spaces between words are better processed and wider with *Wordle*. Such a visual cloud is easier to read compared to the united block of words provided by Nvivo10. However, concerning the qualitative content of each cloud, results from the two software programs are relatively similar. The possibility of grouping similar terms with Nvivo10 also gives a clearer result by automatically emphasizing their significance. For example, the software added up frequencies of the

[49] The procedure of running a word frequency query is given at the following webpage: http://help-nv10.qsrinternational.com/desktop/procedures/run_a_word_frequency_query.htm?rhsearch=cloud.

terms “test”, “testing” and “tests” so that the global term “tests” reaches the second highest frequency with a count of 47. By contrast in *Wordle*, the term “tests” is rendered smaller than “examination” or “Harrow”. Both programs are therefore accurate but some subtle settings can slightly change the final results of each one.

Using these clouds it is possible to better ascertain the principal missions of the Harrow Research Laboratory in its first years. The main priority is Kodak film, in this case the cine film rather than the photographic film. These *roll films* or these *plates* are *tested*, *examined*, *investigated* whilst the *photographic process* of the *emulsion* is *characterized*. At first sight, research work for *colour* photography does not seem to be a prioritised task of the Laboratory in light of the low frequency use of this term. Only one competitor, Agfa, appears in the list of the 25 most used words. “*Rochester*”, the main Kodak Research Laboratory also appears rarely as this term has a total count of 6 only. From these data we can see that the Harrow Research Laboratory was created in the continuation of the former analysis and testing laboratory. A large amount of work was devoted to the quality control of the emulsion and base produced, but also to the testing of Kodak amongst competitive products as some research reports make this clear.

It must be stressed that the crucial activity of controlling the quality of Kodak films and competitors’ films is also confirmed by the high frequency use of the terms such as test, testing, examination, measurement or investigation. But this activity is not *production-oriented* as a standard testing laboratory usually works, in direct relationship with the production department. The new Research Laboratory can be defined as *externally-oriented* considering the examination of competitive products, new chemical components that could be used in the manufacturing of Kodak films such as new sensitizing dyes. The goal of controlling film is also to regularly undertake a comparison of a Kodak film to existing European films as well as to Kodak film produced in Rochester. Qualities that might be controlled would be a film’s sensitometric curve, sensitivity and grain, as well as its flammability.

Despite all the information gathered from this initial qualitative analysis, it is still impossible to fully understand the missions of the Harrow Research Laboratory from raw statistics and word clouds. The conclusions drawn from the analysis of the discourse contained in the reports' titles is unsatisfactory as there is a great risk of referring to a particular report to illustrate a particular tendency. The analysis might then become a sequence of some case studies randomly selected to attempt an objective description of the Research Laboratory work. This is why I decided to use a second method mixing the Grounded Theory methodology within the framework of the interactional expertise as described by Collins and Evans. In 2002, the authors discussed the nature of expertise in technical decision-making rights and proposed a third Wave of Science Studies, the Studies of Expertise and Experience.[50] Collins and Evans identified three levels of expertise: no expertise at all, interactional and contributory expertise. The second one "means enough expertise to interact interestingly with participants and carry out a sociological analysis" and the last one "means enough expertise to contribute to the science of the field being analysed."[51] If I need to place myself within this classification for the purpose of a qualitative analysis of research reports, I can clarify my role of *sociological analyst* as an interactional expert, due to my educational background and my scientific knowledge of the photographic industry. I have the *legitimacy* to select the most relevant research reports from their scientific content. Rather than a "decision-making" right I can claim a "selection-making" right from which I can gather the most important reports from the full set of 350 items.[52]

[50] Harry M. Collins and Robert Evans, *The Third Wave of Science Studies: Studies of Expertise and Experience* (Cardiff: School of Social Sciences, Cardiff University, 2002). See also Harry M. Collins and Robert Evans, *Rethinking Expertise* (Chicago: University of Chicago Press, 2007).

[51] Collins and Evans, *The third wave of science studies*, 254.

[52] Therefore, my legitimacy results from my level of expertise and not from the fact that I would be holding a so-called scientific "truth". About the method of Grounded Theory, the process of selecting by open-coding the most relevant data to gather and categorising them progressively is called the theoretical sampling. I used the concept of interactional expertise to undertake this analytical process. See Corbin and Strauss, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 201.

To cope with the initial Computer-Assisted Qualitative Data Analysis from the reports' titles, I decided to collect data from the same first eight volumes of the Harrow Research Laboratory, checking the reports from the first report H.2c to the H.350. The study covers a period of 6 years from 1929 to the end of 1935, the first years of the Laboratory. Using my expertise of the technical and scientific context of the film industry I gathered data from a theoretical sampling of 62 reports.[53] I defined this sampling as sources of interest because it can clarify a wide scope of topics related to my research questions. For instance, whether or not the laboratory organised a technology watch on competitive products. Or whether or not the British photochemists undertook important studies of the photographic process to increase knowledge produced by the allied laboratory at Rochester. The other reports were not selected because their content was either redundant, or unable to better clarify the activities of a Research Laboratory. The content of the 62 reports was later processed to build a categorisation of the problems studied in the reports. Finally 16 sub-categories were generated, and these sub-categories were classified within 3 general categories: fundamental research activities, industrial research and development activities and *collaboration-oriented* activities, as shown in Table 4 below.[54]

[53] For each report I either summarized the content, or copied a part or the whole report in a file for each volume. The full list of the 62 reports and their titles are included in the appendices.

[54] The use of Grounded Theory was particularly relevant to the analysis of my data. As clarified by Corbin and Strauss, "*in the initial sampling, the researcher is interested in generating as many categories as possible; hence, he or she gathers data in a wide range of pertinent areas. Once the analyst has some categories, sampling is aimed at developing, densifying, and saturating those categories*." See Corbin and Strauss, *Basics of Qualitative Research*, 203.

Fundamental research activities	**Industrial research and development activities**	***Collaboration-oriented* activities**
Development of the instrumentation for the laboratory's activities (3)	Complete memorandum about a specific topic (3)	Investigation into a new technology developed by another company (10)
Investigation into the behaviour of a photochemical compound (2)	Development of new products (2)	Meeting with the staff of the Kodak-Pathé Research Laboratory (2)
Summary of testing procedures at the Laboratory (1)	Investigation due to production issue (7)	New material testing following a collaboration with a third party (3)
Testing of new dyes (2)	Investigation into a competitive product by reverse engineering (9)	Visit abroad to meet partners and to look for new technologies (4)
	Patent issue with competitors (3)	
	Testing and comparison between proprietary and competitive products (6)	
	Testing of film processing (4)	
	Testing of finished products (1)	
Total : 8 reports (13% of studied reports)	**Total : 35 reports (56%)**	**Total : 19 reports (31%)**

Table 4. Classification of the 16 sub-categories generated from the 62 reports within three main categories, with some figures.

At this stage of the analysis it is worth indicating the basic description of the research and development work in a Research Laboratory as defined by Kenneth Mees and John Leermakers of Eastman Kodak in 1950.[55] This work was split into three main sections. The first one was the work on the fundamental science of photography and the theory of the photographic process on a 25 per cent basis. The second one was the work on practical photography and the development of new products and process on a 50 per cent basis. The third one, also on a 25 per cent basis, was the work in the field of chemistry and physics related to photographic problems.[56] At the beginning of the second analysis no attempt was made to match these categories, instead the sorting

[55] Kenneth Mees and John A. Leermakers, *The organization of Industrial Scientific Research* (New York: McGraw-Hill, 1950).

[56] Ibid., 148.

was performed independently without preconceived or historical schemes. It is important to remember that the partitioning of the Harrow Research Laboratory work is different and quite a long way from the partitioning derived from the controlled corporate discourse of the managing staff of the Rochester Research Laboratory. The analysis was done for the work of the British Kodak Research Laboratory and differences between these two structures should not be seen as unusual. The work of Kodak Limited seems to be more concrete with a taste of "science in progress" for the standard fundamental research activities and sometimes with activities that could have been made by other departments in the company such as the investigation due to production issue. However, the most remarkable finding is the third category that I called *collaboration-oriented* activities. It illustrates an unknown part of the research work of the laboratory that clarifies the methods used to perform innovation. This way of managing innovation is quite modern and can be compared with the current model of "Open Innovation" conceptualized by Chesbrough in 2003 and already mentioned in the literature review. This innovation by Kodak Limited is discussed in the section 3.2.4. about the *collaboration-oriented* activities at Harrow. It is now relevant to illustrate the full spectrum of activities through a concise description of some research reports from the set of 62 reports. The case studies below cover the three identified types of activities found through three different sections. These case studies reveal a new vision of the Harrow Research Laboratory and provide a full understanding of a variety of research work undertaken in the 1930s by the British scientists.

3.2.2. The fundamental research activities at the Harrow Research Laboratory

As stated by Walter Clark, the first director of Kodak research in England, about 180 reports were produced during the first three years of the laboratory but "we did nothing on photographic theory."[57] The work on fundamental research developed

[57] "The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album," 15.

later under the supervision of Roy Davies, who became director in 1931. During his first weeks he noticed that the "sensitometric practices both at Harrow and Rochester were archaic."[58] Consequently one of the fields of study of the researchers was the development or the optimisation of instrumentation, while the science of sensitometry was progressively developing. A better or self-modified densitometer, burner or photometer with convenient standard light sources was required to be able to characterise photographic materials in terms of granularity, sensitivity and sharpness but also to improve the replicability during the manufacturing process, a key point in the production of cine and photographic film.

Before moving to Rochester, Walter Clark wrote the report H.148P outlining the sensitometric procedure for film and plates. This apparently trivial report is in fact an important memorandum for the smooth running of testing photographic materials of all kinds. Operations needed to be normalised to allow the comparison of sensitometric data between films and plates from Kodak Rochester, Harrow and Vincennes as well as competitors' products.

> This report outlines the procedure adopted in the Research Laboratory for the routine Sensitometry of plates and films. In addition to the materials submitted to these regular tests, there is a considerable number of materials having special characteristics and which must be examined from the point of view of the special purpose for which they are to be used. The sensitometric procedure has been designed so as to bring it in line as closely as possible with the method employed in the Research Laboratory at Rochester.[59]

Clark then described the procedure of exposing the photographic material in the Works Sensitometer supplied by the Rochester Laboratory, the light source being an Eastman Standard Acetylene Burner screened by a Wratten filter n°79. For density measurement the British Laboratory used the same Eastman Capstaff-Purdy Densitometer as Rochester. The interpretation of results such as the characteristic curve or the speed and inertia of the film was discussed. It is important to notice then

[58] Ibid., 21.

[59] Walter Clark, "Sensitometric procedure for films and plates," research report H.148P, November 5, 1930, ref. A2897, KCA-BL, 1.

the close correlation between the British Laboratory and the Research Laboratory at Rochester concerning the definition and the modifications of bench procedures. In 1932, E.W.H. Selwyn modified the Eastman Densitometer that had been conceived by J.G. Capstaff and R.A. Purdy around 1927 for motion-picture work[60] to be able to measure reflection densities on photographic paper. At Kodak Park, the instrument had already been modified by J.W. McFarlane and L.A. Jones to read reflection density but the novelty of Selwyn's modification was that the constant brightness field was retained during the measure.[61] Following Selwyn's work, Ralph E. Owen and Roy Davies reported, also in 1932, the manufacturing of a standard photometer for the measurement of photographic densities.[62] This progressive standardisation of bench procedures necessary for the development of photographic science and for the homogeneity of the production was also important to enable cross-site comparative studies and to provide a mutual scientific vernacular easy-to-understand by each Research Laboratory.

As to the classic activity of fundamental research, which is to increase the understanding of observed phenomena, the Harrow Research Laboratory did not undertake many studies during its first years. However, the chemist A. Batley worked during the summer 1930 on the effect of ammonium bromide on the pH of the gelatin and produced two research reports about the matter. The starting point of the research was an initial report by a French chemist at Kodak-Pathé, Georges Zelger, written in November 1929, allowing the joint work of Batley and Zelger to be defined as *teamwork*. It also shows that the British researchers retained contact with their French counterparts and were informed about their research. In his report Zelger concluded that "while [the] addition of ammonium bromide has no effect on the pH of

---

[60] Robert Bud and Deborah Jean Warner, *Instruments of science: an historical encyclopedia* (New York: Science Museum, London, and National Museum of American History, Smithsonian Institution, in association with Garland Pub, 1998), 164.

[61] E.W.H. Selwyn, "Adaptation of a Capstaff-Purdy densitometer for the measurement of reflection densities," research report H.203, February 26, 1932, ref. A2897, KCA-BL.

[62] Ralph E. Owen and E. Roy Davies, "Interim report on a photometer for the measurement of transmission and reflection densities," research report H.207, May 5, 1932, ref. A2897, KCA-BL.

a gelatin sol[ution], yet gelatin containing ammonium bromide, if coated and dried on a glass plate, shows a lower pH than the gelatin coated and dried without addition of the bromide."[63] For Batley and the research staff at Harrow, "as the matter may be of considerable importance in emulsion making, further investigations have been carried out in this laboratory, with a view to determining the true cause and mechanism of the effect."[64] The British chemist demonstrated that the phenomena was independent of the origin of the gelatin and was due to the volatilisation of the ammonia from the hydrolysed ammonium salt. Batley observed also that the greater the fall in pH was, the higher the pH of the gelatin. While it might be frustrating for the *interactional expert* not to know whether these small discoveries in the chemical behaviour of photographic emulsion were later used to innovate and improve the Kodak products, the situation mirrors that of the author of the report and the Kodak employees who read it. New fundamental knowledge had been produced and, it was now known by a team of scientists and managers and would be used later should someone find an interest in implementing it in a process. With the same rationale, Selwyn undertook an investigation in 1931 when it was discovered by the Research Laboratory at Vincennes that gelatin exposed to radiation from a quartz mercury vapour lamp hardened. The British chemist studied this physical behaviour of gelatin through "pilot" experiments and started a preliminary discussion about the effect.[65]

During the 1930s one of the major fields of photographic research was the investigation of the colour sensitivity of new chemical components to increase the photosensitivity of film beyond the visible spectrum and to select optimal molecules for future bi or tri-colour processes. For this purpose, testing of new dyes was necessary and one report in particular illustrates well this laboratory's activity as it pertains to a discussion about instrumentation and procedure. The report was created

---

[63] A. Batley, "The effect of ammonium bromide on the pH of gelatin. I.," research report H.116c, July 11, 1930, ref. A2897, KCA-BL, 1.

[64] Ibidem.

[65] E.W.H. Selwyn, "Hardening of gelatin by ultra-violet light," research report H.179c, May 21, 1931, ref. A2897, KCA-BL.

by E.P. Davey in August 1934 and covers the testing of dyes between March and July. These dyes had been selected and provided by Dr. Hamer and Davey's task was to determine the sensitising or desensitising properties of all of them. In short, the dye was incorporated in an emulsion and the colour sensitivity was measured with a wedge spectrograph. Davey indicated that he followed the general procedure used in sensitising the emulsion as recommended by Kenneth Mees. However, an easy comparison between results from the Rochester wedge spectrograph and the one at Harrow was difficult due to some small technical differences. As the two laboratories used different amperage to supply the spectrograph, a measure for the same dye could differ between Harrow and Rochester. Again, as the emitting spectrum of the light sources used at Rochester and at Harrow was different, the American results showed a greater relative colour sensitivity compared to Harrow. The report also states that L.A. Jones sent a letter to the director Davies in March 1934 about the matter.[66] This example shows that the American and British researchers were also actors in the young science of sensitometry, and that the physical nature of instrumentation and the related necessary procedures represented a challenge to and a major technological constraint in the conduct of fundamental research.

Again, such research was not the main task of the Harrow Research Laboratory. But some pioneering studies about the development of instrumentation, the investigation into the behaviour of photochemical compounds or the testing of dyes show that the British Laboratory was able to produce photographic knowledge when necessary. The benefit of this kind of research with no immediate practical aim was expressed by Roy Davies in 1977.

> In the photographic industry, if we understand more fully the wide range of phenomena exhibited by photographic materials, in their manufacture and in their applications, we shall achieve a greater measure of control which will lead to improved performance of our generic materials.[67]

[66] E.P. Davey, "Testing of dyes for sensitizing power. Period March - July, 1934," research report H.301, August 31, 1934, ref. A2897, KCA-BL.

[67] "The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album," 32.

3.2.3. The industrial research and development activities at the Harrow Research Laboratory

These core activities of the Laboratory may appear as routine and necessary work but they are vital for the company as they allow for comparisons with the competitors' manufactured products. They also enable the conduct of technology watch and the solving of production issues, which can threaten the company's survival. From the 62 reports studied, these reports represent more than half, consisting of 8 sub-categories. The first of the sub-categories that was identified is the production of complete memorandums about some topics in relation to the photographic industry and industrial research by competitors. It does not relate to fundamental research as it concerns not only the study of new raw materials for instance, but also the investigation of new products, processes or leading chemistry already studied by independent photochemists or competitors. Thus in 1930 Franck B. Phillips provided a complete literature review about diazotype processes from ca. 1890 to the time of writing, including full references and the description of milestones of the research in the field in Europe.[68] In the same way, Dr. Hamer wrote a 14 page report in 1932 about the many technological attempts to reduce the halation effect, providing references to patents or known solutions.[69]

The investigations pertaining to production issue are recurring and it is interesting to note that the British Laboratory did not take into account the problems from only the Harrow Works but also from the French and German Kodak production at the Vincennes and Cöpenick factories. The reports also show other examples of international collaboration between the Kodak staff. As soon as the new laboratory was created, Walter Clark met the French team of Kodak-Pathé at Vincennes and discussed in particular the problem of white spots on Vincennes film. Marcel Abribat had investigated the origin of the issue and had shown that the white spots were

[68] F.B. Phillips, "Some references to the literature of Diazotype processes," research report H.120g(ii), June 12, 1930, ref. A2897, KCA-BL.

[69] F.H. Hamer, "Anti-halation devices, with especial reference to the use of dyes," research report H.212, April 26, 1932, ref. A2897, KCA-BL.

caused by ferric ions. Because these ions are associated with the dust in the air, the French Laboratory undertook several tests and showed them to Clark. The director of the British Laboratory asked his researchers to investigate the issue at Harrow by using the same procedures.[70] In the next report, Clark reported that, while at Vincennes, he met Mr. Farrow of the Chemical Plant at Rochester, and discussed the corrosion of the steam coils used for heating the water baths in the silver nitrating rooms. Farrow advised Clark on the best steel to use for the steam coils, a sensitive material in the making of emulsion. He suggested Clark use Enduro steel to make the steam coils, as this metal was already in use for the Rochester steam coils. Hoods, basins and steam pipes were all made of Enduro and proved satisfactory. Through Farrow, Clark also heard that Mr. Tozier at the Kodak Toronto factory, was using Enduro hoods, and was satisfied with it.[71] Therefore through informal meetings and discussions, the Kodak industrial knowledge or know-how was spreading and transferring among laboratory and production managers.

As seen in section 3.1.1, the Cöpenick plant was a recent acquisition of Kodak A.G. in Germany. This factory had no research staff and the Harrow Research Laboratory sometimes dealt with the production issues of the German subsidiary. In 1930, Clark investigated a faulty Cöpenick nitrate support that showed some amber-coloured patches and holes.[72] Two years later, Edwin Jelley faced a problem characterised by the appearance of white spots on the processed Cöpenick X-Ray film during the early summer.

> Microscopic examination has shown that many of these spots have a nucleus, and that the nuclei are of sand, gelatinous material or fibres. About two-thirds of the

---

[70] W. Clark, "Investigation of white spots at Vincennes," research report H.82g, February 08, 1929, ref. A2897, KCA-BL.

[71] W. Clark, "Steam heating coils in silver nitrate plant," research report H.83g, February 08, 1929, ref. A2897, KCA-BL.

[72] W. Clark, "Defect on a print made on Copenick nitrate support 4-829," research report H.123p, May 28, 1930, ref. A2897, KCA-BL.

> nuclei are sand particles. An interesting feature is that practically all the particles are embedded in the emulsion.[73]

Jelley found the culprits. The Cöpenick factory was situated in a sandy country and during the hot season, the air became laden with sand and other particles. The water from the wells was full of dissolved iron, iron-bacteria and even sulphur bacteria. The water from the town was also laden with dissolved iron. Jelley worked jointly with technical staff and the manager of the plant, Franck Robinson, to solve the problem. He identified the chemical mechanism of the pollution and suggested two immediate actions, the treatment of the emulsion washing water with a solution of milk of lime and its filtering as well as a treatment by saturating the same solution with carbon dioxide.[74] This kind of investigation was necessary as faulty Kodak films available on the market damaged competition in particular with AGFA films. The solving of production issues was not a technical and routine task only as it had been before the existence of the Kodak Research Laboratories, because the analysis produced by the researchers frequently provided a deeper understanding of unknown parasitic photochemical mechanisms.

This scientific skill in biochemical analysis allowed the Laboratory to conduct many investigations into competitive products by reverse engineering. Before the advent of complex multilayered technologies of colour film on a single base, this corporate practice of technology watch was still possible with standard black and white or duplicating film, papers or negatives plates. The researchers could find out which chemical compound had been used in a specific process by a competitor. If its use was not patent protected, it was still possible to appropriate it for the products of the company. During the year 1930, Clark and his team observed that the Kodak films treated through the Henderson Laboratories in England were appreciably more resistant to abrasion and dirt. This company was created by William A. Henderson in

---

[73] E.E. Jelley, "The periodic occurrence of white spots on Copenick X-ray film," research report H.226, October 31, 1932, ref. A2897, KCA-BL, n.p.

[74] Ibidem.

1918 and gained a solid reputation for the development of cine film.[75] The researchers at Harrow organized some blind tests with Kodak film at the Henderson Laboratories and found that an additional treatment was used during the development process. The nature of the treatment was not entirely clear though.

> [It] appears to consist in the application, to the emulsion surface of the print, of a very thin layer of cellulose nitrate, containing a substance having a marked acid reaction. It is suspected that acetic acid is present in the mixture applied, to ensure the necessary adhesion between the gelatin and the nitrocellulose protective layer.[76]

Such a modified film was good because its strength when used in a projector was not lowered, as shown by wear and tear tests by the Harrow laboratory's staff. Sometimes the scientists were more successful for instance with the determination in 1930 of the nature of the dyestuff used in the backing of a Gevaert Anti-Halo plate. Through chemical and spectrographic examination Selwyn and Jelley found that the dye appeared "to be Aurin, partially neutralized (23.4%) with alkali."[77] Some studies were also more significant than others. In 1934 when E.P. Davey investigated the properties of Agfa Direkt Duplikat film, the report was sent to Mees in the United States, to Bent, Maitland and the "Management" in England, to Lair and Abribat in France and to Franck Robinson in Germany. In the introduction of the report Davey clarified the goal of the investigation.

> Agfa Direkt Duplikat Film is described by the makers as the first application of solarisation to commercial photography. This investigation represents an attempt to discover something of the nature and modus operandi of the film. The emulsion is already fogged when purchased, and exposure bleaches the latent image, so

[75] The Henderson Film's Industries are still active today. During the 1930s, "Henderson was busy inventing and patenting such improvements in the film industry as colour tinting of feature films, improvements in sound production with the introduction of sound on film in 1927 and special formulas to extend the life of nitrate film". A few years later Henderson also collaborated with Earl Sponable, the director of Research and Development at the Twentieth Century Fox in the United States. See "Henderson's Film Industries – Then," Henderson's Film Industries, accessed May 9, 2014, http://www.hendersonsfilmindustries.co.uk/html/then.html.

[76] W. Clark, "Henderson-treated film," research report H.128p, June 26, 1930, ref. A2897, KCA-BL, 3.

[77] E.W.H. Selwyn and E.E. Jelley, "Identification of dye backing of photographic plate," research report H.152p, December 11, 1930, ref. A2897, KCA-BL, 2.

> that the process is the opposite of what occurs ordinarily – i.e. bleaching instead of formation of latent image.[78]

Davey studied the new process and succeeded in developing a similar emulsion prefogged and bathed in a pinakryptol green dye, giving a speed in the same order.[79] Davey was apparently later instructed to continue investigating a similar process as he produced a second report on the matter the next year. The rationale of this additional study was to get the confirmation of the initial conclusion, namely that in the German process the image was produced only by solarisation and with no other effect such as photo-reversal by dyes. “In a thorough investigation, the next step would be to attempt to reproduce the emulsion synthetically, and thus to confirm the original conclusion.”[80] This time, Davey concentrated his search on the literature on solarisation and discovered new leads about the manufacturing of such an emulsion. According to Arens’ researches on solarisation, the emulsion could be prepared by peptising a silver-iodo-bromide precipitate. So Davey undertook some bench work and produced an iodo-bromide emulsion which solarised strongly, with similar photographic properties to those of Agfa Direkt Duplikat film. In this way, should the management decide later to launch a product similar to the German film, Kodak Limited had already developed a process to manufacture it.[81]

Other activities that can also be classified with standard industrial research and development work consisted in discussions about patent issues with competitors, such as the very first Harrow Research report as it has already been studied, and testing of film properties or film processing. For instance, a critical aspect for cine film was its

---

[78] E.P. Davey, “The properties of Agfa Direkt Duplikat Film,” research report H.317, December 18, 1934, ref. A2897, KCA-BL, 1.

[79] In the report Davey cited two *Laboratory reports* 51186 and 51186A containing a description of the ordinary properties of the German film. This is one of the few evidence of such a reporting procedure and according to my research the *Laboratory reports* have unfortunately not been archived nor kept by their authors. One can think that these reports might have been used as preliminary documentation for the writing of the research reports.

[80] E.P. Davey, “The properties of Agfa Direkt Duplikat Film. II. Preparation of a similar solarising emulsion,” research report H.333, May 01, 1935, ref. A2897, KCA-BL, 1.

[81] Ibid., 12.

mechanical resistance when used inside the projector as well as the consistency of the perforation pitch allowing the film to run and turn smoothly inside the projector. In 1934, E.D. Eyles suggested a reorganisation of the wear and tear testing of manufactured film throughout the European factories with the assistance of Mr. Collison. He also collected the dimensions of sprockets and guides, the measurements of the tension on the film in its passage through the projector and undertook a comparative testing on Harrow, Vincennes and Cöpenick samples of safety film. For Kodak Limited, the result was good.

> Analysis has shown that in general the Harrow pitch measurements are more consistent among themselves than those of either Copenick [sic]or Vincennes. This is surprising in view of the fact that at present no precautions are taken at Harrow to condition the film prior to measurement, or to make such measurements under controlled humidity conditions.[82]

The same attention was directed when a comparison was requested between Kodak products and equivalent competitive products. Sensitometric testing on Kodak and competitive films and plates were regularly conducted. In the spring 1931 T.D. Sanders and W. Clark produced twelve reports about sensitometric testing on Harrow films and plates and products from competitors with Agfa, Lumière, Guilleminot, Wellington, Ilford and Capelli among them.[83] The sensitometric characteristics of the photographic material such as its speed, gamma and the length of the straight-line portion to the characteristic curve allowed the researcher to determine which product was the best and the most appropriate for a specific use. To conclude this paragraph about the testing and comparison between proprietary and competitive products at Harrow it is worth citing two of Clark's studies about the flammability tests on safety film made in 1930 and 1931. It is important to keep in mind that as the film industry kept their formulae and manufacturing processes secret, the only way of controlling the quality of new safety film, that is to say nonflammable film made of cellulose acetate, was the conduct of burn tests to determine if the "safety" term could really apply. In his first

[82] E.D. Eyles, "Wear and tear testing," research report H.331, March 25, 1935, ref. A2897, KCA-BL, 9.

[83] For all these reports the same number 144 was used but the extension was changed from H.144p to H.144p(XII).

report, the result of burn test on cine Kodak film on Rochester and Pathé supports highlighted that the Pathé support was considerably safer.

> Rochester base ignites fairly readily, and when alight, burns to completion. Further, when burning, the Rochester base is inclined to drop burning material which continues burning on the floor for some time. Pathé base does not do this.[84]

The Agfa 16mm safety film was even worse than the Kodak cine film. As methods of the burn test were not standardised yet, Clark also experimented with a German method of testing and compared it to the American procedure used by the Society of Motion Picture Engineers. He started a correspondence with Professor Lehmann who was responsible for this new method in Germany, discussing the weaknesses in the German proposals and sending more samples of Kodak film to test. In the end, the results appeared contradictory.

> There seems to be little or no parallelism between the results of tests by the German and American methods. In a number of cases, a film which appears more inflammable than another by the American method is given as less inflammable by the German method. Incidentally, by the German method Rochester 16mm. safety film burnt more readily than any other 16mm. film tested.[85]

The discussion was not over, and Clark and Lehmann were able to talk again about burn tests face to face during the Eighth International Congress of Photography at Dresden on 3-8 August 1931 where the German scientist presented a paper about safety film.

This selection of reports referring to industrial research and development activities points out the important benefits of such studies for the company. Solving production issues increased the understanding of photographic emulsions produced and enabled new physicochemical methods of reverse engineering. The conduct of complete reports about a specific process, patent studies and comparative studies with

[84] W. Clark, “Burning rates of film, paper and textile fabrics,” research report H.118p, March 17, 1930, ref. A2897, KCA-BL, 11.

[85] W. Clark, “Burning tests on film according to the German method,” research report H.118p(II), July 10, 1931, ref. A2897, KCA-BL, 11.

competitive products also provided a better understanding of the global economic and technological environment to the company.

3.2.4. The *collaboration-oriented* activities at the Harrow Research Laboratory

As seen in Clark's report, setting up testing procedures and controlling Kodak emulsions and supports as well as the products from the competitors was an efficient strategy to determine the key points and the weaknesses of its own products. But it does not have much to do with innovation, although it could provide some avenues to follow that other companies used for some products. When I began studying the first volumes of the Harrow Research Reports, I had some preconceived ideas about how the research work could be handled. One could consider the endless bench work undertaken by chemists and physicists to conceive an experimental emulsion or to better understand a cutting-edge chemical compound; highly-skilled, genuine but isolated researchers working in a vacuum in their own laboratory. One of the great surprises of the research was to find some reports introducing a new method of industrial research turned towards other sources of technology and innovation: research structures, companies of the photographic and movie industry or independent inventors. This time the Kodak researchers not only performed a technology watch on innovative products and processes but they also sought advice and technologies from individuals or companies by contacting them and sometimes by establishing a technological collaboration. The transfer of technology was frequently bilateral and as the goal of this kind of cooperation was to combine the research capacities of each party, I use the term *collaboration-oriented* activities, already introduced at the end of section 3.2.1., for this third main category.

Evidence of such activities can be found in the confidential report of a visit made to Belgium and Germany by Clark in the Spring of 1929. According to him, the goal of the journey was "to see a number of places where photographic work is being carried on, to re-establish personal contact with a number of photographic workers, and to discuss photographic work in Germany in a general way."[86] One of Clark's first tasks was to visit Kodak A.G. in Berlin and the factory of Cöpenick. There, he discussed cine Kodak processing with Mr. Webb and Dr. Busch as some cine film was not properly processed. This was worrying because most of the German customers preferred Agfa's 16mm cine film to Kodak's. Clark gave his technical expertise and suggested the use of sensitometric strips to better check the chemical baths used. He also met Emanuel Goldberg afterward in Dresden at the Zeiss-Ikon factory and the ICA laboratories and Goldberg showed him a comparison between the two cine films, with better results for Agfa film. Clark decided to repeat the same test at Cöpenick and Harrow to confirm Goldberg's results. At this stage of the report it says that Clark also visited Professor Lehmann at the Technische Hochschule in Charlottenburg-Berlin.[87] The two scientists discussed the current research of the photographic department at the Technical University, such as the definition of a non-flammable film or investigations on new emulsions. Clark was aware of the interest of academic research for Eastman Kodak.

> In view of the influential position of Lehmann in official and Kinematograph circles in Germany, and his thorough current knowledge of the trend of Kinematograph and photographic affairs, it would seem desirable to make the fullest possible use of services he may care to render. He could be of considerable value for the company.[88]

In Belgium, Clark faced a tortuous case about a new colour process that an inventor and his agent wanted to sell. It illustrates the method used by the Kodak staff to evaluate the interest of a potential invention and to approach its author. The Belgian agent Mr. Van Sint Jan had already contacted George Eastman without success for a Mr. Proust, claiming a process of hypersensitising cine film and a process of colour

[86] W. Clark, "Visit to Germany and Belgium," research report H.81g, June 24, 1929, ref. A2897, KCA-BL, 1.

[87] Referring to Clark's report H.118p(II), it is now demonstrated that Clark already knew Professor Lehmann before 1931. The surname of the German photochemist is never mentionned in both reports, however it is most probably Dr. Erich Lehmann, one of Adolf Miethe's assistants and presumably his successor at Miethe's death in 1927. See Wentzel, *Memoirs of a photochemist*, 15.

[88] Clark, "Visit to Germany and Belgium," 6.

photography. But it appeared that both inventions came from the work of a Mr. Dony, the former associate of Mr. Proust.

> Dony first worked privately, and all the main ideas in the methods of hypersensitising and colour photography, now exploited by Van Sint Jan for Proust, were due to Dony. Proust wanted Dony to sign a contract with him, but as he was to receive a sum he considered inadequate, he would not agree, and parted company with Proust. Dony is now employed in the repair shop of the Kodak Co. at Brussels.[89]

It was essential for Clark to make everything clear about the chronology of the invention, and also about its real origin and property, should the Kodak company be interested in the new technology. He talked with Dony and got the confirmation that he had no agreement with any firm. Mr. Wildson, head of Kodak Co. in Belgium, came together with Dony to meet the agent Van Sint Jan and Proust for a demonstration of the colour process but as Proust recognized Dony, nothing was shown to the Kodak staff.

> It appears that Van Sint Jan and Proust are exploiting processes developed from Dony's ideas, and that, knowing Dony is now with the Kodak Co., they do not wish us to know too much about it.[90]

Finally, Clark managed to get some samples of Dony's hypersensitising cine film and sent them to Harrow for testing. Nothing more can be found about the eventual relationship with the Dony colour process and the Harrow Research Laboratory. For Clark, the visit in Belgium was also the opportunity to find out about recent activity by the competition in the photographic industry. The young Nadox factory near Brussels had been taken over by the Union Chimique for the manufacture of sensitive goods. One emulsion technician from Bayer and another from Lumière had been hired by the Union Chimique and as this new factory could threaten the market for Kodak in Belgium, Mr. Wildson suggested Clark contact this company to organise a merger in a near future with Eastman Kodak. Clark finished his visit in Ghent where he met André

[89] Ibid., 11.

[90] Ibid., 12.

Callier, an expert in optics and lens design.[91] Kodak Rochester was already equipped with one of his lens-testing devices, which was an improvement of a prototype developed by Goldberg in 1925. Clark recommended using Callier's device to test the Kodak lenses at Harrow for curvature of field and chromatic aberration. He judged all his work of the highest order.

> It is recommended that the services of Callier be used as far as possible for designing and constructing optical apparatus cheaply but well. He would welcome an extension of the use of his lenses on Kodak cameras.[92]

To Kodak, Callier was far more than a supplier, he was seen as a scientific consultant with whom a collaboration could lead to a general improvement of the optical characteristics of Kodak lenses.

Other reports clarify the practical side of the collaboration between Kodak Limited and independent inventors. During the first half of the year 1930, Clark reported joint work with Mr. August, an individual developing a new photocomposing machine from an August-Hunter model.[93] It is not known how Mr. August and Kodak Limited were introduced but the first report about the collaboration indicated that Mr. Barber, a technical manager of the Harrow Developing and Printing Department, had been assisting Mr. August in his developing work several months. The main points studied were the preparation of a satisfactory master positive film, the selection of a light source, a lens and a commutator for controlling exposures for the machine.[94] The

[91] Callier founded in Ghent the *Société Belge d'Optique et d'Instruments de Précision* in 1919. The factory produced photographic lenses, microscopes and other optical devices during the Interwar period.

[92] Clark, "Visit to Germany and Belgium," 16. Callier was Goldberg's friend and both scientists developed in 1913 an instrument that they called spectrodensograph. It was used to measure the intensity of light of different wavelengths. See Buckland, *Emanuel Goldberg and his knowledge machine*, 62.

[93] The principle of photocomposition is to photograph characters on film from which printing plates can be made. The initial model mentioned in the report was the photocomposing machine *Thothmic* developed and launched by Edgar Kenneth Hunter and his brother-in-law Johannes Robert Carl August in 1925. Hunter and August never managed to produce a marketable industrial model of photocomposing machine. See Alan Marshall, *Du plomb à la lumière: la Lumitype-Photon et la naissance des industries graphiques modernes* (Paris: Éd. de la Maison des sciences de l'homme, 2003), 51-53.

[94] W. Clark, "Report on visit to Mr. August, March 4th, 1930," research report H.110d, March 05, 1930, ref. A2897, KCA-BL.

practical terms of the collaboration were not well defined and it seems that the independent inventor suffered from the situation.

> Although I told Mr. August that I could not discuss any financial matters at all, he took every opportunity of impressing me with his need for freedom from financial worries to enable him to get ahead with his work. At one point he became slightly abusive of the Kodak Co., and their "desire to get something for nothing" and their inertia when he asked for money.[95]

Kodak Limited finally funded Mr. August and as the progress was significant due to his joint work with Barber, Clark thought that a demonstration of the machine could be made soon at slow speed.[96] Indeed Mr. August came to visit Harrow in May and managed to make his photo-composing machine work. The speed of the device was a key point and the speed of the prototype, although satisfying, was too weak to market the product with these characteristics. However Clark remained confident.

> This is the first demonstration that the writer has had that the mechanism of the photo-composing machine is capable of working at a speed higher than one change in 10 seconds. The results lead to the opinion that it is probable that the machine itself could be made to work at a rate suitable for practice.[97]

Such a collaboration seemed to be a beneficial partnership and to make sense for both sides.

Sometimes contact and information transfer were more challenging while the independent inventor was cautious and anxious that his new technology might be incorporated in some Kodak products without any compensation. This is for instance the situation encountered in 1930 with a mysterious Mr. Robins proposing a new "non-inflammable and non-explosive" film to Kodak Limited. The researchers looked for the corresponding patents and tested the film thoroughly to understand its nature. The cellulose nitrate or acetate could have been replaced with viscose. With regard to

---

[95] W. Clark, "Visit to Mr. August, April 17th, 1930," research report H.110d(II), April 22, 1930, ref. A2897, KCA-BL, n.p.

[96] Ibidem.

[97] W. Clark, "Visit to Mr. August, 19th May, 1930," research report H.110d(III), June 03, 1930, ref. A2897, KCA-BL, n.p.

colour photography, the technology was innovative. Indeed the film was made of three laminated layers, possibly intending to produce a panchromatic emulsion, each layer was sensitised for a portion of the visible spectrum. The Kodak scientists also found that the film was sensitised by bathing and therefore was not very sensitive. The shrinkage of the film was too high. Finally it was found that this sample of film was not entirely new.

> A film similar in type to the present was offered to the Company a year or two ago, examined by Mr. Blake, and rejected. It is obvious that the present film is the same as this previous one. No mention of this had been made by Mr. Miller. Towards the close of the negotiations, however, the writer tackled Mr. Miller about it, and obtained an admission that it was the product of the same inventor, but "considerably improved as the result of further research." [98]

As a result, Clark informed the Kodak Research Laboratory at Rochester with a copy of the report and a sample of the film and decided to wait for their opinion before any further negotiations.

On some occasion the *collaboration-oriented* activities of the Laboratory came from professional contacts or friendships with members from other research laboratories. In 1929 Mr. Le Rossignol of the Research Laboratories of the General Electric Co., Wembley, suggested that Clark investigate the photographic action of thoriated tungsten lamp filaments. It could give a measure of the amount of thoria present in the tungsten and the Harrow researchers looked for the most appropriate emulsion.[99] During the same period, the Harrow Research Laboratory worked in conjunction with another scientist of the Research Laboratories of the General Electric Co., Mr. G.H. Wilson, to test some projector lamps probably because General Electric did not have the procedure and equipment yet to test light sources.[100]

---

[98] W. Clark, "A safety film (Robins)," research report H.139d, September 02, 1930, ref. A2897, KCA-BL, 5.

[99] W. Clark, "Photographic activity of thoriated tungsten filaments," research report H.65p, December 16, 1929, ref. A2897, KCA-BL.

[100] W. Clark, "Some Kodascope projector lamps," research report H.100p, December 20, 1929, ref. A2897, KCA-BL.

Some investigations into a new technology developed by other companies were directly connected with potentially workable (at least according to the first tests) tri-colour processes, such as the processes of Colour Snapshots Ltd. The English company was created in 1928 and its processes were based on a patent by William Tarbin with a new tripack arrangement to Ducos du Hauron's initial multiple-layer package that had been patented in 1895.[101] Two comprehensive reports illustrate the lengthy investigation undertaken by the Kodak research team to determine whether or not the colour film of this very young but well-funded company was worth purchasing. The colour film was made of a tri-pack with three emulsions but also with three supports, generating some optical problems and significant thickness in the film. According to Clark, the film itself and its base was made by Imperial and Selo Limited. Initially, Mr. Tritton of Colour Snapshots Ltd worked with with Clark and Crowther of Kodak Limited to discover the best Kodak camera to use with the experimental film so that the three layers were uniformly blocked with a workable pressure. Tritton gave some spools of film to Clark and Crowther to expose it at the Developing and Printing Department at Harrow.[102] Tritton, Mr. Klein and two technicians of Colour Snapshots Ltd came to Harrow to discuss the results and to prepare prints from the negatives (see Illustration 7). Clark justified the writing of the report in technical and economic terms.

> This report is intended to record our experiences of the handling of the process, with full manipulative details, general information gleaned in conversation with Messrs. Klein and Tritton, and general remarks on the process to serve as a guide to its possibility as a commercial proposition.[103]

The structure of the tri-pack was carefully studied. The red-sensitive film was in the front, the green-sensitive film had its emulsion facing the emulsion of the front film, the back film being blue-sensitive. Oddly enough, the three films were not cemented together, because they had to be separated during the printing process of the tri-pack

---

[101] Brian Coe, *Colour Photography: The First Hundred Years, 1840-1940* (London: Ash & Grant, 1978), 111.

[102] W. Clark, "COLORSNAP process of colour photography," research report H.84g(II), February 01, 1929, ref. A2897, KCA-BL.

[103] Ibid., 1.

made of a complicated superposition and register of three dye-transfer images by imbibition. The Kodak staff attempted to expose the experimental film with the best procedure and let Klein and Tritton prepare the colour prints through the imbibition technique. However the poor results and the procedures used by the staff of Colour Snapshots Ltd disconcerted Clark.

> No attempt is made to control the individual gradation of the separated negatives; all are developed together. The correct conditions for dyeing the positives were not known. […] The "experts" seemed to have no definite idea of the relative colour values required of the three images. […] Not one of the prints prepared could be regarded as satisfactory. All were diffuse, and most of the colours false.[104]

The commercial side of the new technology was also unclear. An agreement for the distribution of the product with Messrs. Houghton-Butcher had been voiced, but Klein finally invalidated this information. He nevertheless stressed the interest of Agfa in the new technology while confirming that "no agreement for manufacture, distribution or processing would be made until Messrs. Kodak Limited had signified whether they were interested or not."[105] Clark's summary of the situation was a terrible indictment of the Colour Snapshots Ltd company.

> The process is theoretically not sound; the process is not capable of yielding satisfactory colour prints, even in the hands of experts […] ; the process itself is not really understood by the Colorsnap experts ; the method of processing is so uncertain and involved as to be of doubtful commercial value as a Developing and Printing proposition […].[106]

[104] Ibid., 9.

[105] Ibid., 12.

[106] Ibidem.

Illustration 7. Colorsnap representing some members of the Kodak Research Laboratory with friends on May 20, 1929.[107]

Kodak researchers did not pursue further investigations on the Colorsnap tri-pack process, and the many faults of the young company finally resulted in its compulsory liquidation in December 1929.[108] It is difficult to ascertain to what extent Kodak's poor opinion about the new tri-pack process was one of the contributing factors reasons. But for Kodak, the success or the failure of a study in the framework of a research activity was not the most important indicator. This case illustrates well that hazard or opportunities can lead to marketable products or to dead ends, and that the time spent on a scientific investigation is not wasted time.

Another important chapter about research in colour photography during the interwar period relates to Kodak's first Kodacolor process. George Eastman unveiled it in June

---

[107] Illustration from Coe, *Colour Photography: the First Hundred Years*, 114. The photographer was Ralph E. Owen, also a researcher from Kodak Limited. This view was taken in Stanmore Common, a public park in the London Borough of Harrow. It may have been done during the visit of the staff of Colour Snapshots in Harrow.

[108] Coe, *Colour Photography: the First Hundred Years*, 116. At the end Colour Snapshots Ltd had to apply the colour by hand on black and white prints made from the element front of the tripack as the colour rendering was unnatural.

1928 during a celebration at his home in Rochester. The technology of the first Kodacolor process had been first developed by Rodolphe Berton with his additive process. The Société Keller-Dorian-Berthon was created when Berthon created a partnership with Albert Keller-Dorian, the director of a factory. In 1925, the French company offered the rights of its patents to Eastman Kodak and these rights were finally purchased in 1926. In the Kodak Research Laboratory at Rochester John Capstaff and his team improved the French process and it was finally marketed two years later.[109] It is therefore peculiar to find in the Harrow research reports two reports of visits to the Keller-Dorian offices in France in January and August 1929. During the first visit Clark was with Abribat of the Kodak-Pathé Laboratory and they apparently studied the duplicating machine for Keller-Dorian film which was still in use outside the United States. But both reports are precise and detailed containing technical data and sketches including the embossing system of this lenticular film and its processing. As this three-colour additive process is important to Kodak's long-term research in colour photography, I will study these reports in the next chapter about colour research, in section 4.1.3.

To conclude with the *collaboration-oriented* activities of the Harrow Research Laboratory it is necessary to mention some evidence of team work between Kodak's British and French Laboratories during their first years. Only two reports were found for the period 1929-1935 that show a straight scientific collaboration between the two laboratories but the topics discussed were significant. In November 1930 Clark made a second and extensive visit to Vincennes, met most of the members of the Research Laboratory such as Abribat, Lecté, Moreau, Calame and Lair and reviewed the work in progress in the research departments. The French were still investigating colloidal chemistry following a production issue with the appearance of white spots on some

[109] *Journey: 75 years of Kodak Research*, 30. "About three years ago Keller-Dorian of Paris demonstrated some colour pictures on 35 mm. film which they had produced by the Berthon additive process. These appeared so promising that the Eastman Kodak Company arrange to purchase the Keller-Dorian patents and the Research Laboratory started to work out the process for the Ciné Kodak." J.G. Capstaff and M.W. Seymour, 1928, "The Kodacolor Process for Amateur Color Cinematography", *Transactions of the Society of Motion Picture Engineers* 12 (1928): 940.

Kodak-Pathé emulsion.[110] This problem provided an opportunity for a research work to ascertain the role and the behaviour of gelatin with some specific chemicals. As the French had experienced the fading of the latent image with roll-film, Abribat investigated the oxidising properties of materials used in making film support. He and Lecté studied the effect of several materials and observed the change of sensitivity, latent image and fog for the emulsion. They also were investigating the chlorination of gelatin and the dehydration of gelatin with acetone. Later Clark balanced the pros and the cons of acetone's use.

> Although this use of acetone might be of value for rapid drying of test pieces, it is not possible to say offhand whether it is of value on the manufacturing scale. It certainly could not be applied to emulsions containing materials soluble in acetone. Further, the cost of acetone would be considerable, and it would be necessary to install a recovery plant.[111]

Another aspect of the French research was the study of the swelling of the gelatin and of cellulose esters in water over a long time. The benefit of this work was the understanding of the structure of the gelatin and to ascertain for instance if there was an intermicellar and intra-micellar swelling proceeding successively. Whatever the final industrial application of this fundamental research, both laboratories were sharing their knowledge and exchanging ideas. This exchange was bilateral and Clark also provided some of his findings.

> M. Lecté has started a series of experiments on the adsorption of Methylene Blue by silver halides. I have sent him a report of some measurements I made some years ago on this subject. I think they are well worth following up, as they may shed some light on the surface properties of silver bromide in an emulsion, and their variations with conditions of emulsion manufacture.[112]

Another reason for Clark's visit was the improvement of sensitometric standardisation. How was Kodak to compare and discuss photographic density

---

[110] As it has already been mentioned earlier. See W. Clark, "Investigation of white spots at Vincennes," research report H.82g, February 08, 1929, ref. A2897, KCA-BL.

[111] W. Clark, "Visit to Vincennes, November, 1930," research report H.155g, December 31, 1930, ref. A2897, KCA-BL, 3.

[112] Ibid., 7.

measurements if the same language was not used on both sides of the Channel ? In France, a Fabry and Buisson Microphotometer was used, giving parallel light densities with a range of density up to 4.5. Clark recommended the Eastman Capstaff-Purdy Densitometer that was in use at Rochester and Harrow. The initial French reaction was cautious. Lair asked to undertake preliminary tests first. Clark agreed but pointed out that the chemist Moreau had tested the Eastman Densitometer during a visit at Harrow and had given a positive opinion about the instrument. Other sensitometric procedures were compared such as the standard light source and developer employed.[113]

Two years later, a conference on graininess in cine-film held at the Harrow Research Laboratory also presented an opportunity to share scientific knowledge on the topic and to discuss a possible standardisation for the measurement of graininess. Roy Davies, the new director of the British Laboratory was the keynote speaker while the former director Clark, working at Rochester since 1931, was the scientific representative of the American Laboratory. Abribat represented the Kodak-Pathé Laboratory. The starting point of the conference was the research work undertaken by Selwyn and Batley on measurement on graininess of Cine Kodak film.[114] The discussion started on the theoretical aspects of the graininess, its variation with the density of the film, Selwyn introducing the notion of physical graininess : "it is the variation of the density of the material from point to point, as you measure the density over a very small area."[115] The British chemist had investigated the method of L.A. Jones and Hardy proposed in 1925 at Rochester and discussed the correspondence between the visual effect and the physical measurement of graininess. The talk focussed on a clear definition of the human eye's behaviour, Abribat pointing out that the eye did not behave like a camera, but could see only by continuous scanning. The role of the retina

[113] Ibid., 5.

[114] E.W.H. Selwyn, "Physical measurement of graininess," research report H.233, November 26, 1932; R.H. Bomback and A. Batley, "Measurement of graininess of processed Cine-Kodak film," research report H.240, February 22, 1933, ref. A2897, KCA-BL.

[115] W. Clark, "Conference on graininess in cine-film at the Harrow Research Laboratory. May 13th, 1933," research report H.249, May 13, 1933, ref. A2897, KCA-BL, 1.

was studied, and Clark finally "objected that he could not see how a standard could be set."[116] Selwyn defended himself with a long intervention including mathematical formulas, but just after him the speakers started to think about "terms of practical experience".[117] So little had been done practically and this represented a problem. A controversy arose when Abribat introduced the relationship between graininess and the presence of silver. Davies and Selwyn contested his technical arguments. The discussion was definitely too theoretical. Phillips signalled to move forward.

> Mr. Phillips asked whether the discussion could shift on to the practical application. Had they to wait for the completion of this correlation before they could use a working method to measure the graininess of the Cine-Kodak films ? He felt that if they had to wait for that correlation they might have to wait for years.[118]

Phillips had studied Rochester's methods during several journeys to Kodak Park and knew that the Americans had no definite opinion about the objective and subjective side of the measurement of graininess. Davies was of the opinion that the researchers at Rochester should start to use Batley's method, "while the theoretical aspects were still under examination."[119] Phillips agreed with him and also suggested to Clark that Rochester organise an investigation of the relationship between processing deviations and the granularity of the picture. It was better to do it in the United States as the British researchers could not undertake such a survey with sufficient scale. Finally, Clark reviewed the Rochester comments on Selwyn's report H.233 and agreed to request general work on the graininess from the Rochester Research Laboratory.[120] These long minutes of proceedings were also sent to Mees and to Bent, the manager of the Harrow plant. It is not known how the quest for a convenient standard in graininess measurement came to an end and whether or not the American Kodak Laboratory organised a long-term study from Selwyn's and Batley's work. But at least

---

[116] Ibid., 3.

[117] Ibid., 4.

[118] Ibid., 6.

[119] Ibid., 7.

[120] Ibid., 10-11.

from this collaborative work of the laboratories emerged the idea that the three research structures of Eastman Kodak were sharing their newly developed knowledge when the finding or the innovation was of interest. Thus the behaviour of the Harrow Research Laboratory with the other Kodak Laboratories was not far from its work with third party companies and the investigation on their new technologies, in the framework of *collaboration-oriented* activities.

In the section above, I have undertaken an exhaustive study of the production of knowledge at the Harrow Research Laboratory through the analysis of the research reports. From the data collection two strategies were taken to perform a qualitative analysis of 350 reports created from 1929 to 1935. The first method focused on the technical discourse embedded in the titles of the reports and necessitated the use of two Computer-Assisted Qualitative Data Analysis Software to generate statistical figures and visual tag clouds. The data produced through this method provided little information about the general work of the Harrow Research Laboratory. A second method based on Grounded Theory and the interactional expertise of Collins and Evans was therefore used to enable analysis of the content of the 350 reports from a photographic and scientific background. 62 reports have been kept for their content and classified within 16 sub-categories of 3 general categories: fundamental research activities, industrial research and development activities and *collaboration-oriented* activities. The last category exhibited a modern method of innovation for an industrial research structure of the interwar period. The selected case studies have shown the way the British Laboratory undertook some collaboration with companies and individuals. I have also introduced some of the teamwork with the French Kodak-Pathé Laboratory, as an archive of this structure has recently emerged in France. Thus the next section deals with the organisation of Kodak research in France compared with the British structure. It also enlightens the existence of scientific collaboration and transfer of technological or scientific knowledge between Rochester, Vincennes and Harrow.

3.2.5. Transfer of knowledge between Harrow, Rochester and Vincennes

During 2013, the discovery of the new French Kodak-Pathé company archive at Chalon-sur-Saône, France, provided a complementary and critical insight into the activities of Kodak research within the three main research laboratories. The initial study of the Harrow research reports clarified the role of the British Research Laboratory, its mission and exchanges with the main laboratory at Rochester. With the additional French archive, it was now possible to suggest an answer to the following questions: how was Kodak-Pathé research reorganized from the initial structure of the Pathé-Cinéma research laboratory? How was the additional research organisation incorporated into innovation strategy at Eastman Kodak ? As the French archive was only in an intermediary state and not entirely inventoried in 2013, I again opted to use grounded theory to draw as much relevant data as possible from the unidentified corpus of qualitative data. My theoretical sampling in the archive started from a few "local concepts", or categories, as stated by Glaser and Strauss in 1967.[121] I initially knew that I could rely on a presumably complete set of research reports and on additional data with the other Research Laboratories. With a circular process of data collection including intermediary steps of data analysis I was able to refine the sampling of materials for my visits to the archive and to generate some theories about the French methodology of industrial research. During the collection process some outstanding material was found unexpectedly because it was not classified in the folder consulted. Due to this situation and to the important amount of work still necessary to inventory the archive, I did not consider performing a standard comparison between the French and the British research reports and instead choosing to focus on one important research question. Therefore this section is about how the French Laboratory collaborated with its American and British counterparts, and about how scientific knowledge circulated among the three laboratories.

[121] Barney G. Glaser and Anselm L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*, reprint (New Brunswick, London: AldineTransaction, 2006), 45.

The nature of the French reports and a method of classification that differed from the British system also made the research reports incomparable. At Kodak-Pathé, the research reports were classified by author in a research notebook presumably during a lengthy archiving process for an unknown period of time. If the scientist was a prolific researcher the unidentified archivist created several research notebooks in his or her name. One peculiarity of the archive clarifies the French context of photographic research: there is no partition between the period of Pathé up to 1927 and the period of Kodak-Pathé from 1927 onwards. For chemists already working for Pathé and later for the new Kodak-Pathé organisation their research reports were classified together, largely in chronological order. It seems that this way of archiving the research reports highlights the research work undertaken before 1927 by the scientific team of Pathé. Unlike the British Research Laboratory, its counterpart at Vincennes did not start from scratch but benefitted from a large body of technological knowledge that had been produced since the first years of the twentieth century. Moreover, this amount of knowledge clarifies and confirms the strategic interest of George Eastman in the French film manufacturer and the following merger in 1927.

Some other notebooks did not relate to a specific researcher but to a specific activity, such as *Activité Labo Recherches* but they are in the minority. The nature of the research notebooks can vary. The research reports were generally typescripts with occasional curves, figures or photographs. One can also find some correspondence which is either original material or typed copies of original letters. Some rare research reports were handwritten directly by the researcher and incorporated into the research notebook this way, while a few handwritten drafts of report or letter have also been found somewhere in the corpus.[122] On a cautionary note, it is important to say that it was impossible to study another important source of information, identified in French as the “livres de fabrication”. These chronological manufacturing notebooks are either lost or not kept in the Kodak-Pathé archive with the exception of the first

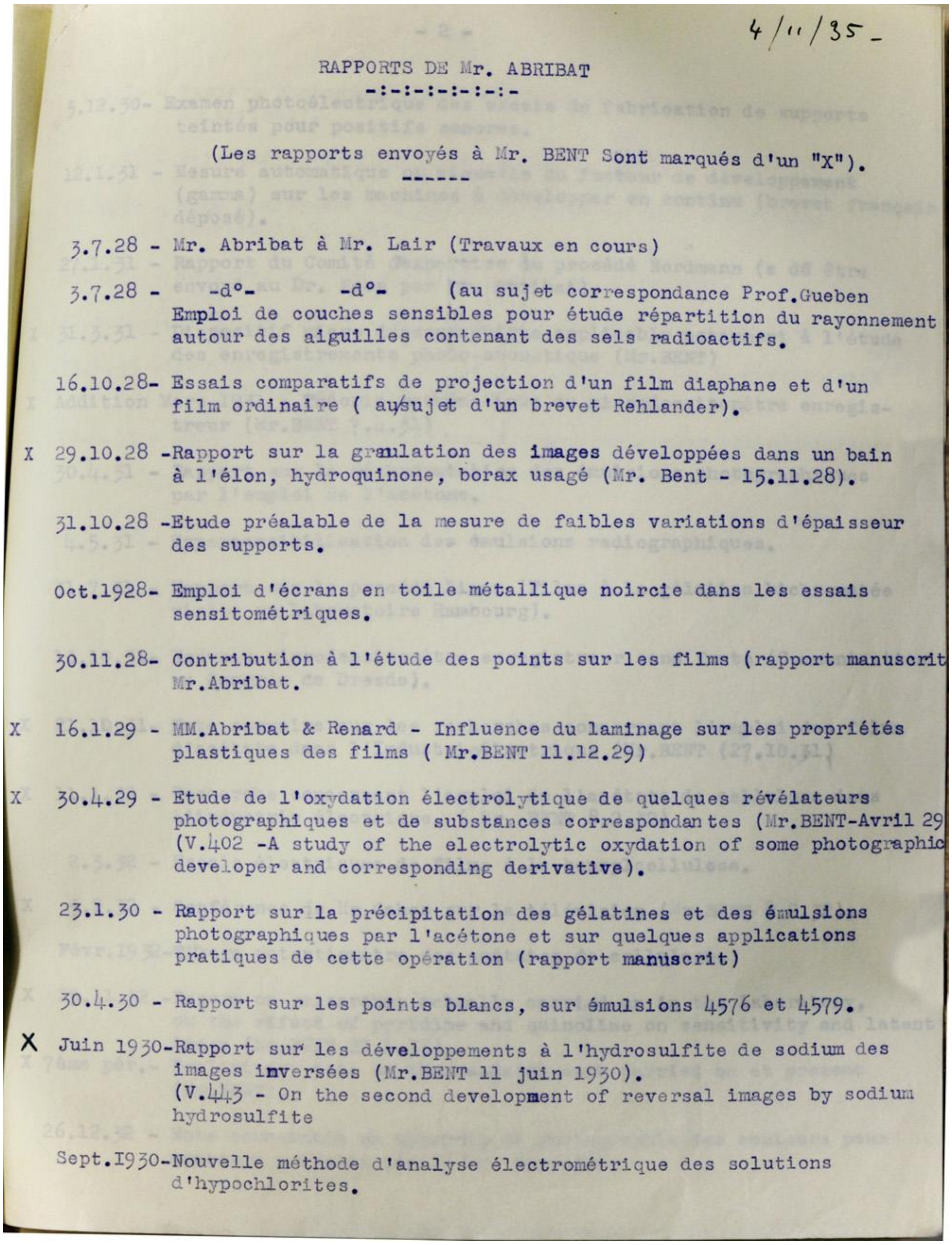
[122] During my research I only investigated the corpus of research notebooks but the Kodak-Pathé archive is far more important in volume with materials relating to accounts, marketing, human resources and some photographic collections about the industrial history of Kodak-Pathé.

one. The keeping of manufacturing notebooks belonged to the Pathé period as the only manufacturing notebook kept in the archive is dated back to 1906.[123] Due to the existence of notes and annotations about the manufacturing notebooks on some research reports, it is possible to better understand the rationale of the knowledge transfer. The research reports that were considered as essential for the technological or scientific knowledge produced were incorporated in the manufacturing notebook of that period. There is evidence of this methodology of incorporation at least up to the Second World War, therefore this practice continued well beyond 1927. In the manufacturing notebook, the best research reports were placed next to activity reports and minutes of general meetings. However, the loss of the subsequent volumes of the manufacturing notebooks was not detrimental to my research because all the research reports, classified by author, are preserved in the French archive as well as the reports that were not selected for incorporation in the manufacturing notebook. It is theoretically possible to ascertain the complete research work produced by a chemist or a physicist during his or her full career at Kodak-Pathé.

With a better understanding of the nature of the Kodak-Pathé archive we can now return to the research questions above and ascertain the circulation of the scientific knowledge among the Kodak Research Laboratories from the study of some material found in the French archive. The first document is an inventory of the research reports produced by the director Marcel Abribat for the period 1928-1935 (see Table 5). This handwritten and typed document was found in a research notebook of another researcher with no direct connection with Abribat. It is made of several stapled sheets of paper, unlike the standard research reports that are bound into research notebooks. Thus this document was certainly never classified and its discovery was only made by chance. The major characteristic of the document is that each report also sent to Kodak Limited is identified with a specific mark "X" making it possible to identify what

[123] "Livre de fabrication de la Compagnie générale de Phonographes Cinématographes et Appareils de précision. Siège social : 98, rue de Richelieu – Paris". The year 1906 is probably not complete as the unique « livre de fabrication » in the archive is the volume 1 of that year.

kind of scientific knowledge was shared with the British researchers and in what proportion.



- 2 -

4/11/35 -

RAPPORTS DE Mr. ABRIBAT

-:-:-:-:-:-

(Les rapports envoyés à Mr. BENT Sont marqués d'un "X").

3.7.28 - Mr. Abribat à Mr. Lair (Travaux en cours)

3.7.28 - -d°- -d°- (au sujet correspondance Prof.Gueben
Emploi de couches sensibles pour étude répartition du rayonnement autour des aiguilles contenant des sels radioactifs.

16.10.28- Essais comparatifs de projection d'un film diaphane et d'un film ordinaire (au sujet d'un brevet Rehlander).

X 29.10.28 -Rapport sur la granulation des images développées dans un bain à l'élon, hydroquinone, borax usagé (Mr. Bent - 15.11.28).

31.10.28 -Etude préalable de la mesure de faibles variations d'épaisseur des supports.

Oct.1928- Emploi d'écrans en toile métallique noircie dans les essais sensitométriques.

30.11.28- Contribution à l'étude des points sur les films (rapport manuscrit Mr.Abribat.

X 16.1.29 - MM.Abribat & Renard - Influence du laminage sur les propriétés plastiques des films (Mr.BENT 11.12.29)

X 30.4.29 - Etude de l'oxydation électrolytique de quelques révélateurs photographiques et de substances correspondantes (Mr.BENT-Avril 29 (V.402 -A study of the electrolytic oxydation of some photographic developer and corresponding derivative).

23.1.30 - Rapport sur la précipitation des gélatines et des émulsions photographiques par l'acétone et sur quelques applications pratiques de cette opération (rapport manuscrit)

30.4.30 - Rapport sur les points blancs, sur émulsions 4576 et 4579.

X Juin 1930-Rapport sur les développements à l'hydrosulfite de sodium des images inversées (Mr.BENT 11 juin 1930).
(V.443 - On the second development of reversal images by sodium hydrosulfite

Sept.1930-Nouvelle méthode d'analyse électrométrique des solutions d'hypochlorites.

Table 5. Extract of the inventory of the research reports produced by the director Marcel Abribat for the period 1928-1935.[124]

[124] "Liste des rapports de Monsieur Abribat de 1928 à 1935, " inventory, November 11, 1935, ref. 33498, CECIL.

Year	Date	Research reports sent to Walter Bent[125]
1928	29/10/1928	*Rapport sur la granulation des images développées dans un bain à l'élon, hydroquinone, borax usage (Mr. Bent – 15.11.28)*
	Number of other research reports that were not sent to Kodak Ltd : 6	
	Percentage of research reports sent to W. Bent for the year : 14%	
1929	16/01/1929	*MM. Abribat & Renard – Influence du laminage sur les propriétés plastiques des films (Mr. Bent 11.12.29)*
	30/04/1929	*Étude de l'oxydation électrolytique de quelques révélateurs photographiques et de substances correspondantes (Mr. Bent – Avril 29) (V.402 – A study of the electrolytic oxydation of some photographic developer and corresponding derivative).*
	Number of other research reports that were not sent to Kodak Ltd : 0	
	Percentage of research reports sent to W. Bent for the year : 100%	
1930	06/1930	*Rapport sur les développements à l'hydrosulfite de sodium des images inversées (Mr. Bent 11 juin 1930). (V.443 – On the second development of reversal images by sodium hydrosulfite).*
	Number of other research reports that were not sent to Kodak Ltd : 4	
	Percentage of research reports sent to W. Bent for the year : 20%	
1931	31/03/1931	*Dispositif micro densographique applicable notamment à l'étude des enregistrements photo-acoustique (Mr. Bent)*
	Addition Mars 1931	*Théorie mathématique du microdensitomètre enregistreur (Mr. Bent 7.4.31)*
	21/10/1931	*Note sommaire sur les recherches concernant l'emploi des films d'acétate dans l'Industrie électrique (Mr. Bent 27.10.31)*
	Number of other research reports that were not sent to Kodak Ltd : 6	
	Percentage of research reports sent to W. Bent for the year : 33%	
1932	11/01/1932	*Recherche concernant l'emploi de l'acétate de cellulose dans l'industrie électrique (Mr. Bent 8.2.32)*
	5/02/1932	*Conférence de Mr. Cahen sur la télévision (Mr. Bent 8.2.32)*
	29/11/1932	*Report on researches actually carried on in the laboratory, on the effect of pyridine and quinoline on sensitivity and latent image (Mr. Bent 27.1.33).*
	7ème pér.	*Preliminary note on the research work carried on at present (Mr. Bent).*
	Number of other research reports that were not sent to Kodak Ltd : 3	
	Percentage of research reports sent to W. Bent for the year : 57%	
1933	-	-
	Number of other research reports that were not sent to Kodak Ltd : 2	

[125] Walter G. Bent, a chemical engineer from the Massachusetts Institute of Technology spent fifteen years at Kodak Park and at the Kodak plant in Toronto. In 1920 he was appointed as the new Works Manager at Harrow. In 1930, he was replaced by William R. Webb and became General Manager of Kodak European factories. See Gauntlett, "A History of Kodak Limited," 33, 57, 65, 152.

	Percentage of research reports sent to W. Bent for the year : 0%	
1934	-	-
	Number of other research reports that were not sent to Kodak Ltd : 2	
	Percentage of research reports sent to W. Bent for the year : 0%	
1935	30/01/1935	*(Abribat-Pinoir) – Appareil pour la mesure de la conductivité électrique des films émulsionnés (Mr. Bent)*
	Number of other research reports that were not sent to Kodak Ltd : 1	
	Percentage of research reports sent to W. Bent for the year : 50%	
1928-1935	**Total number of research reports produced during the period : 36**	
	Total number of research reports sent to W. Bent during the period : 12 (33%)	

Table 6. List of research reports produced by Marcel Abribat and sent to Walter Bent for the period 1928-1935.[126]

The summary included in Table 6 shows that about 1 in 3 reports was sent to Harrow and that there is no set topic. Abribat's growing responsibilities from the start of the Research Laboratory at Vincennes, did not leave him much time to produce research reports and the amount of reports for the period is therefore rather small. However this list of reports has been compared with the tables of contents attached with Abribat's research notebooks and it appears that it is the correct nature and quantity of reports. For some reports sent to the Works Manager Bent at Harrow one can find an English translation but translation was not systematic. This document ascertains that the recipient was only Bent but we do not know how Bent spread the following reports within the Harrow Research Laboratory. At least one can assume that some or all of the British researchers read the French reports that Abribat decided to share. The first conclusion of a brief analysis of the inventory is that in a mathematical sense one report out of three was sent to Harrow during that period of eight years (12 out of 36). But it is difficult to theorise this data, as for some years no report was sent to Harrow. The second conclusion is about the nature of the fields of study covered by the reports: topics are mostly heterogeneous. Some reports deal with the mechanical and

[126] The text in italic is a quotation from the original document. Source : "Liste des rapports de Monsieur Abribat de 1928 à 1935," inventory, November 11, 1935, ref. 33498, CECIL.

chemical properties of photographic films (graininess or physical resistance) or the optimisation of developers. Others deal with the development of new sensitometric instrumentation, the strategy of finding new markets for cellulose acetate or the technical watch on new technology like television. Concerning the Research Laboratory at Rochester, only one research report is labelled as "having been possibly sent to Dr. Mees by Mr. Abribat". It is the report concerning the expert committee of the Nordmann process filed on 27 January 1931. This process was an innovative way of duplicating lenticular tricolour film better than any existing duplicating processes of the period, like the Keller-Dorian's technology of collimation. Abribat was not a member of the expert committee but it seems logical that he reported to Mees on the results of the test of the Nordmann process, as Eastman Kodak could have been interested in this duplicating process for the Kodacolor lenticular process launched in 1928. As the copy of the report in Abribat's research notebooks indicates, Charles Nordmann had already patented his technology and the goal of his process was to establish an affordable industrial development without violating any existing patent. The mission of the expert committee was to appreciate the quality of a lenticular duplicated film compared to the original in terms of sharpness, colour rendition, colour cast and absence of moiré. The report concluded that the test was positive however it is not indicated anywhere that a copy was sent to Mees.[127] Strangely the same report was not sent to Walter Bent at Harrow. One reason for the paucity of reports sent directly to Eastman Kodak might be that in the early years of the French Research Laboratory, it had been decided in-house that the French team would report to their British counterpart only. This situation changed progressively, especially from the end of the Second World War as I discuss in the last part of this section.

Another inventory found in the French Kodak archive elucidates the transfer of knowledge between Vincennes and Harrow in a more general way. It concerns only the year 1935 but all researchers of the French Kodak Laboratory are cited. For each of

[127] Marcel Abribat, "Rapport du comité d'expertise du procédé Nordmann," research report, January 27, 1931, ref. 33074, CECIL, n.p.

them the inventory lists their reports. Each document is codified with a reference from the type V. xxxx where “V” represents the French place of Vincennes (for instance V. 1191). Should one report also be sent to Harrow, a letter close to its reference indicates the identity of the British addressee. For some researchers the inventory also includes a list of notes produced by him or her. These short reports relate to production matters or internal issues and none of them were sent to Harrow. Notes are not codified but are only classified with an indication of the date. Table 7 below represents the summary of the quantity of reports produced per researcher for the year 1935, the total number of reports that were sent to Harrow and the detail of these shared reports with the name of each addressee.[128] For a better understanding of the knowledge transfer, the titles of the British recipients are provided in an additional line. For each box filed, the chronological number of the reports is given. This is not a qualitative indication about each report but it does show whether the same report has been sent to several addressees or on the contrary to a single person.

[128] As notes were not shared with the other Kodak laboratories I decided not to count them in the quantity of research reports produced per researcher. Three researchers only have produced notes (Lecte, Marot and Mathieu). Therefore, they are not included in the figure.

Title of British addressees →		General Manager of Kodak European factories	Harrow Works Manager	Rochester Emulsion Coating Dept Manager[129]	Cöpenick Works Manager	Harrow Research Laboratory Scientist	Managing Director of Kodak Ltd.[130]	(Not known)	General Director of Kodak Research	-
***French Researcher* ↓**	**Reports prod-uced (total)**	**Reports sent to BENT**	**Reports sent to WEBB**	**Reports sent to SULZER**	**Reports sent to ROBINSON[131]**	**Reports sent to EYLES**	**Reports sent to BLAKE**	**Reports sent to SCHMIDT**	**Reports sent to MEES**	**Number of different reports sent to Harrow**
Abribat	1	1 (n°1)		1 (n°1)	1 (n°1)					1/1
Bousquet	5	3 (2,3,5)	2 (1,5)	2 (3,5)	2 (1,5)					4/5
Clément	10	10 (1 to 10)							1 (10)	10/10
Mme. Cuissard	29	3 (3,15,16?)	4 (3,15,16, 29)	1 (16)	2 (15,27)					5/29
Mr. Cuissard	7									0/7
Guillais	4	1 (4)	1 (2)	1 (4)	1 (3)					4/4
Landucci	4	3 (1,3,4)	2 (2,3)	3 (1,2,4)						4/4
Léauté	10				1 (9)					1/10
Martin	1									0/1
Pinoir	8	1 (3)	1 (3)	1 (3)	1 (3)					1/8
Renard[132]	52	17 (5,7,13,16,26,34, 36, 37,38, 39,41,43, 47,48,49, 50,52)	15 (9,18,21, 22,23,24, 26,30,34, 36,37,38, 39,41,43)	11 (4,10,21, 30,34,36, 37,38,39, 41,43)	6 (9,18,22, 24,39,41)	4 (17,30,31,3 2)	2 (16,21)	2 (16,25)		30/52
Sylvestre	10	3 (3,6,10)		3 (3,6,10)						3/10
Zelger	17	2 (9,12)		2 (9,12)	2 (9,16)					3/17
Total of different French reports sent to Harrow on 1935							**65/159**			

Table 7. Inventory of the French research reports produced and shared with the Harrow research team and other Kodak managers for the year 1935.

[129] A.J. Sulzer was certainly the manager of the Emulsion Coating Department between 1926 and 1931 as some evidence of his responsibilities has been found in the Kodak Collection Archive in a personal notebook attributed to C.T. Robinson. See the notebook "X-Ray film Dept", ref. A1649, box 136, KCA-BL.

[130] Ernest Edgar Blake started to work for Kodak Ltd. in 1903. He was appointed manager of the Cine Film Department in 1911 and Managing Director in 1930. In 1946, he became Chairman of the Board of Directors of Kodak Ltd. and General Manager of European companies. See Gauntlett, "A History of Kodak Limited," 56, 85; *Kodakery* 5, no. 12, March 27, 1947: 1-5.

[131] Franck Robinson, the Works Manager of Kodak A.G. near Berlin has not to be mistaken for Charles Thomas Robinson, the alleged production manager at Pathé-Cinéma then at Kodak Limited.

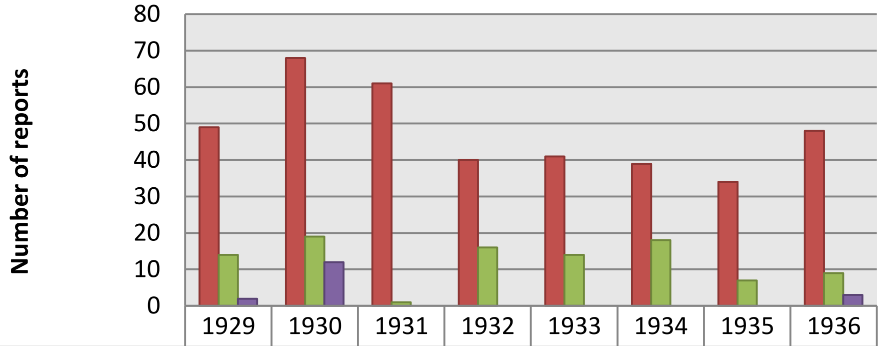
[132] H. Renard also sent two reports to others British colleagues, the 21st to Curtis and the 23rd to Mc Master.

The example from 1935 stresses the importance of the Kodak-Pathé research team in which twelve researchers were qualified and requested to provide research reports throughout the year. Unlike the Kodak British tradition, co-authoring was rare and this may be inherited from the Pathé period. One piece of information is missing. The inventory does not ascertain the criteria by which context the reports to be shared had been selected. Abribat might have been the only decision-maker. Or each researcher could have been responsible for the research work he or she wanted to share. An expert committee that met periodically may have selected the most important reports.

The amount of work produced per researcher is not even. The outstanding production of Mrs Cuissard (29 reports) and of Mr Renard (52 reports) has to be highlighted. It indicates that for the period some scientific fields were more crucial than others. Renard was in charge of everything relating to cine film. He worked on modern emulsions such as Kodak and Agfa safety films or Kodatrace and its competitor by Kalle. He studied the influence of film dimension, perforation and gauges on film mechanical resistance and improved wear and tear procedures. He also reported on several projectors and the film behaviour in such new equipment. He was in charge of the study of new Safety films made in Rochester and undertook another study with Matthieu of the quality of the Harrow perforation through microscopic examination. These multiple checking procedures between Rochester, Harrow, Vincennes but also Berlin (Cöpenick) were the opportunity of insuring a standardized production amongst the several production sites as well as a standard of quality at its highest level. As to Mrs Cuissard, she was a skilled chemist and made analytical studies of new materials such as collodion made by Nobel or synthetic resin made by Albanol I.G. She tested the mechanical properties of new experimental bases, undertook technology watch of radio films from Lumière and Agfa and of cine positive films. She studied new plasticisers, adhesives to repair Kodatrace and raw acetates from several suppliers. She was also in charge of research on safety films' improvement. The ten other researchers studied various subjects, some of them relating to technological development of the film production process or related to the nature of the chemicals used for the making of the film support and emulsion. The ratio of reports sent to the other Kodak sites (65 out of 159) represents 41% of the written production and is not so far from Abribat's ratio (33% of reports sent to W. Bent). This new ratio is particularly high. It demonstrates that more than one report out of three was read by at least one British or American counterpart. The titles of the addressees are not equivalent compared with the title of the report's producers. Unlike these general managers and production managers, the French team was composed from pure researchers plus the director of research Abribat. In the list of addressees the unique exception is the chemist E.D. Eyles but only Renard sent four reports to him. This difference in the responsibilities of Kodak employees may stem from some traditional management procedures stating that the knowledge had to be sent first to the general manager and then spread by him through the departments under his responsibility. Another noteworthy statement of fact is that the technological knowledge of the French was sent to all the three Kodak plants (Rochester, Harrow and Cöpenick) and not only to the teams of Kodak research laboratories. It shows that at least for the French producers of knowledge the information was important to share and useful for several strata of technological departments including pure research laboratories but also production departments whose work was crucial to enable the yield of products of consistent quality.

A third inventory kept in the same folder of the newly discovered French archive illustrates now how scientific knowledge circulated back to France as well, from the research work of Harrow scientists to the French Kodak-Pathé researchers. This inventory provides a list of research reports received between 1929 and 1940 including the date of production, the title, the authors and the reference number of the report should the information was known (see Table 8). The inventory was no doubt interrupted in 1940 due to the Second World War. Having compared the selected British reports listed in this document with the list of the first 350 research reports produced at Harrow, I confirm that they correspond to the reports kept in the Kodak Collection archive with their correct reference number H.xxx, "H" being for the British place of Harrow, exact titles and authors. This way it is possible to ascertain what kind of scientific knowledge was shared between Harrow and Vincennes. Unlike the preceding inventory, this one does not provide a list of potential addressees.

Presumably the reports were sent to Abribat first and then spread among the Kodak-Pathé research laboratory.



	1929	1930	1931	1932	1933	1934	1935	1936
Harrow research reports for the year	49	68	61	40	41	39	34	48
Research reports shared with Vincennes	14	19	1	16	14	18	7	9
Monthly reports shared with Vincennes	2	12	0	0	0	0	0	3

Figure 6. Proportion of Harrow research reports shared with Vincennes between 1929 and 1936.[133]

The inventory contains a very important piece of information. The list contains evidence of monthly reports about the activity of the Harrow research laboratory first written by Walter Clark and that had not been found in the Kodak British archive. These "Monthly reports of research laboratory" are clearly identified between 1929 and 1931, the last reports for July to December 1930 being received in February 1930. Up to 1936 there is no reception of the monthly reports and it might be that they were not produced after 1931 on (see Figure 6). However, in March 1936 some "reports from the research laboratory Harrow for the months of January, February and March" can be found in the 1936 inventory and it is difficult to ascertain whether the production of these activity reports was continuous or interrupted between 1929 and

[133] The source for the Harrow research reports for the year is the Kodak Collection archive, ref. A2897, British Library. The source for the research and monthly reports shared with Vincennes is the written inventory kept in the Kodak-Pathé archive, ref. 33498, CECIL. This archive provides the data up to 1940 but I decided to conform to my initial study of the Harrow research reports from 1929 to 1935. I added the data for the year 1936 as I also inventoried the reports for that year and as it indicates the upward trend about the production and share of British reports that took place up to 1940.

1936. As these reports were shared with Vincennes, they were probably also sent to the main Research Laboratory at Rochester.[134] The presence of similar reports of activity but in the French archive is now more understandable, as for instance the report of Abribat written in February 1951 about the "Main activities of the Kodak Pathé Laboratories". These procedures can be understood as corporate practices in the management and transfer of scientific knowledge. It is worth noticing that studies of such bureaucratic practices have been underestimated by science and social historians, as stressed by Becker and Clark in 2001.[135] At this stage of the thesis however, a simple statistical study of the bureaucratic production and of the exchange of reports provides crucial information about knowledge transfer. Therefore one can conclude that on average one out of three reports was sent to Vincennes by the British researchers. It is important to notice that this ratio is similar to the ratio found for the other exchange of reports from Vincennes to Harrow in the Abribat's inventory and the second inventory of the French researchers.

[134] Up to now, one of the rare evidence of the existence of monthly reports was the transcript of an interview of Davies, second director of the Harrow Research Laboratory. "Before I left [Rochester], Dr. Mees said that there was one thing he would insist on – that I write him a letter each month. It was this that gave rise to the Monthly, and later the Quarterly Reports that senior staff were asked to submit." Roy Davies, in "The Harrow Research Laboratory. Origins and Growth 1928-1976. A retrospective album", 20.

[135] Becker and Clark, *Little Tools of Knowledge: Historical Essays on Academic and Bureaucratic Practices*, 1.

1935

I0 Janv. A.243	A bibliographye of photographic reversal by desensitizing dyes........	H.320	Davey
7 Fevr. 135	Time and intensity scale sensitometric curves for a range of I4 eastman negative materials with light of daylight and tungsten (2360°)quality........	H. 325	D.A.Jone Owen
I5 Mars Bibliogr. 141	Machine tank development of amateur roll film and maintenance of standard negative quality........	H. 328	Selmann
1 avril	the sensitometric testing of motion picture positive film		R Davies (chemise bleue)
I2 Avril Bibliogr. 142	Hand tank development of amateur roll film and maintenance of standard negative quality	H.332	Selman
II Octob. 146	Variation in sensitivity of Cine positive film..........	H. 343	Roy
9 novembre A.145	Surface pyrometer for the measurement of temperatures of coated plates and film during production	H. 348	Sanders → A. Battey
2 Decemb. 147	Variation in sensitivity of cine positive film ---------- (double) ------	H. 350	Roy

Table 8. Inventory of Harrow research reports received at Vincennes on 1935.[136]

The constant value of this ratio is significant because it points out the uncertain nature of industrial research. The outcomes of basic and applied research being unpredictable, some research and experiments were not worth sharing with the other Kodak Research Laboratories. As a secondary consequence, uncertainty also created the necessity of a hierarchy in the importance of each research report.[137] This selection was made by an undefined group of scientific experts in Harrow as well as in Vincennes.

The year 1931 is the exception for this ratio of one out of three. Only one report about the "permanence of colorimetric pH standards" was sent to France out of the 61 research reports produced at Harrow. The possible reason for this break in the knowledge transfer could be the replacement of the director of the British laboratory as Roy Davies succeeded Walter Clark when he left for Rochester in May 1931. Finally, the topics covered by the reports shared are heterogeneous as the topics of the French

[136] "Rapports Harrow reçus à Vincennes 1929-1940," inventory, undated, ref. 33498, CECIL.

[137] Mees' view about the notion of uncertainty in industrial research has already been studied in the literature review. See Shapin, *Scientific Life*, 136-137.

reports sent to Harrow also were. Bilateral knowledge transfer[138] covers several scientific fields and is not restricted to some routine topics such as sensitometric data about Kodak films. Therefore the data about photographic innovation and innovative experimental products was also shared both ways between Harrow and Vincennes. It is worth noting that the British reports shared concern the development of instrumentation for sensitometry or spectrophotometry, competitive or Kodak experimental processes, the testing of new material or new sensitising molecules. They are also about scientific aspects of non-flammable film, sensitometric procedures and regular testing of Kodak films and products from the competition. The variety of these topics stresses the vital importance of the Research Laboratory in the corporate structure of the company. It was used to develop photographic science, improve production processes and make innovation grow.

The direct consequences of these research report exchanges are difficult to assess. It is problematic to estimate how the knowledge of a scientific fact can influence the activity of a researcher. Basically it can prevent him or her from working on an inappropriate track or it can persuade the researcher to maintain the development of a promising technology such as the use of a new sensitising dye to synthesise experimental emulsions. Beyond the scientific topics shared, the Kodak practices of knowledge transfer illustrate an innovative way of international communication during the Interwar period. The three Research Laboratories were producing a network of knowledge and the circulation of this knowledge has been confirmed by some evidence found in the British and French Kodak archives. It is necessary to stress that this network of knowledge also produced increasing teamwork between the laboratories. The Kodak-Pathé archive holds many examples of collaborations for which the production departments or the Research Laboratory at Vincennes worked together with their colleagues either at Harrow or Rochester. There is a report of a visit made by some researchers and managers from Harrow to the scientific staff at

[138] This expression means here the exchange of research reports both ways and consequently the exchange of technical and scientific knowledge.

Vincennes. Abribat, the author, mentioned the technical subjects that were discussed with Messrs. Soper, Berg, Stevens and their other British colleagues. Designated with a handwritten note on the report as the “Harrow committee”, this collaborative structure may be an attempt to organise some regular meetings between the French and British Kodak research. During the visit the researchers discussed colloidal chemistry starting from some repellency issues during the coating of the emulsion on the film support. One of the challenges was to better understand how gelatin physically reacts with tensioactive agents such as wetting agent or emulsifier, to improve the coating process.[139] During the same period, an important folder kept in the French archive demonstrates how the three laboratories worked jointly between 1946 and 1948 on the development of a new cement from an initial study by the French researchers. The folder contains a typed summary of the correspondence between the American, British and French researchers as well as this original correspondence. Industrial research on new cements for cine film could appear trivial compared to other topics studied by the laboratories but splicing together several rolls of cine film tightly was absolutely necessary to deliver satisfying products to the movie industry. As film supports were evolving, the nature of the cement had also to be adapted to the nature of the new support. When new cellulose triacetate supports were first produced by Eastman Kodak for 16mm Kodachrome, Rochester tried to develop a universal cement for use in the European plants as well, but it was almost impossible to adapt it easily to the local productions of cine film. The French chemist Léauté spent a few months in 1946 at Rochester to work on the use of the dioxane film cement n°22.100 produced by the Americans. In parallel the researcher Collot at Vincennes studied a new cement formula for use with triacetate film for which a new component, trimethylene oxide, was necessary. This chemical was unavailable in France and the French Laboratory worked with Dr. Allen of the Rochester Research Laboratory to produce it there in small quantities. Both sides found that the new cement formula was very efficient but Dr. Steiner of the medical department at Kodak

[139] Marcel Abribat, “Compte-rendu Abribat,” notebook “Activité labo recherches,” March 6, 1951, ref. 33023, CECIL, 1-6.

Park studied the toxicity of trimethylene oxide and discovered that it was producing severe skin irritations in contrast to the alternative dioxane. The medical concern was so critical that the use of the innovative chemical component was eventually abandoned.[140] The fact that these research studies about film cement came to a deadlock should not be seen as a failure. The results of fundamental or industrial research are governed by a game of chance to a great extent and the process of following a so-called 'wrong' track produces peripheral discoveries and scientific facts as well. Most important, this second example shows how more than a dozen people collaborated on a mutual research project, from the general managers to the pure researchers and the medical staff. Such collaborative arrangements could be further studied along with other examples of international collaboration between the three Research Laboratories present in the French archive, but such an in-depth study lies outside the framework of this research and I want to end this section of the chapter with a final document arguing again the strategy of knowledge transfer between Vincennes and the two other Kodak laboratories.

Compared to the three inventories of shared reports already studied above, this report explaining the transfer of reports between the three Kodak research laboratories was written after the Second World War in 1951 and thus illustrates the evolution of knowledge transfer conventions at Kodak-Pathé. This basic report lists the transfer of reports from Eastman Kodak to Kodak-Pathé and from Kodak Limited to Kodak-Pathé for the year 1950. It also provides Kodak-Pathé's policy for the process of transferring reports. In reports that were exchanged from Rochester to Vincennes, one can learn that 187 research reports were produced in 1950 at Kodak Park and 106 (56%) were received by the documentation centre at Vincennes. Vincennes had also received the Monthly reports of the Rochester Research Laboratory since August 1949, which reminds us of the fact that equivalent reports were found in the third inventory of the

---

140 "For example, if trimethylene oxide were used in a film cement, it is quite likely that skin irritation would result in an appreciable number of individuals using this cement even though little injury would be found in a similar use of a cement containing dioxane." J.H. Steiner to J.H. Folwell, in "Documents Rochester. Dossier 6. Lettres sur les colles et céments pour films ciné," March 26, 1947, ref. 33481, CECIL, np.

Harrow research reports sent to Vincennes. The report also indicates that Mr. Lecte, a specialist of photographic technology at the Vincennes works also received some reports, in particular the Quarterly reports on emulsion making and the Monthly reports of the emulsion department of the Research Laboratory. In the way Harrow to Vincennes, 86 research reports out of 100 were received by the documentation centre, as well as the Monthly reports of the Research Laboratory since September 1949. Mr Lecte also received the Quarterly reports on emulsion making at Harrow, the Quarterly reports of the emulsion department of the Research Laboratory and the Quarterly reports of an experimental laboratory working on emulsion making. Finally, in the research reports exchanged from Vincennes to Rochester and Harrow, it was first stated that all the research reports sent to Rochester were also sent to Harrow. Of course, not all reports were shared and the document provides the process of selecting the most important reports.

> The selection of the reports is completed by a committee whose members perused from day to day all the reports. At the end of each month a list of reviews representing all the reports is provided to the members in order for them to remember their content and each member selects a list of reports that are interesting to share with Rochester and Harrow. This selection is made including as much reports as possible and only reports or notes whose results seem to be not enough clearly established, or with a purely local interest for Vincennes are dismissed from the selection.[141]

The unidentified author includes statistical numbers for the year 1950. The Research Laboratory at Vincennes produced 114 research reports and 93 were sent to Harrow and Rochester (81%). The same year, it had been decided to make copies on microfilm of all notes, research reports and activity reports since 1940, and to send one set of microfilms to Rochester. First and foremost, this document proves that, at least for the year 1950, Vincennes and Harrow shared more than 80% of their research reports and Vincennes received around one report out of two from Rochester. It is far more than

[141] "Échange de rapports entre Eastman Kodak & Kodak-Pathé d'une part et entre Kodak-Limited & Kodak-Pathé d'autre part," February 13, 1951, ref. 33023, CECIL, 3. The author of the report signed it at the end but it has not been possible to identify him (the signature could signify "Bouchard"). This quotation is my own translation from the French text.

the average ratio I have found for the 1930s exchanges between Harrow and Vincennes (one report out of three) and it could be that this increase in the amount of scientific knowledge transferred at Eastman Kodak was a trend after the Second World War. The document also proves that the production of reports increased and that their nature diversified. The writing of Monthly and Quarterly reports developed gradually in addition to the research reports for which in-house publishing was not done at regular intervals.[142] In this way the scientists of the research laboratories were informed of the work from their counterparts abroad, but also of the technical research from some production departments such as the emulsion, the film finishing or the developing and printing departments. It is as if the internal transfer of scientific knowledge at Eastman Kodak was progressively accelerated after the creation of the new structure in 1928-1929 with the three Research Laboratories probably in order to increase the spirit of competition but also to increase the chance of innovation and development of technologies that could be used in new marketable products.

The section above provides the corporate regulations for the management of knowledge, but does not clarify the process of its production through individual research. In order to understand the nature of this particular research it is necessary to turn to a different kind of source – the research notebook. Kodak Limited decided to keep some of them in its corporate archives. They do not represent structured pieces of scientific knowledge such as those contained in the Harrow and Vincennes research reports, but only personal notebooks of researchers and production managers in which many kinds of technical and scientific data can be found. However the analysis of these personal notebooks may provide an estimate of the contribution of the European Research Laboratories to innovation at Eastman Kodak. Some studies of specific notebooks in the following section will provide some clearer answers.

[142] In the second inventory of the Harrow research reports received at Vincennes, I also identified from 1937 on the receiving of a “Monthly report on the sensitometric characteristics of certain Harrow, Vincennes and Copenick film products” written by the British researchers Hance, Jones and Sanders. Sometimes data from the Toronto plant were also included in such report.

3.3. A Research tool : the personal notebook of scientists and managers

During my research through the primary sources of the Kodak Collection archive and also in the archive of Kodak-Pathé in France, one specific artefact created and used by the technical and scientific staff of Eastman Kodak caught my eye. There were an appreciable number of paper notebooks, each belonging to one employee, that can be qualified as personal notebooks.[143] At least one individual was responsible for the making and preserving of the physical notebook, which frequently covered several years of data collection.[144] This individual progressively filled out the personal notebook by hand. The large number of notebooks found in the Kodak archives, as well as in a corporate archive introduced in the section below, points out that this method of keeping and archiving technical or scientific knowledge in notebooks was an industrial research tool often used by photographic and cine film manufacturers.

To clarify how the personal notebooks were used and the nature of their content, I selected the notebooks of four different scientific profiles, to point out the variety of industrial research in terms of practices and methodology. The first notebook was found in the corporate archive of the French company Pathé, one of Eastman's biggest competitor in Europe up to 1927. The notebook belonged to Marcel Mayer, the works manager at Pathé in Joinville-le-Pont, France. The second set of notebooks belonged to Charles T. Robinson, a production manager who worked at the same plant in Joinville-le-Pont and then for Kodak Limited. Robinson's collection allows a deeper insight into production processes. The third set of notebooks belonged to Franck B. Phillips, a physicist of the Harrow Research Laboratory who additionally incorporated his

[143] For instance, the box n°96 in the Kodak Collection archive at the British Library contains 20 personal notebooks belonging to 5 researchers.

[144] The personal notebooks are mostly handwritten by one author but have not to be mistaken for private notebooks, personal records or diaries. These handwritten objects are usually created due to the unique will of her or his author. Concerning the personal notebooks found in the Kodak and photographic archives, this is not the case and the creation and use of the notebooks may have been requested by the company.

thoughts and his rationale in his writings, breaking with Mayer's and Robinson's protocols. The last set of notebooks was attributed to F.W. Thomas Krohn, the first photochemist at the Harrow Works already studied in chapter 2. Krohn combined both aspects of the use of the notebook with the addition of his thoughts and rationales alongside photochemical data and so conceived the notebook as a cognitive tool.

3.3.1. The contribution of Marcel Mayer from Pathé at Joinville-le-Pont

Ironically, the first personal notebook that I identified and studied belongs to an archive of one the most important competitors of Eastman Kodak, the Pathé company. The Marcel Mayer index notebook is currently kept by the Foundation Jérôme Seydoux – Pathé in Paris and a digital annotated version of the notebook has been available online since 2013.[145] The first inscriptions date back to 1923, the year in which Mayer was appointed as the general manager of the works of Pathé-Cinéma at Joinville-le-Pont. That is why this document is not a laboratory notebook including a list of photochemical experiments and the analysis of results. Its author was not a scientist of the Pathé laboratories but a technical manager. Mayer's indexed notebook was filled out up to the year 1930 and contains some operating instructions to produce specific substances, some technical explanations about manufacturing methods and some raw chemical formulas of confidential processes. These data represent Pathé trade secrets in the form of know-how, and were the technical as well as the scientific assets of the company. It was certainly not intended to be shared outside the company but presumably within a small network of managers working on film production. The use and importance of Mayer's notebook are open to interpretation. Stéphanie Salmon, who is the responsible for historical files in the Foundation Jérôme Seydoux – Pathé, argued that the notebook appeared within the context of a new industrial management. Since the end of the First World War Charles Pathé had been thinking

[145] "Le répertoire Mayer," Fondation Jérôme Seydoux - Pathé, annotated by Anne Gourdet-Marès and Jacques Malthête with the collaboration of Stéphanie Salmon, accessed August 12, 2014, http://www.fondation-jeromeseydoux-pathe.com/dossiers.

about the application of Taylorisation principles to his factories and Mayer's indexed notebook could be evidence of analysing and inventorying manufacturing techniques of the company according to this new principle of management.[146] Mayer's notebook might also be the only document where manufacturing methods and chemical formulas were noted down. In the photographic industry, like other industries dealing with chemical recipes, the transmission of technical knowledge was frequently verbal amongst the managers and technicians working in the manufacturing departments and the data kept in the notebook could therefore represent a break with tradition. They could be consulted or modified progressively should an improvement be made in a formula or a specific process. This argument that the notebook was used by several people is supported by the fact that it has an alphabetical index 12 pages long at the back.[147] The indexed notebook was therefore paginated and intended to be consulted by its author and possibly by other knowledgeable readers in film manufacturing techniques. Therefore, Mayer's notebook was an important tool for Pathé because it was used to record tacit knowledge produced by insiders, but also to possibly share and transfer this knowledge in-house.

The notebook contains some formulas of Kodak substances or related to Kodak films such as an American cement, a developer for Kodak positive film or the chemicals used in the well-known Kodak D-76 developer in 1929.[148] The most interesting information related to Eastman Kodak is a long description of the techniques used for the recovery of film on an industrial scale from 1909 onwards. At that time Pathé was able to manufacture an appreciable amount of cine film after the long-term research work at the Blair factory in Foots Cray but the engineers and chemists at Vincennes also found a way of reusing a positive film that had already developed by removing the gelatin layer, the metallic silver and the eventual impurities from it. To skin the film support from the gelatin layer it had to undergo a pancreatic digestion for which the pancreas

---

[146] Stéphanie Salmon, "Tinting and toning at Pathé: The Jacques Mayer notebook," *Film History* 21, no. 2 (2009): 177-179. The correct first name is Marcel.

[147] "Le répertoire Mayer," 213 (electronic pagination).

[148] Ibid., respectively 32, 200 and 60 (original pagination).

and intestines of pigs were used.[149] In this way the factory was able to coat another emulsion layer on the recovered film support. By generating new film from old, Charles Pathé was able to increase his independence from his main film supplier Eastman Kodak.

3.3.2. The many lives of Charles T. Robinson in the photographic industry

In the Kodak Collection archive at the British Library there are many personal notebooks of Kodak researchers and technical managers. Some of them possess a structure similar to Mayer's notebook. The quantity of personal notebooks is significant, and it points to the fact that they are important sources.[150] I decided to focus on a particular case study by investigating the personal notebooks of Charles Thomas Robinson, a British native who worked for several photographic manufacturers: the European Blair Camera Company, the Photofilm Company, Pathé and Kodak Limited. Although he can be described as a discreet manager and always remained in the background of film manufacturing departments, the name Robinson appeared frequently in the course of my research work through the Kodak Collection archive.

Robinson's biography is important. He was professionally connected with Pathé and its British subsidiaries, Eastman's biggest competitor in Europe. He moved to France to work at Pathé in Joinville and finally returned to Kodak Limited in Harrow when Kodak-Pathé was created in 1927. During his working life, he learned, developed and transferred technical knowledge within the framework of secretive practices used by

[149] Ibid., 183-185 (electronic pagination).

[150] In addition to the box 96 in the Kodak Collection archive with its 20 personal notebooks, boxes 134 and 135 contains 10 notebooks, boxes 157 and 158 3 notebooks, box 212 2 notebooks and box 329 one notebook. The 26 notebooks of C.T. Robinson can be found in box 136.

the photographic manufacturers he worked with.[151] It is difficult to know if Robinson was already working for the European Blair Camera Company when it was bought by Pathé in 1906. In any case Robinson started to work for Pathé at this date and continued to do so up to June 1927. In 1909 he moved from Blair to the Photofilm Company at High Barnet and when Charles Pathé closed both the Blair and the Photofilm companies in 1910, he joined the French employees of Pathé at Joinville-le-Pont.[152] One of Robinson's personal notebooks spans the years 1908 to 1911 and clarifies the work of the young photochemist during his first years at Joinville.[153] It contains various technical data including several chemical formulas and operating instructions for the manufacturing of film or substances such as substratum. Robinson also provided a memorandum about organic toning processes. In September 1908, he wrote that the toning method he indicated in his research reports in April and May of the same year had been simplified by the French chemist Georges Zelger.[154] Robinson then provided a full description in French of the toning processes. The clear and descriptive nature of his writing in almost perfect French stresses that the technical knowledge about toning was meant to be shared among the technical staff at Joinville. In his discourse Robinson also indicated some research work "at the laboratory" to improve or develop new formulas for toning cine positive film. For some things, Robinson was more concise and preferred the use of the English.[155]

---

[151] As he wrote on 19 April 1912 in a small black notebook alongside with his boot size, Robinson was born in Foots Cray in England on 30 July 1882. Charles T. Robinson, "The property of C.T. Robinson," personal notebook, ref. A1649, box 136, KCA-BL, n.p.

[152] Charles T. Robinson to Walter Bent, April 16, 1929, ref. A1648, box 136, KCA-BL, n.p.

[153] C.T. Robinson, "Monsieur Tom Robinson," personal notebook, ref. A1274, box 96, KCA-BL, n.p. The notebook is neither indexed nor paginated. The handwritten notes alternate between English and French languages.

[154] One can assume that Robinson met Zelger when the French employee of Pathé was sent to the Blair factory in 1906 to do some research work about film manufacturing. See chapter 3, section 1.2.

[155] For instance, Robinson used the following description to provide the process of remelting the emulsion layer. "Refonte. The emulsion to be melted as quickly as possible (45 mins at Joinville). While it is being melted when the temperature is about 35° add the extra gelatine & the potasse, and when it reaches 70° add the rest of the chemicals as follows. Magnesie, Bromure, Saponine, Alun Alcool after adding these chemicals filter at once and then reduce the temperature as quickly as possible to 32°.

The various technical data enclosed in Robinson's personal notebook weakens Salmon's argument that personal notebooks at Pathé existed as a consequence of the Taylorisation of film production.[156] First the content of Robinson's notebooks reveals that the knowledge of the processes and the chemical recipes described was more important than understanding the general organisation and management of the production departments. Secondly, Robinson's notebook is similar in content to Mayer's notebook but was created and used much earlier. Therefore, filling in such a notebook with photographic knowledge cannot be considered a novel practice in the 1920s, when Mayer started his own notebook. Instead the early compilation of Robinson's notebook could demonstrate that the existence of personal notebooks is a distinctive characteristic of the photographic industry, controlled by the constraints of the industrial secrecy. Chemical formulas and specific processes were the most precious asset for photographic film manufacturers and needed to be protected by secretive practices if a patent strategy was not used by the company.[157]

Consequently, Robinson's progressive notebook making can be qualified as an archival practice of technical and scientific knowledge. This activity continued during the whole of Robinson's commitment with Pathé Frères. Another notebook filled between 1923 and 1926 contains many formulas of varied emulsions and supports, such as a nonflammable base using the cellulose acetate from the French supplier Usines du Rhône, the Pathé Blue negative emulsion or the emulsion for the Velox paper.[158] Another list of formulas relating to remelting technology at the "Fabrication C", a production building at the Joinville works, is signed by Robinson and indicates that he

(Before adding the extra gelatine it must be thoroughly melted)." Charles T. Robinson, "Monsieur Tom Robinson," n.p.

[156] Salmon, "Tinting and toning at Pathé: The Jacques Mayer notebook," 179.

[157] See chapter 2, section 2.1.1.

[158] Charles T. Robinson, "FORMULAS. Substratum & Supports," personal notebook, ref. A1747, box 154, KCA-BL, n.p. Although the notebook is not attributed to Robinson, I claim that it was the property of the British chemist as notes alternates between French and English and as the handwriting used is similar with handwritings in others Robinson's notebooks.

probably was a production manager for Pathé.[159] Furthermore the technical data about the Velox paper consists of a letter from Mr. Bossard that was first signed, and later summarized and retyped by Robinson. It describes research work on the emulsion to improve photographic characteristics such as contrast and density in the shadows. Bossard[160] was a researcher investigating emulsions and gelatine and his letter in the notebook might demonstrate collaborative work between him and Robinson in this particular field. Robinson was not a scientist with academic degrees but he was aware of the Pathé Frères laboratory's research work and used the technical knowledge produced by this research structure. Of course, he was also dealing with the routine work of a production department. In the same notebook there is a list of raw materials with some suppliers' names and the monthly quantity requested.[161] Like the nature of industrial research advocated by Kenneth Mees, Robinson's research work contained a significant proportion of work applied to the development of production. This research work in the production buildings can be seen in another of his notebooks dating back to 1919. He collaborated with several researchers from Vincennes to produce experimental emulsions, receiving new formulas and discussing the results first with pithy comments in the notebook and also certainly with the researcher himself face to face or over the phone. For instance Robinson produced 16 kilograms of experimental emulsion for Mr. Roussel on 26 April 1919 and he qualified the result as "sensible but grainy". On 21 May of the same year, 4 kilograms of the emulsion made for Mr. [Paolontone] was further "coated at Laboratory" which may indicate that the best experimental emulsions were coated on a photographic support to test them in real conditions.[162]

[159] A general map of the Pathé Frères works at Joinville-le-Pont can be found in the first pages of the Mayer's notebook. See "Le répertoire Mayer," 8 (electronic pagination).

[160] See Bossard, research notebook, ref. 33135, CECIL.

[161] At least for the period 1923-1926, 20 tons of nitrocellulose were bought per month at the *Poudrerie du Moulin Blanc* in France, 80 tons of acetone in England per month. In May 1926, 2020 kilograms of silver were bought at 493 francs per kilogram. See Charles T. Robinson, "FORMULAS. Substratum & Supports," n.p.

[162] Robinson, "The property of C T Robinson," n.p.

At the end of the 1920s, Robinson's many activities become difficult to follow. Another of his personal notebooks proves that he was sent to Cöpenick near Berlin when Charles Pathé decided to collaborate with the *Vereinigte Glanzstoff Fabriken AG* to build a new film manufacturing plant.[163] Pathé Frères would provide the technical knowledge to help build the plant and train the technical staff. The German company took the name of *Glanzfilm AG* and was created in 1922, but the Cöpenick plant was not finished before 1926. It is difficult to ascertain when exactly Robinson worked in Germany. His notebook on Glanzfilm covers the period 1924 to 1927 and contains technical notes in French, English and a little German. He was probably consulted for the installation of the film manufacturing equipment.[164] The notebook also provides some technical comparisons between the production of Vincennes and Cöpenick, as well as Harrow. These three film manufacturing plants would become the property of Kodak Limited from 1927 onwards and it is interesting to notice that Robinson transmitted technical knowledge from Pathé to Kodak Limited. He was finally hired by the British subsidiary of Eastman Kodak between 1927 and 1929 and the last evidence of his work at Kodak Limited is dated 1942.[165] One last notebook belonging to Robinson clarifies the first months of the tripartite organisation of Eastman Kodak with the sites of Rochester, Harrow and Vincennes. Robinson was not the only author of this notebook as it is composed in his and other's handwriting. It includes miscellaneous data principally about 16mm. cine film production issues. It includes memos about technical specifications, copies of letters about technical problems, and draft notes about everything. There is for instance a cable sent by Bent to the production manager Sulzer at Rochester requesting from the Americans the maximum and minimum limits of thickness of support for the Cine Kodak Reversing Film to Lair in

---

[163] A German company, literally "the United Artificial Silk Works Corporation". See Charles T. Robinson, "C.T. Robinson GLANZFILM," personal notebook, ref. A1649, box 136, KCA-BL, n.p.

[164] For more information about the collaboration between Pathé-Cinéma and Glanzstoff, see Stéphanie Salmon, *Pathé : A la conquête du cinema. 1896-1929* (Paris: Tallandier, 2014), 462-464.

[165] See the file ref. A1680, box 140, KCA-BL. It includes a proposal for using rolls of scrap film as incendiaries. Concerning the date of Robinson's hiring at Kodak Limited, his letter to Bent on 16 April 1929 does not clarify this point as it may represent a request of pay rise that needed to be approved by Rochester. See note 106.

France. At the end of the notebook there are many 16mm film samples from 1938 and before: infrared, Type A. “S” Kodachrome, Kodachrome type 1936, Dufaycolor, Kodaline Fast, Cine Kodak Eight, Harrow S. Pan, Kodaline Slow etc. It indicates that the notebook was filled and carefully kept during these years and constitutes an archive of technical knowledge about the varied Kodak cine films and the science of film making.[166]

Some evidence indicates that Robinson collaborated with his new British colleagues and researchers up to the Second World War. In 1935 the physicist E.D. Eyles sent him a copy of his research report about the routine physical testing of 16mm film at Harrow.[167] In 1934 Robinson provided some procedures about slitting and perforating cine film to the researcher Franck Phillips, as it has been found in one of his personal notebooks.[168]

3.3.3. Franck Phillips’s notebooks as tools to solve technological issues

Robinson’s case begs the question, is the notebook of a researcher different or similar to the notebook of a production manager at Kodak Limited? A set of Phillips’ notebooks kept at the British Library allows a structural and content-based comparison with Robinson’s notebooks. Studying them highlights critical differences in the nature of the information in each one. Phillips’ notebooks are not only about recipes, formulas and descriptive technology but also about research and development of new processes or procedures and the related rationale for that procedure. Phillips, a physicist, also introduced teamwork, between the Kodak Research laboratories which

---

[166] Charles T. Robinson and anonymous authors, “16M/M FILM,” personal notebook, ref. A1649, box 136, KCA-BL, np.

[167] E.D. Eyles, “Routine physical testing of 16 mm. film at Harrow”, research report H.334, May 15, 1935, ref. A2897, KCA-BL.

[168] Franck B. Phillips, personal notebook, year 1934, ref. A1270, box 96, KCA-BL, 37.

was a more scientific collaboration than Robinson's collaborative work with the Pathé Works at Vincennes.

Five of Phillips' research notebooks have been identified and studied. Their structure is more homogeneous than Robinson's notebooks as for each copy the pages are manually numbered and a basic index can be found at the end or at the beginning of the notebook. This structure is similar to the organisation of Mayer's notebook and the Robinson notebooks that include an index. Phillips's notebooks cover the period 1926 to 1938. Their contents vary greatly, Phillips's handwriting being concise and frequently instructive. Some notes may have been used by the author for writing technical reports, while other sections provide detailed visit reports including information about what had been said, suggested, accepted or questioned by the parties.

In his first notebook dated 1926, Phillips reported some issues about the method used to duplicate the current 16mm cine Kodak film. While summarizing the instructions provided by the Rochester Research Laboratory he also discussed some stages of the duplicating process.

> In the Rochester instruction (2652/7) [or 2652/1] there is ambiguity about the state of the carbonate & sulphite. On p 11 we are told : "*In the case of desiccated chemicals like sodium sulphite and sodium carbonate*…" while on p12 "…*dissolve all the carbonate possible ; decant the solution & dissolve the remaining crystals in warm water*."[169]

Apparently unable to reproduce the process using Rochester's instructions, Phillips stated further that they "*are obviously misprinted on pp14&15*" and decided to change the volume of one of the solutions. At the end of the notebook he reported what was possibly a discussion with Capstaff, the designer of the 16mm cine Kodak process that clarified the origin of the technical issue.

> Mr Capstaff considers that the emulsion supplied to us in the first place (R.L.G.) was not of the same quality as that used when the directions were written, consequently he agrees that our film wanted extra development & that the

[169] Franck B. Phillips, "1926-HARROW," personal notebook, ref. A1270, box 96, KCA-BL, 11.

> addition of hypo to the two developers was correct. (…) The addition to the 2nd developer of hypo is an improvement in his judgment, & this will be incorporated in the new instructions. He denies that strengthening the clearer can have any effect, beneficial or deleterious & has tried its effect on the re reversal phenomena but has concluded that it is without effect.[170]

This last excerpt demonstrates effective teamwork between the British scientist and his American counterparts to solve a photochemical issue and improve a recent process. Phillips did not write any final statement but decided to include the opinion of a well-known colleague. This information could be used later and discussed again should Phillips have trouble developing a satisfactory duplicating process for cine film at Harrow. Seven years later, the researcher visited Kodak Park at Rochester again and wrote his thoughts in another personal notebook, where it is evident that he continued to argue and postulate. He worked in collaboration with the Cine Kodak Processing Department and reported on the ripple effect that could be observed sometimes on cine film.

> The reason Rochester film does not show it so much is connected with the fact that Rochester Acetate base is not “curved” so much as Pathé base & therefore drying of the emulsion is balanced by drying of the base solvents on the [buch], – the latter effect – tending to balance the former.
>
> Note that the smaller [curve] of the Rochester base may account for its greater [shrinkage] compared with Pathé since in the former case prolonged drying cannot cause such evaporation of solvents as in Rochester base. Therefore Pathé [shrinks] in dimension less than Rochester. For sound film 16mm why not use either Rochester support or Pathé not “curved” so far ?[171]

The standardisation of the production of Kodak films was a real headache even before the Kodak-Pathé period and the production at Vincennes. Depending on the Kodak manufacturing plant, the film base produced was more or less flawed and sometimes, as Phillips remarked, one specific flaw reduced another one. In this example, Pathé’s support was rippling more but was shrinking less than Rochester’s. Unlike Robinson’s written discourse, Phillips notebooks provide the rationale of the researcher alongside

---

[170] Ibidem, 63a-64a.

[171] Phillips, personal notebook, year 1934, 38a.

formulas and operating instructions. It could be said that Phillips kept records of his mental reflections and of his technical discussions about his research work. What is unknown is how Phillips used his notebooks in his research work and how often he consulted them.

3.3.4. The notebook of the photochemist Krohn as a cognitive tool

To end this section, it is important to point out that the characteristic of providing the thoughts and the rationale of the researcher in a notebook was not specific to Phillips, but was also found in notebooks kept by others. It would not be relevant to study all the notebooks kept at the British Library in the framework of my research, however a last example of notebook written by a chemist we have already discussed shows the importance of the data enclosed in the notebooks for the intellectual process of doing fundamental or applied research. I mentioned the existence of a notebook attributed to Krohn, the photochemist, in the previous chapter. After his official retirement from Harrow Limited in 1932 Krohn was still active and undertook scientific studies about film technology in his personal laboratory. The personal notebook of the chemist encloses a letter about a method for removing bubbles during the coating of acetone-acetate dopes that follows a typed report about the making of colour films. In this letter Krohn first explained the issue and indicated that he found an easy solution to avoid the appearance of bubbles by boiling up the dope for 5 minutes and by cooling it just before coating. Krohn not only provided the method in his letter but also the observations and the reasoning that led him to the solution.

> Some time ago I noticed when coating blue dopes for Series 3 that the bubbles would start as minute bubbles here and there along the surface and would then gradually grow in size. This gave me the idea that they were largely due to air, dissolved in the dope, gradually getting released round a nucleus once it was formed. It seemed probable that if this idea were correct we should be able to get rid of or materially reduce the bubble trouble by boiling off the dissolved air, then making up the weight of the dope against cooling it down to 20°C-22°C. (…) I had on several occasions [? strated] the dopes, just before coating, by boiling them and that these dopes coated very free from bubbles. At that time I put this freedom from bubble down to the viscosity of the dope having been increased. In

> S346 – PF/326 + S347 – PF327 I tested the idea and was more than pleased to find that my expectations were fulfilled. (…)[172]

Although Krohn's handwriting is sometimes difficult to decipher, the reader can follow the entire process of his thoughts about the bubble issue including the empirical and experimental work. It is difficult to identify the nature of the so called colour films studied by Krohn. The coating of a blue emulsion layer could indicate the 3-colour Kodachrome process, but according to Gauntlett, full-scale Kodachrome film manufacture did not start at Harrow before the end of the Second World War.[173] Thus Krohn's activities may represent experimental work about the production of Kodachrome film in England. Why did he provide so much information about his rationale ? This characteristic of his notes may surprise the reader. Did he know that the notebook would be read by other technical or scientific staff at Harrow? But even if his notebook was not supposed to be shared with others, the very descriptive literary style of Krohn's autobiography shown in section 2.2.1 stresses that the photochemist was used to adding in-depth descriptions as much as possible when writing. The presence of the corpus of personal notebooks in the British archive demonstrates that Kodak managers considered it important for the company to keep this specific kind of technical knowledge, as some in-house correspondence suggests in the Kodak Collection archive.[174] Krohn may have thought that his observations about the boiling of the emulsion were available to use and improvement for a later coating technology at Harrow. It is unclear whether or not Krohn, Robinson and others were requested to fill in notebooks during their professional life at Kodak Limited. The keeping of a personal notebook seems to have been a regular practice in the photographic industry, sometimes in a form like a laboratory notebook, sometimes an

---

[172] Krohn (attributed to), "Colour Film Formulas," np. Series 3 and other numerical codes represent either an emulsion, a film base or an experimental colour film.

[173] Gauntlett, "A History of Kodak Limited," 61.

[174] For instance see the letter of the Company Archivist Geoff Bawcutt to J. Ridley of the Financial Division and to R.A. Jeffreys, Director of Research, 26th March 1984, ref. A1565, box 126, KCA-BL. Bawcutt discussed the importance of the archives and included a slide presentation of eleven documents of historical interest, pointing out the scientific value of some of them such as "the definitive log-book of official Kodak Limited formulae complete with its amendments for the pre-WW1 period."

index notebook of confidential formulas, or a draft notebook as a place to note scientific rationales and even as a private notebook including children's drawings and poems.[175] The disparate nature of the notebooks studied demonstrates their exceptional value within the photographic archives and merits further academic study.[176]

3.4. Conclusion of Chapter 3

Chapter 3 introduced the European Kodak Research Laboratories opened in Britain and in France at the turn of 1928. In the first instance, Mees's decision to open a Research Laboratory at Harrow was to identify competent interlocutors to receive the Rochester research reports, and to keep them informed about new procedures or improvements in the film production. The Harrow research structure was therefore supposed to focus on applied research and production improvements, while gathering scientific and technical knowledge produced at Rochester. These activities follow what is now called "Closed Innovation" excluding interactions with external actors or technologies. The nature of the innovation performed by the Harrow Research Laboratory diversified rapidly, though. This was particularly due to Eastman Kodak's need to develop research in organic chemistry in Europe. In Britain, photographic research undertaken at Ilford Limited proved more successful in the 1920s than equivalent research

[175] As can be found in Charles T. Robinson's notebook, "The property of C T Robinson," np.

[176] The literature about note taking and notebooks in the history of science is important but I cannot review it completely within the framework of this thesis. For example, a workshop held at the Max Planck Institute for the History of Science in Berlin in 2003 investigated how the study of research notebooks could clarify the nature of scientific investigation itself in the history of science. See Frederic Lawrence Holmes, Jürgen Renn, and Hans-Jörg Rheinberger, *Reworking the bench: research notebooks in the history of a science* (Dordrecht [etc.]: Kluwer, 2003). Closer to the context of industrial research, Eastman Kodak implemented in the 1990s an electronic laboratory notebook (ELN) system to improve the sharing and the management of knowledge through the Research Laboratories. See David R. McLaughlin, "The Wired Laboratory," in *Impact of advances in computing and communications technologies on chemical science and technology: report of a workshop*, ed. National Research Council (US) (Washington, D.C.: National Academy Press, 1999), 154-170.

conducted at Kodak Limited. The discovery in 1928 of new optical sensitizers made of carbocyanines dyes by Ilford Limited's Dr. Hamer forced Mees to initiate some research work on these innovative chemical compounds at Rochester. Soon, one part of Harrow's Research Laboratory was a command centre where competitive intelligence was planned and scientific knowledge gathered from Ilford Limited and other competitors. More recently, the Harrow Research Laboratory was also used as a "regional innovation cluster". In a structural sense, the British Laboratory represented a duplication of the first American Research Laboratory on a smaller scale. It followed a similar organisation with the accelerated hiring of qualified scientists, the use of several Research Departments and the existence of a library with a core of scientific literature. The British researchers started to produce their first research reports in 1929, following the "model" of industrial research institutionalised by Mees. In terms of innovation management, the Harrow Research Laboratory can be said to have mixed "Closed and Open Innovation" models to optimise the development of scientific knowledge in photography and secure the innovative technologies necessary to the production of experimental emulsions and films. Considering this, I argue that the Harrow Research Laboratory represents a new "model of innovation" which I call "Hybrid Innovation" due to the mixed nature of the resulting industrial research, on the one hand focused on experimental research in-house and, on the other hand developing outward-looking skills to identify and possibly take over or collaborate with innovative firms, scientists or technologies.[177]

[177] In May 2013, Christensen et al. introduced in a paper a new model of "Hybrid Innovation", which is different from my present claim. For Christensen, a "Hybrid Innovation" is rather an innovative combined technology which includes an old and a new technology. This resulting hybrid technology is targeting existing customers and combines the advantages of both sustaining and disruptive innovations. In my own definition of "Hybrid Innovation", I consider the industrial research methods used to innovate and not the already existing technologies, either old or new, produced by industrial research activities. However, the goal of my model of "Hybrid Innovation" is similar to the goal of Christensen's hybrid technology. It is used to benefit from the "best of both worlds" to either improve industrial research performance or to facilitate the introduction of a disruptive technology on a specific market. See Clayton M. Christensen, Heather Staker and Michael B. Horn, "Is K-12 Blended Learning Disruptive?: An Introduction of the Theory of Hybrids" (white paper, Clayton Christensen Institute, San Mateo, CA, May 2013), 8-24.

The origins of the French Kodak-Pathé Research Laboratory are not comparable. The French subsidiary of Eastman Kodak arose from the 1928 purchase of an independent film production and film manufacturing company. As early as 1906, Pathé launched experimental production of cine film in England, purchasing the declining cine film manufacturing plant of the European Blair Camera Company in Foots Cray. A cooperative team was implemented between British and French photochemists to work together for several months. From this technological collaboration, the researchers at Pathé archived their experimental work in research notebooks and a number of research reports. The most interesting reports were copied and classified in the annual manufacturing books. Thus the research organisation at Pathé can be said to have been a model of "Closed Innovation" with research objectives focused on the introduction of innovative technologies such as non-flammable supports or experimental colour processes, and on the improvement of existing products. The research and production structures worked in closed collaboration with some of their suppliers and partners but generally did not undertake organised technology watch or scientific collaborations as a company might do in "Open Innovation" model. The scientific knowledge developed by the French photochemists was a real asset to the company and carried influence in the purchase by George Eastman in 1927. In parallel, there is evidence that the French owner Charles Pathé was willing to sell his industrial works to his competitor Eastman Kodak. After the merger, the American manufacturer was able to use a scientific knowledge network with an enlarged international research organisation.

The two European Research Laboratories were supposed to work in joint collaboration according to Mees's request. Despite cultural disparities and an already existing structure, the French Research Laboratory partially adopted the organisation of its American and British counterparts. In particular, the French followed the policy of spreading knowledge outside the laboratory by publishing a French version of the American Kodak *Monthly Abstract Bulletin* as early as 1927 and an equivalent of the *Abridged Scientific Publications from the Kodak Research Laboratories* from 1942. The quality of Kodak research after 1928 in the United States, England and France could thus be demonstrated through such publications, although these external communication tools had to be handled with care to avoid the unwanted sharing of proprietary know-how and scientific knowledge. Usually published several months after the research period, a corpus of scientific papers that had been approved by the Eastman Kodak managing staff would not reveal the reality of the routine work undertaken and the organisation in practice at the three Kodak Research Laboratories. It was clear that the information contained in these papers was sufficiently disconnected from the research work undertaken in the Kodak Research Laboratories. By contrast, a study and analysis of the corpus of Kodak research reports was particularly appropriate to show how industrial research was conducted in the Kodak European laboratories.

The exhaustive study of the production of knowledge at the Harrow Research Laboratory through the analysis of the British research reports led to my identification of a modern method of innovation in the traditional industrial research activities. The research reports have never been studied before and as they contain the complete corpus of fundamental and applied research performed from 1929 to 1964, it was the best source of information pertaining to the organisation of industrial research and the methods of innovation used by Kodak in Europe. The qualitative analysis covered data collected from 350 reports created from 1929 to 1935 and resulted in the identification of three main core activities. It appeared from the analysis that standard industrial research and development activities constituted 56% of the Harrow Research Laboratory work, examples of which include investigations on production issues or investigations into a competing product through reverse engineering. Standard fundamental research activities, such as the development of instrumentation or the testing of new dyes, represented only 13% of the research work. Surprisingly, the remaining 31% were made up of collaboration-oriented activities. Such activities constituted a modern method of innovation for an industrial research structure of the Interwar period, underpinned by the selected case studies which clarified how the Harrow Research Laboratory undertook collaboration with companies and individuals. Some research reports pointed to teamwork with the French Kodak-Pathé Laboratory and the establishment of a long-term industrial collaboration regarding both production issues and fundamental research. Thus the British Kodak Laboratory, which was initially working in the framework of "Closed Innovation", was also open to the external resources of scientific knowledge and innovative processes. This method of gathering and producing technical and scientific knowledge is similar to what could be called a modern model of "Open Innovation". It is worth noting that the findings above fit with my preceding argument for naming the Harrow Research Laboratory activities "Hybrid Innovation".

A study was conducted in the second section of Chapter 3 on the organisation of the Research Laboratory at Kodak-Pathé from 1927 as the scientific archive of the French subsidiary of Eastman Kodak had just emerged in Chalon-sur-Saône. The analysis of scientific and technical transfer of knowledge between the three Kodak Research Laboratories in Vincennes, Harrow and Rochester shows that a general procedure of bilateral knowledge sharing was set up during the period studied in the 1930s. This practice demonstrated that an individual research laboratory never worked independently of its counterparts. It was possible to identify for some periods in which a kind of scientific knowledge was shared, by whom and what amount of technological and scientific knowledge was transferred. The scientific facts and the innovation produced were shared frequently during the 1930s between the American, British and French Research Laboratories. There was also a general upswing in sharing knowledge in-house after the end of the Second World War. The development of international teamwork and the spirit of competition within the Eastman Kodak research structure was the result of this transfer of scientific knowledge.

The study of personal notebooks enhances our understanding of the methods used by production managers and researchers to develop technical or scientific knowledge during their day-to-day work. Even if some questions remain unsolved about these archival documents such as their origin and the decision to produce and keep them, it is nonetheless clear that in the photographic industry it was important to keep know-how and scientific knowledge written down and to share it with a restricted pool of authorised people within the company. For the authors themselves, the note-taking and later consultation of their notebooks also represented a cognitive process clarifying the rationale behind specific research.

Having established the processes of producing scientific knowledge in-house in an industrial organisation it is important to understand how that knowledge was made concrete, protected and legitimised through the patenting process. Using important folders in the Kodak Collection Archive pertaining to film colour technology, and the patenting process with independent inventors in other archive documents, I will analyse the relationship between the managers of the Patent and Trade Marks Department at Harrow and at Rochester with the initial inventors of scientific facts. This will allow me to establish how they tackled long procedures of patenting technologies and how intellectual property was finally incorporated in the company's assets. The studies will ascertain the rationale of the scientific collaboration at Eastman Kodak by introducing one of Mees' successes, the progressive incorporation of the two photochemists Mannes and Godowsky into the structure of the Research Laboratory at Rochester.

Chapter 4: Scientific collaboration and patent strategy: the case of colour photography

This chapter demonstrates how the British researchers of Kodak Limited as well as the French photographic research of Pathé and Kodak-Pathé regularly interacted with long-term research projects on two and three-colour film processes during the 1920s. In addition to this competition and teamwork across the Atlantic, the first section of the chapter illustrates the context of the development of the two-colour Kodachrome and the lenticular Kodacolor processes. In a second stage I introduce the three-colour Kodachrome by ascertaining how the two independent photochemists Mannes and Godowsky undertook their first experiments before their collaboration with Kodak and what their initial patent work was for the quest for a viable colour process. I then provide the mechanisms of the social agreement between the two chemists and the Kodak scientists, pointing out Kenneth Mees's strategy to recruit highly skilled people in the field. New materials in the Kodak Collection archive illustrate the conditions under which the collaboration was agreed, detailing patent issues before and from the recruitment of Mannes and Godowsky. Indirect information collected in other sources clarify how teamwork developed progressively in the field of colour photography. This teamwork foreshadowed the later creation of an experimental colour processing department to improve negative and positive processes at the time of the Second World War. The successful collaboration of Eastman Kodak with Mannes and Godowsky is an opportunity to explain the definition of an invention, elaborated through the routine work of the laboratory as well as within the body of the patent.

Section 2 complements the study of the meaning of the patent strategy by stressing the contribution of Kodak Limited to the research on colour photography. I use two case studies related to the establishment of patent works to secure intellectual property of Eastman Kodak on colour film technologies. The first case study is the long-term collaborative work of the Patents and Trade Marks Department of Kodak Limited with the independent chemist Michele Martinez which led to the filling of decisive patents for colour film technology. I analyse in particular the folder relating the difficulties of the wording of a patent application in order to patent it successfully in the United States under the number US2269158 ("Color Photography"). During the editing period of the patent in 1940 Martinez, an Italian citizen, was interned as an enemy alien at the n°2 Metropole Camp in Douglas, Isle of Man and was prevented from producing any laboratory work. The study of the complete set of correspondence between the researcher, the Kodak staff of the Patent Departments of Harrow and Rochester and the Examiner of the Patent Office allows a description of the methodology of knowledge production from the scientific, collaborative and administrative side. This case study is important because it illustrates how a scientific fact is constructed from laboratory work and previously patented work.

The second case study also concerns an independent chemist who maintained a stormy collaboration with the Kodak Research Laboratories while producing cutting-edge technologies in colour photography. Karl Schinzel's initial work in 1905 on a subtractive integral tripack system influenced the research of Mannes and Godowsky and a correspondence folder in the Kodak Collection archive indicates that the three men worked together many years later for a few months at Kodak Park in 1938. Like the collaborative work between Kodak and Martinez, the material shows a long-term cooperation between Karl Schinzel and the Kodak Research Laboratories and new evidence about the planning of another Research Laboratory in Switzerland under the direction of Schinzel, financed by Eastman Kodak, which was never opened due to the outbreak of the Second World War. After the analysis of the scientific and corporate collaboration between Eastman Kodak and Schinzel, illustrating the duties of the chemist towards Eastman Kodak for the planned Research Laboratory, I study in particular the letters the chemist sent to the Patent Department of Kodak Limited from Switzerland during the winter 1939. These letters are about the editing of British and American applications for patents and the author discusses several claims and especially the scientific inquiries of the British Kodak staff. The analysis of Schinzel's correspondence regarding the development of patents is a new methodology to ascertain the nature of scientific facts contained in patent literature. It provides previously unpublished evidence of the collaboration between Schinzel and Kodak within the framework of the innovation process.

This important chapter ascertains different kinds of scientific collaborations between the teams of the three Kodak Research Laboratories as well as between them and independent inventors. It stresses the contribution of Kodak Limited to scientific research in colour photography. Patent strategy undoubtedly influenced photographic research at Eastman Kodak and in the main Research Laboratories of the competition by concentrating teams of researchers on specific fields of study, while diverting them from other fields they could have explored. This chapter emphasizes the key part played by patents in the innovation process itself.

4.1. Collaborative Research for a subtractive tripack process

The quest for a viable and marketable colour process dominated the first half of the twentieth century not only on the part of George Eastman and the Kodak researchers but also in the research laboratories of competitors and through academic networks. I have already mentioned the first attempts undertaken at Kodak Park in Rochester to study and develop new additive colour processes in section 2.3. In 1904 John H. Powrie and Florence Warner worked unsuccessfully on their screen colour process but technical results remained unsatisfactory and from October 1910 the MIT graduate Emerson Packard directed a prototype colour laboratory starting from Powrie and Warner's work. This thesis is not the place for a technical and chronological narrative of the many additive and subtractive colour processes that punctuated the first decades of the twentieth century. That technical history has already been done in several publications and papers.[1] To introduce the research work of Mannes and Godowsky that led to the three-colour Kodachrome in 1935, I narrow my study down to the preceding colour processes directly connected with Eastman Kodak. Their development and introduction to the market coincided partially with the long years of research provided by the two independent photochemists and it shows that industrial research about colour did not stop when a particular colour process was released. Even for the new Kodachrome in 1935, it was clear in Kodak scientists' eyes that the innovative tripack film had to be improved and that other colour film technologies could overtake the difficult technology of controlled diffusion developed by Mannes and Godowsky.

[1] Edward J. Wall, *The History of Three-Color Photography* (Boston : American Photographic Publishing Company, 1925); Joseph S. Friedman, *History of Color Photography*, 1st ed. (Boston : American Photographic Publishing Company, 1944); Coe, *Colour Photography: the First Hundred Years, 1840-1940*; Collins, *The story of Kodak*; Jack Howard Roy Coote, *The Illustrated History of Colour Photography* (Surbiton: Fountain, 1993); Brayer, *George Eastman: a Biography*.

4.1.1. The development of the two-colour Kodachrome at Rochester

Soon after the creation of the Kodak Research Laboratory at Rochester in 1912, scientists started undertaking technology watch about any announced or existing colour processes and working in-house on additive or subtractive technology. At Kodak Park, a young researcher, John G. Capstaff, started experimental work in 1914 and developed the first Kodachrome film process that was introduced to the public in 1915.[2] This two-colour subtractive process had already been conceived by the fall of 1914 and its introduction to the market was delayed due to the outbreak of the World War I in August 1914. American-made sensitising red dye was not satisfactory and the better red dye from Germany was no longer available following the start of hostilities.[3] The two-colour Kodachrome was patented in 1916[4] but never marketed despite the importance of two markets, the professional photographers and medical photography.[5] The research work done by Capstaff and his team in 1914 is not well documented. Baum McCarthy pointed out that the initial observation made by Capstaff in 1910 while working at Wratten & Wainwright on the effect of tanning bleach was probably the starting point of the research work. When a negative image was bleached, washed and dyed a positive dye image could be seen on the photographic support. At Rochester, Capstaff worked on a method for colour cinematography but he decided to use glass plates instead of celluloid film for greater ease of handling. He then had the idea of testing the tanning bleach effect on two glass plate negatives made through red and green filters. The final stage to get a photograph in natural colours was to superimpose two dye-positives and to observe the assembled coloured bi-pack by transmitted light.[6] World War I, however, was not the only cause

---

[2] *Journey: 75 years of Kodak Research*, 29.

[3] Brayer, *George Eastman: A Biography*, 223.

[4] John Capstaff, "Photographs in color and method of making the same," US Patent 1,196,080, filed September 21, 1914, and issued August 29, 1916.

[5] Brayer, *George Eastman: A Biography*, 223.

[6] Jane Baum McCarthy, "The Two-Color Kodachrome Collection at the George Eastman House," *Image* 30, no.1 (1987): 1.

of failure for the first Kodachrome process. The colour rendering was particularly appropriate for European flesh tones as well as tones in orange, red, green and black. But the process was not good for reproducing blue, violet and magenta colours.[7] It had in fact inherited the disadvantages of a two-colour process, for which the removal of the third colour was made to simplify the making of the colour film. From that point of view Capstaff may have been influenced by the Kinemacolor, a two-colour additive process of cinematography. As a two-colour subtractive process such as Capstaff's process provided a slightly better colour rendering than a two-colour additive one, the Kodak researcher thought that his invention most closely corresponded to one solution of making photography in natural colours.[8] Despite the commercial failure, Capstaff kept on working on his process during the First World War and filed a new application in 1918 for another procedure of the two-colour Kodachrome.[9] For this modification Capstaff used a technique initially developed in the photomechanical printing trade. Positive images, printed from separation negatives, were developed, washed and bleached in a solution of ferric chloride and tartaric acid. This treatment hardened the gelatin depending on the amount of silver. The plates were then fixed, washed and dyed with the same Kodachrome dyes as the first version of the process.[10] It is not known if the second procedure of the two-colour Kodachrome improved the colour rendering or the sharpness of the process. However, the photosensitivity was still weak and the process still required powerful artificial lighting to provide satisfactory portraits.

[7] Ibidem, 3.

[8] Early two-colour photographic processes could only approach an accurate reproduction of colours and were inaccurate for the rendering of some colours. A photographic process said in natural colours would normally mean a structure made of three coloured separations through red, green and blue filters for an additive process or three coloured layers for a subtractive process, to provide an accurate colour rendering.

[9] John Capstaff, "Color photography," US Patent 1,315,464, filed February 14, 1918, and issued September 9, 1919.

[10] Friedman, *History of Color Photography*, 467-468.

4.1.2. The research work of Berthon on a lenticular process at Pathé

While Capstaff's unfinished process of was progressively abandoned in Rochester, research in colour photography was actively being carried out in France. I have already written that the Berthon additive process and his association with the industrialist Keller-Dorian led to the development of the first Eastman Kodak Kodacolor process, when the patent rights were purchased by the American company in 1926. The initial patent of Rodolphe Berthon is also frequently cited in the histories of colour photography. Filed in May 1908 in France and in May 1909 in England, the patent contained a new lenticular screen technology and a three-colour reproduction system.[11] One side of the film base was embossed with a honeycomb structure and it represented an optical solution to the reproduction of colour. Each microscopic spherical embossing worked as a small lens to render the red, green or blue spectrum of the photographic subject. A standard camera could be used provided that the diaphragm of the lens was fitted with a three-colour screen. As early as 1944 Friedman pointed out that the first scientist to consider the possibility of a lenticular film material was Gabriel Lippmann early in 1908.[12] During a sitting at the French *Académie des sciences*, he revealed the theory of a screen process that could possibly reproduce colours but also provide the three-dimensional image of the photographic scene.

> Before coating the emulsion on the film base, suppose this base has been squeezed under heat in a kind of embossing machine, so as to create on each of its faces many little projections in the shape of spherical rings. Each projection whose front face of the film base, the one which will remain bare, is covered is intended to act as a convergent lens.[13]

---

[11] Rodolphe Berthon, "Perfectionnements aux procédés photographiques trichromes," French Patent 399,762, filed May 1, 1908, and issued July 7, 1909; Berthon, "Improvement in three-colour photographic processes," English Patent 10,611, filed May 4, 1909, and issued May 4, 1910.

[12] Friedman, *History of Color Photography*, 222.

[13] Gabriel Lippmann, "Épreuves réversibles. Photographies intégrales," *Comptes rendus de l'Académie des sciences* 146 (2 mars 1908), 446-51. "Avant de coucher l'émulsion sur la pellicule, supposons que celle-ci ait été pressée à chaud dans une sorte de machine à gaufrer, de manière à faire naître sur chacune de ses faces un grand nombre de petites saillies en forme de segments sphériques. Chacune

Kim Timby recently pointed out that despite the theoretical aspect of Lippmann's description of the process, Berthon reacted and undertook some research work so fast that he submitted a patent application for his lenticular screen process just two months after Lipmann's communication.[14]

As very little is known about Berthon's biography and early work, it is challenging to determine at first glance whether he behaved as an opportunist inventor benefitting from Lippmann's theory or if he really contributed to the lenticular screen through optical research work. In the English patent 10,611 he was referenced as an *engineer* and, according to Friedman, he was an *astronomical optician*. In addition, a recent investigation points out that Berthon partnered with Joseph Gambs, an optician and dealer in Lyon, France. Berthon and Gambs were granted 7 patents from 1905 to 1908 regarding projection techniques, in particular the adaptation of standard projectors to additive three-colour photography.[15] Until now, there has been an historical gap between the patent filed in May 1908 by Berthon and the transfer of Keller-Dorian-Berthon technology to Eastman Kodak in 1926. New archival material clarifies how the photographic research was conducted on the lenticular additive process during some of these years and under what conditions and whose supervision. According to records at the French Kodak-Pathé archive, Berthon worked for the French film manufacturer as a researcher in Vincennes for at least one year between 1913-1914. The research notebooks of Berthon contain 38 research reports relating to colour photography, lenticular screens, patents, film embossing technology or experimental emulsions. This research work deserves further scholarly studies due to its sheer volume but it is worth

des saillies dont est couverte la face antérieure de la pellicule, celle qui restera nue, est destinée à faire office de lentille convergente." (p.447).

[14] Kim Timby, "Colour Photography and Stereoscopy: Parallel Histories," *History of Photography* 29, no.2 (2005): 183-196. The author also stressed that classic histories of photography and cinema, while placing Lippmann at the origin of lenticular film, neglected the scientist as the precursor of the recording of a three-dimensional image.

[15] Nicolas Le Guern, « Des Recherches de Rodolphe Berthon chez Pathé en 1913-1914 au Procédé Lenticulaire Kodacolor » (paper presented for the Conference « Les Cahiers de Recherche Pathé (1904-1930), » Fondation Jérôme Seydoux-Pathé, Paris, December 7-8, 2015).

providing some previously unpublished information that clarifies the relationship between the scientist and the firm Pathé.[16]

Although his principal concern was the development of his additive lenticular process, surprisingly Berthon was still investigating the Powrie-Warner colour process in 1913. This process was a line screen three-color additive process for which the screen was made with bichromated colloid or fish-glue. The colour technology was similar to the additive principle of the autochrome process but with a regular linear screen instead of a random arrangement of colored grains. While recognizing that the Powrie-Warner process provided “the most remarkable transparency and brightness of the screen”, Berthon also pointed out that unfortunately the colour saturation was too weak due to the extreme thinness of the bichromated and tinted layers. It was possible to notice some colour differences between Powrie-Warner plates and the reproducibility of the process was not satisfactory. To increase the saturation of the dye, Berthon worked out an additional procedure by bathing the plate successively in a solution of tannin and basic fuchsine.[17] His interest in the Powrie-Warner process can be clarified by accounting for the thorough research of John H. Powrie. After his failure to collaborate with Eastman Kodak in 1904, Powrie never stopped working on his process. At the end of 1908, Johnson noted that Powrie and Warner intended to manufacture two kinds of plates not yet on the market.[18] Later in the 1920s, Powrie eventually developed a scientific cooperation with Warner Brothers. He was able to work at the Warner Research Laboratory in New York City to adapt the process to colour motion pictures

---

[16] Elizabeth Brayer is *a priori* the unique scholar having reported that the Berthon process had been purchased by Pathé in 1914 and that the French competitor was working on this colour process the same year. She revealed in 1996 that George Eastman was aware of this research work and informed some of his associates in 1914 through correspondence. “Pathé (…) is about to bring out a color process which will revolutionalize the industry… Invented by a man named Berthon… The colors are in the film, reproduction simple […].” See Brayer, *George Eastman: a Biography*, 220-222.

[17] Rodolphe Berthon, "Couleurs naturelles,” research report, May 21, 1913; "Étude critique de la reproduction des couleurs en projection”, research report, May 25, 1913; "Sensibilité des chromates. Recherches sur le procédé Powrie-Warner,” research report, May 28, 1913, ref. 33125, CECIL.

[18] "In those employed for producing negatives in colour, the lines will run lengthways; in those from which colour positives are to be printed, the lines will run across the shorter side of the plate.” G. Lindsay Johnson, *Photographic optics and colour photography, including the camera, kinematograph, optical lantern, and the theory and practice of image formation* (London: Ward & Co., 1909), 238.

and reported on his process to the members of the Society of motion picture engineers in 1928.[19]

Berthon was certainly aware of the most promising innovations of his time related to colour photography. Through the autochrome and the Powrie-Warner process, he was investigating a method of producing colour granular screens with a symmetrical pattern. He concluded from his research that photographic and chemical methods of making the screen should be abandoned: only mechanical methods could produce correct colour homogeneity and screen regularity.[20] From his study of the work of other photochemists he reported the patents granted in the period, discussing their interests to improve his own researches on colour technologies.[21] Many of his reports were also dedicated to the development of his lenticular process, for which the greatest difficulty at this time was the production of the film's embossed support. Berthon undertook some embossing experiments with Eastman celluloid film and Pathé acetate film, with different embossing material. He used for instance a knurled cylinder heated between 115°C and 135°C to shape the film support with lenticular pattern. Results were encouraging but not entirely satisfying.[22] Other reports related to the development of optical systems principally used to project lenticular colour film with a significant reduction of light loss. Berthon's last report in his research notebook provided an overview of the experimental work done so far on the lenticular colour process and some thoughts about what was still required to transfer the prototyped process to the production stage. He pointed out two major issues to improve: the

---

[19] John Powrie, "A Line Screen Film Process for Motion Pictures in Color," *Transactions of the Society of Motion Picture Engineers* (April 1928): 320-334. See also Roderick T. Ryan, *A History of Motion Picture Color Technology* (London: Focal Press, 1977), 36-37. Friedman noticed that Powrie was a prolific patentee in the field of dichromate photography for the formation of the screen. Friedman, *History of Color Photography*, 155.

[20] Rodolphe Berthon, "Réseaux polychromes granulaires symétriques," research report, June 4, 1913, ref. 33125, CECIL; Berthon to Charles Pathé (most likely), June 6, 1913, ref. 33125, CECIL.

[21] Rodolphe Berthon, "Brevets divers," research report, June 25, 1913; "Brevets communiqués," research report, July 23, 1913, ref. 33125, CECIL.

[22] See for example Rodolphe Berthon, "Couleurs naturelles," research report, July 10, 1913; "Couleurs naturelles – Projections en couleur," research report, August 18, 1913; "Gaufrage de film à sec," research report, September 4, 1913, ref. 33125, CECIL.

sharpness of the images and the colour brightness. Berthon finally concluded that "the fundamental experience of strains on the film can only, after all, give accurate information about the requested time to the industrial development of cinematography on embossed film."[23] At the outbreak of the World War I a few months later it appears that the collaboration of Berthon with Pathé ceased.

The analysis of four research reports included in Berthon's folder provides a partial answer for the sudden separation between Berthon and Pathé. I argue that the end of their collaboration is due to the lack of recognition of Berthon's work with respect to the authorship of four patents. Indeed four of the research reports are similar to nearly complete patent drafts. For instance, the report written on July 24, 1913, referred to an optical system that made it possible to superimpose three juxtaposed prints on a single sensitive layer. The text accompanied a technical sketch most likely by Berthon.[24] In the list of patents that were granted to Pathé for the years 1913-1914, there is a corresponding patent that was also accompanied by the same drawing among others (see Illustration 8). The fact that the name of the inventor was not included in the final patent is a practice that breaks with Anglo-Saxon patent procedures. At Eastman Kodak or Kodak Limited, the name of the researcher or the independent inventor collaborating with the firm was always mentioned in the patent. Berthon's disappointment also indicates that in the mind of an inventor, the granting of a patent represents the recognition of scientific knowledge conceived by the inventor, on behalf of a community of researchers or competitors.

---

[23] Rodolphe Berthon, "Cinématographie en couleurs naturelles," research report, March 16, 1914 ; "Brevets communiqués," research report, July 23, 1913, ref. 33125, CECIL. "L'expérience fondamentale sur les déformations du film peut seule, en définitive, donner une indication précise sur le temps nécessaire à la mise au point industrielle de la cinématographie par films gaufrés." (p. 5).

[24] Rodolphe Berthon, "Perfectionnements aux appareils trichromes," research report, July 24, 1913, ref. 33125, CECIL.

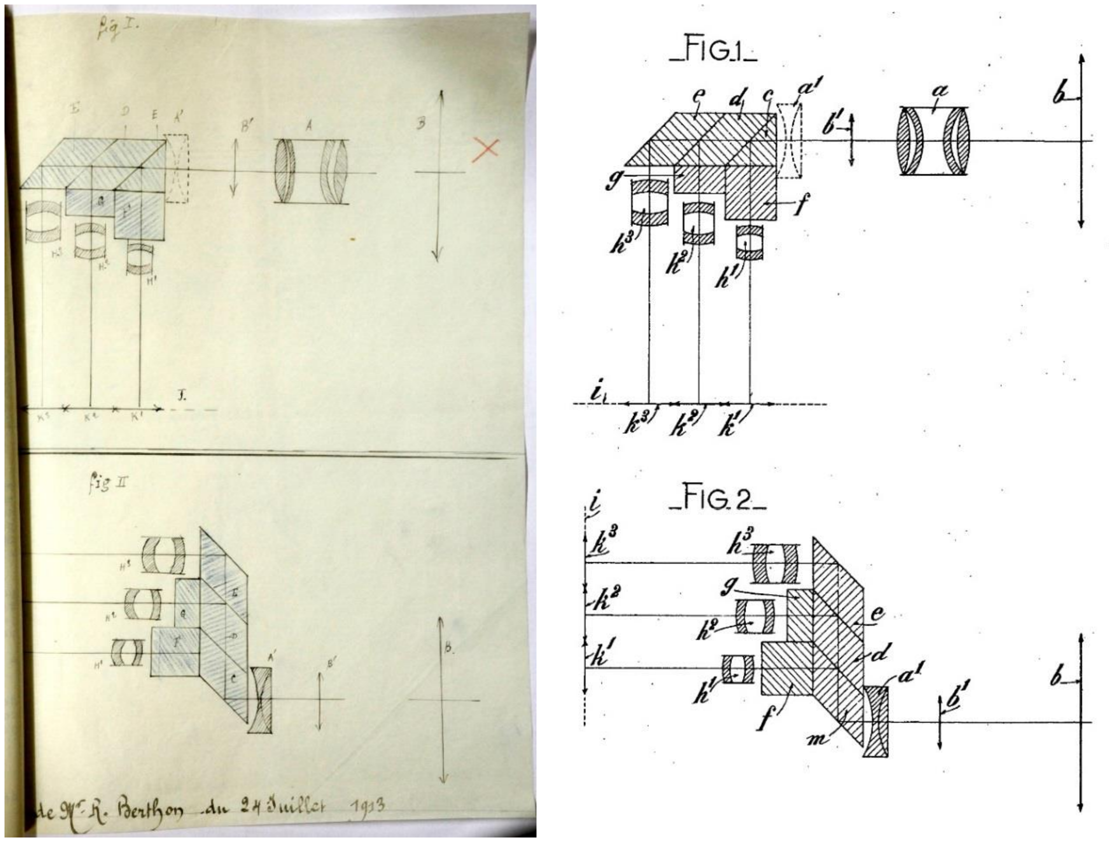


Illustration 8. Berthon’s technical drawing attached to his research report on July 24, 1913 (left) compared with the first illustrations included in the French patent 461,248 issued to the company Pathé on December 23, 1913 (right).[25]

Yet another important piece of information is also available in Berthon’s folder. Beginning at least at the end of the year 1913 Berthon was in contact with the company Keller-Dorian. In November 1913, Berthon tested a sample of ferro-nickel metal received from Keller-Dorian for the making of embossing rollers.[26] The information is important because it fills a gap between Berthon’s research work at Pathé and his later collaboration with Keller-Dorian, which is rather well

[25] Ibidem, np; Compagnie Générale des Établissements Pathé Frères, “Système optique applicable aux appareils trichromes,” French Patent, filed August 9, 1913, and issued December 23, 1913. See also Le Guern, “Des Recherches de Rodolphe Berthon chez Pathé en 1913-1914 au Procédé Lenticulaire Kodacolor,” 9-10.

[26] Rodolphe Berthon, “Échantillon de Ferro Nickel (Keller Dorian),” research report, November 12, 1913, ref. 33125, CECIL. At Pathé Berthon was assisted by Mr. Lazuech.

documented.[27] We know now that the first relationship between Berthon and the Keller-Dorian company was the relationship between an industrial laboratory and one of its suppliers. This French company specialised in engraved rollers and was directed at that time by Albert Keller-Dorian, who diversified his activities by opening a developing and printing laboratory in Paris in 1913. Further to the success of the laboratory, a research department for colour cinematography was later created.[28] It is not known to what extent Keller-Dorian was aware of Berthon's research work but he filed an application at the end of 1914 to secure a method of making "lenticulated films for color photography, comprising in combination a transparent support having a large number of minute juxtaposed objectives upon one of its faces, and a sensitive layer upon its other surface."[29] This application was apparently done without the collaboration of the Pathé researcher, because Keller-Dorian may have been aware of the innovative nature of Berthon's process.

4.1.3. From the Keller-Dorian process to the Kodacolor additive process

There are no sources that clarify the collaboration of Berthon with the Keller-Dorian company during the first years of the Interwar period. Numerous applications filed for improvement in the lenticular process in the 1920s provide some indication. It appears that only two patents were granted under the joint names of Keller-Dorian and Berthon. The application of the patents, filed in December 1922 and February 1923 in France, was made on behalf of the French company *Keller-Dorian & Cie*, and the

[27] See section 4.1.3.

[28] Juan-Gabriel Tharrats, Eva Tharrats, and Henri Bousquet, *Segundo de Chomón un Pionnier Méconnu du Cinéma Européen : Espagne, France, Italie, 1902-1928* (Paris : L'Harmattan, 2009), 236.

[29] Albert Keller-Dorian, "Film for photographic projections in colors," US Patent 1,214,552, filed December 29, 1914, and issued February 6, 1917.

Société du Film K.D.B., two corporate names that did not exist for very long.[30] According to Coote, it was in December 1922 that the K.D.B. lenticular process was first shown in Paris.[31] The development of the process made by Berthon at the Keller-Dorian company is not known. Ede recently indicated that a research team was set up by the company in 1925 including the optical engineer Henri Chrétien and the photochemist Léopold Löbel. Berthon was strangely not incorporated with the researchers but he was occasionally consulted about some development work.[32] Beyond the Keller-Dorian industrial research, the fact is that in 1925 rights were offered to the Eastman Kodak Company by the French company to further develop and adapt the K.D.B. photographic process to 16mm amateur cinematography.[33] The researchers at Rochester had also studied lenticular technologies before 1925 but even with the French K.D.B. process in their hands, it took three additional years to fully

---

[30] See English Patent 207,836, issued December 18, 1924, convention date December 2, 1922, and English Patent 211,486, issued February 19, 1925, convention date February 16, 1923. Albert Keller-Dorian's company frequently changed its corporate name. Keller-Dorian & Cie was assignee of *Société Keller-Dorian Berthon et Cie,* a company at the same address. In 1925, the company's name changed for *Société du Film en Couleurs Keller-Dorian*, following the death of Albert Keller-Dorian in July 1924 and the restructuration of the company. From 1928 on the name changed again for *Société Française de Cinématographie et de Photographie Film en Couleurs Keller-Dorian*. As for Berthon, he created his own company in 1929 and his late patents made reference to the *Société Française Cinéchromatique (Procédés R. Berthon)*. See for example the English Patent 294,493.

[31] Coote, *The Illustrated History of Colour Photography*, 56; Louis-Philippe Clerc, « Cinématographie en couleurs par le film K.D.B., » *Science*, *Technique et industries photographiques* 3, no. 2 (February 1, 1923): 12-13.

[32] François Ede, « Un Épisode de l'Histoire de la Couleur au Cinéma : le Procédé Keller-Dorian et les Films Lenticulaires, » *1895 Revue d'histoire du cinéma,* no.71 (2013): 190-191. This recent paper is up to now the most documented work on the Keller-Dorian-Berthon lenticular process.

[33] Coote in his history mentionned an article of Glenn E. Matthews, a Kodak researcher, clarifying that the rights were acquired from the *Société du Film en Couleurs Keller-Dorian* in 1925. See Coote, *The Illustrated History of Colour Photography*, 54. However, this information was not retrieved in Glenn E. Matthews, "Photography in Naturals Colors," *Journal of the Society of Motion Pictures Engineers* 16, no.1 (1931): 188-219. The correct year of purchase by Eastman Kodak of the patent rights seems to be 1926. In any case, Ede clarified that in July 1926 some members of Keller-Dorian research team resigned following in-house dissension. The subsequent difficult situation might have forced the company to sell the rights of the K.D.B. process to Eastman Kodak. However, the financial agreement between the two companies is not known and it is difficult to conclude. Regarding Eastman Kodak and Keller-Dorian, Ede also noted without additional information that Raymond Edwin Crowther [of the Patents and Trade Mark Department of Kodak Ltd.] was sent to Keller-Dorian works to study the colour process but the author did not provide any period or year. Ede, « Un Épisode de l'Histoire de la Couleur au Cinéma, » 193.

develop a viable and marketable colour process, named Kodacolor. Mees clarified this research period in a paper.

> A great deal of study was involved. It was necessary to standardize the methods of making the lenses on the film ; to design and make a suitable emulsion strongly sensitive to green and red light and yet with sufficiently fine grain for the minute structure of the separate color elements to be resolved ; and, especially, to work out suitable methods by which the film could be developed and reversed while the rendering of color was retained.[34]

In his "dream letter" written to Frank Lovejoy in 1926, George Eastman did not expect these technological complications. In April 1926, he was sailing near Port Sudan for a hunting trip in Africa lasting several months and was so anxious to release a successful three-colour process that he anticipated the commercial launch of the Kodacolor process.[35] It is unclear whether Mees had been requested to analyse the process in the Keller-Dorian works or not. As James confirmed in 1990, Mees did agree the technological interest of the French process and recommended that Eastman Kodak purchase the patent rights. So it is possible that Mees went to Paris in the year 1926 to check the lenticular technology of Keller-Dorian for himself.[36]

In the transfers of knowledge involved, it is striking to see how a theory initially designed by Lippmann was practically developed by a French optical engineer called Berthon, financed by Pathé for some years, further developed by collaboration with the industrialist Keller-Dorian and finally gathered and optimised by the research staff of Eastman Kodak. The research work undertaken after 1925 and summarised by Mees above was not known up to now. In some sources in the European Kodak archives, there are traces of this work. First of all the Abribat's research notebooks kept in the Kodak-Pathé archive contain some evidence of collaborative work with the Keller-Dorian company. In 1928 he reported to his manager Lair the existence of a study in

---

[34] Kenneth Mees, "Amateur Cinematography and the Kodacolor Process," *Journal of the Franklin Institute* 207, no.1 (1929): 12.

[35] "Last night as I lay in my berth I dreamed a dream, I dreamed that Mees came to Paris and examined the Keller-Dorian process and found no fundamental defects in it – That it was ready to be put into production." From James, *A Biography-Autobiography of Charles Edward Kenneth Mees,* 160.

[36] Ibidem, 162.

progress of the photographic and cinematographic Keller-Dorian processes.[37] Abribat wanted to plan a series of tests with several film supports emulsified or not, before or after the embossing process. He also suggested that a study of the film support's plasticity should be undertaken to improve the development of Kodak's own embossing technology. Two Harrow research reports complete the French archive and inform us about the rest of Abribat's investigation at the Keller-Dorian company. On January 1929 Walter Clark reported a visit made the same day with Abribat to Keller-Dorian works in Paris and conducted by the chief engineer Vidal. Clark noted the complete working of the embossing machine and all the mechanical details about the embossing cylinder, its nature and manufacturing. The empirical method of controlling the embossing process was also discussed as well as the reproduction technique of 35mm Keller-Dorian films. Clark completed his report with three pages of technical sketches about the equipment used for the embossing process.[38] At the end of the same year, Clark stressed the importance of the reproduction of Kodacolor films in another report about a second visit to the same Keller-Dorian works. The visit was made with Ludwig Blattner, who had just purchased the rights to exploit the Keller-Dorian process outside the United States of America.[39] Clark first saw two projections of films recently exposed for Blattner. The second one was the "Collier de la Reine" and Clark judged that "the colours and gradations were excellent; the rendering of the green of the grass was perfect."[40] But the first director of the Harrow Research Laboratory was more intrigued by the reproduction process of the Keller-Dorian film. He detailed the copying machine made by the French manufacturer Debrie with its

[37] "As a rule, I spend all my afternoons at the Keller-Dorian laboratories and workshops where I am initiated as much as possible into the manufacturing and researches undertaken by the company Keller-Dorian." From Marcel Abribat, "Travaux personnels en projet ou en cours," research report, July 3, 1928, Vincennes, ref. 33073, CECIL, 2.

[38] Walter Clark, "Visit to Keller-Dorian Works, Paris," research report H.79g, January 1, 1929, ref. A2897, KCA-BL.

[39] A short biography of Ludwig Blattner can be found in William D. Rubinstein, Michael A. Jolles, and Hilary L. Rubinstein, *The Palgrave Dictionary of Anglo-Jewish History* (Basingstoke: Palgrave Macmillan, 2011), 100.

[40] Walter Clark, "Report on second visit to Keller-Dorian, August 1929," research report H.79g(ii), November 7, 1929, ref. A2897, KCA-BL, 1.

light source, optics and diaphragm. He selected a negative and a copy of the film was made in his presence. Copies of Keller-Dorian films were good, and Clark judged that it was almost impossible to distinguish between the original and the copy. For the Kodak representative, the technology used for the copying machine was interesting for the reproduction of Kodacolor film. However, as the film format was different, Clark suggested contacting the Debrie company directly to adapt the 35mm Keller-Dorian optical printer to the 16mm Kodacolor film.

The second report also clarifies the destiny of the Keller-Dorian process, in parallel with the Kodacolor and other lenticular processes. In 1929, the French Keller-Dorian company granted to Moviecolor Limited, a British corporation, the exclusive right to exploit its process worldwide while Kodak was supposed to furnish film to the British company. Moviecolor Limited then worked with Blattner to supply him "with raw stock and apparatus produced under the process."[41] During his conversation with Clark, Blattner informed him that the Agfa company was interested in the Keller-Dorian process and wanted to run the laboratory but that he would do nothing "until the Kodak policy was definitely settled." In his report Clark concluded that Blattner's indication was used to force the Kodak company into a decision about its relationship with Moviecolor Limited.[42] Details of the dispute between Eastman Kodak and Moviecolor are not entirely clear, but it appears that the American company as well as the Technicolor company conspired in the following years to progressively control the Keller-Dorian process and patents so that it would not be used anymore.[43] Near the end of the report, Clark mentioned that before the visit, Abribat had experienced some

---

[41] Moviecolor Limited. v. Eastman Kodak Company, Technicolor, Inc. and Technicolor Motion Picture Corporation, 288 F.2d 80, United States Court of Appeals Second Circuit, decided March 10, 1961. See paragraph 15.

[42] Clark, "Report on second visit to Keller-Dorian, August 1929," 8.

[43] Moviecolor Limited. v. Eastman Kodak Company, Technicolor, Inc. and Technicolor Motion Picture Corporation, op. cit., paragraph 15. "Defendants, 'separately or in concert, conspired to and effected' the organization of a Delaware corporation, hereafter American Keller-Dorian, and induced French Keller-Dorian to assign to American Keller-Dorian all its patent rights and its rights under the contract with Kodak. This was done in order to deprive plaintiff of the benefits of plaintiff's contracts with French Keller-Dorian and Blattner and to obtain control of the process with the intention of suppressing it."

difficulty in getting into the Keller-Dorian works. According to Blattner, an Agfa representative was also in the works when Abribat came and Blattner did not want to talk about the duplicating machine in his presence.[44] In any case, the Keller-Dorian process never took off and it can be considered as an industrial failure. American investors created the Kislyn Corporation in 1930 to develop Berthon's later *Société Française Cinéchromatique*, and Berthon started a scientific collaboration with the American Technical Director Carl Gregory. However, the international venture never really took off as well and the German group Siemens-Halske eventually purchased the rights of patents at the end of 1930. After four years of industrial research in Germany at Spandau and collaboration with the film manufacturer Perutz, the lenticular Siemens-Opticolor process started an industrial stage in 1935.[45] But it was discarded in 1938, outpaced by the innovative subtractive three-colour Agfacolor Neu and new Kodachrome processes.

[44] Clark, "Report on second visit to Keller-Dorian, August 1929," 9.

[45] Ede, « Un Épisode de l'Histoire de la Couleur au Cinéma, » 198-200.

4.1.4. The long-term development of three-colour Kodachrome

Kodacolor, despite its successful launch on the market, possessed the inconvenience of additive systems and some technical limitations due to its optical structure such as the necessity to use almost the maximum aperture of the lens, therefore reducing the depth of field.[46] At the Rochester Research Laboratory, Capstaff continued improving the two-colour Kodachrome at the beginning of the 1920s but Eastman and Mees had agreed to consider another promising technology. With the long-term research undertaken by Leopold Mannes and Leopold Godoswky for a three-colour multi-layer process, a new form of innovation took place at Eastman Kodak. It was the alliance between amateur, or independent research and the industrial research organisation of one of the main film manufacturers of the period. Thus given the final result of the three-colour Kodachrome released in 1935, the scientific collaboration between the two independent researchers and the Kodak researchers can be judged as a positive, successful one. This *full* collaboration differs from the model of the Kodacolor's development, for which patent rights were purchased from a third-party company without a sharing of knowledge. The research odyssey of Mannes and Godowsky between 1920 and 1935 is well documented and I will only point out some events and milestones of their research work, before introducing new sources clarifying the collaboration of the two young men with Eastman Kodak.[47]

As Brayer points out, the modern legend indicating that Kodachrome was invented by two skilled musicians living far from science is wrong. Mannes and Godowsky had the standard profiles of talented inventors who used a scientific background to transform the theory into a true process through experimentation. Godowsky studied chemistry, physics and mathematics at the University of California and Columbia University and

[46] For a summary of the reasons of lenticular system's commercial failure, see Coote, *The Illustrated History of Colour Photography*, 56-57.

[47] Friedman, *History of Color Photography*, 108-124; Coe, *Colour Photography: The First Hundred Years*, 120-128; Collins, *The Story of Kodak*, 205-215; Coote, *The Illustrated History of Colour Photography*, 134-149; Brayer, *George Eastman: A Biography*, 224-227.

Mannes received his Bachelor of Science degree in physics from Harvard in 1920.[48] The two men had already met in school in 1916 and become friends with a mutual amateur interest in photography. The next year, Mannes and Godowsky saw in New York a film entitled *Our Navy* made with a four-colour additive process. The colour rendering was not good and they started to undertake some research work at their high school to develop a better additive process. They succeeded in improving a parallax issue encountered with multiple lens systems, before parting to attend Harvard and Berkeley respectively. However, they continued their research work during their holidays and managed to conceive a viable two-colour additive process. It consisted of side-by-side images on a single strip of film exposed in a double-lens prototype camera. An experimental film was made but upon failing to adapt the projection equipment to the two-colour film Mannes and Godowsky gave up their first colour process.[49] When they had graduated from University, they started to work full time as professional musicians but were still experimenting during their spare time on colour processes. At the beginning of the 1920s, they progressively turned from the additive to the subtractive theory, considering rightfully that the multi-layer film could be a better solution. In their makeshift laboratory at home, they managed to coat double-layered plates able to record part of the visible spectrum.[50] But they also worked on the theory of three-colour photography and filed their first patent application on 4 October 1921, to secure the making of a coloured positive from a set of separation negatives. According to Friedman, Mannes and Godowsky's application did not consist of especially new concepts and would have been difficult to adapt in a practical manner.[51]

---

[48] Brayer, *George Eastman: A Biography*, 224; "Leopold Mannes, 1899-1964," *Image* 12, no. 4 (1964): 15.

[49] Douglas, *The Story of Kodak*, 206. Unfortunately, the author never cited his sources and the book has no bibliography as well.

[50] Brayer, *George Eastman: A Biography*, 225.

[51] Leopold D. Mannes and Leopold Godowsky, Jr., "Color photography," US Patent 1,538,996, filed October 4, 1921, and issued May 26, 1925. See Friedman, *History of Color Photography*, 108-109.

During this period, Mannes and Godowsky faced an important constraint. They had to seek funds to significantly improve their research work and results, as their families decided to stop their financing. In 1922 they were able to meet George Eastman directly to present their work on colour photography. Eastman was intrigued by their findings, but the meeting finally had no financial results.[52] Then the two researchers tried another approach with Eastman Kodak. From his studies Mannes knew Robert W. Wood, head of the Experimental Physics Department of Johns Hopkins University. Wood was also a friend of Kenneth Mees and agreed to write a recommendation in favour of the two men. In a letter to Mees dated 6 February 1922, Mannes informed him of "a new and simple method of photography in color recently invented by Mr. L. Godowsky and myself", and did not forget to add Wood's note to his mail. During his next trip to New York, the intrigued Mees finally met Mannes and Godowsky at the Chemist's Club and was impressed by the progress of their photographic work. From then on and during the following years Mees accepted to supply them with the materials they would need for their research, especially some film coated with several layers, provided that the two Leopolds would keep him informed of their further developments.[53] The same year, Mannes had also approached Everett Somers, a secretary of the investment firm of Kuhn, Loeb and Company. It appeared that this company was interested in investing in colour research and soon Lewis Strauss, a young associate of Kuhn, Loeb and Company who was aware of the practice of photography visited Mannes and Godowsky in Mannes' apartment. Following the demonstration of the experimental process, Strauss granted Mannes and Godowsky financial help for their research.[54]

[52] Brayer, *George Eastman: A Biography*, 225.

[53] James, *A Biography-Autobiography of Charles Edward Kenneth Mees*, 164-166. Brayer, *George Eastman: A Biography*, 225; McCarthy, "The Two-Color Kodachrome Collection at the George Eastman House," 10; "Leopold Mannes, 1899-1964," 16.

[54] "I was persuaded to go to the laboratory of Mannes and Godowsky, which was the kitchen in an apartment, and there with a Brownie box camera I was permitted to photograph some strips of colored crepe paper fastened to the wall with thumbtacks. The plate was then developed, and there (…) the primary colors, though muddy, unquestionably had been reproduced. Convinced, I arranged for the necessary money to pay for patent applications and attorney fees and to rent and staff a small laboratory." Lewis L. Strauss, *Men and Decisions* (Garden City, N.Y.: Doubleday, 1962), 97-98. The author

The investment by Kuhn, Loeb and Company was a twenty thousand dollar loan. The money was invested in the research and around one year later, Mannes and Godowsky filed another application for a two-colour negative process.[55] A red-sensitive emulsion was coated on a transparent support, and an orthochromatic emulsion blue and green-sensitive was coated on the red-sensitive emulsion. After development and fixation the bipack was treated with ferricyanide to convert metallic silver into silver ferrocyanide. The new feature of the patent consisted in the method used for the development of the ferrocyanide images : the diffusion into the gelatin of the solution used could be controlled at will. Thus one could develop only one layer without polluting the other one. Mannes and Godowsky took care not to unveil any formula or detailed mechanisms of this controlled diffusion.[56] Due to their professional situation, they remained rather isolated from academic and industrial research in photography but a fortunate event in 1925 allowed them to develop their knowledge of colour coupler technology. The well-known independent photochemist Edward J. Wall had just published his *History of Three-Color Photography* and Mannes and Godowsky knew that they were cited in the book for their 1924 patent.[57] After the purchase of Wall's book, they discovered the scientific narrative of the monopack film and the potential of colour development.

Mannes and Godoswky were now working on a technology of *integral tripack* or *monopack*, whose structure was made of three layers each containing an emulsion sensitised for a single primary color. With Wall's book they read that a young independent photochemist Karl Schinzel was the first to patent the use of a subtractive monopack for color reproduction in 1905. In his process called *Katachromie* Schinzel

---

also indicated further that his company backed the inventor Edwin H. Land as well for his light-polarizing products.

[55] Leopold D. Mannes and Leopold Godowsky, Jr., "Color photography," US Patent 1,516,824, filed February 20, 1923, and issued November 25, 1924.

[56] Friedman, *History of Color Photography*, 109-110.

[57] "L. D. Mannes and L. Godowsky patented the direct superposition of two emulsions, the front one being slow and sensitized for green and bluish-green, with a yellow dye incorporated (…)." Wall, *The History of Three-Color Photography*, 158. See also Coote, *The Illustrated History of Colour Photography*, 139.

suggested using a coated plate with several layers of silver bromide emulsion separated by plain gelatin films. Each sensitive layer was coloured complementary to its sensitivity. However, this innovative process was theoretical and the few dyes available were not sufficient to allow its practical use.[58] Thus, it is evident that when Mannes and Godowsky started to explore the possibilities of the subtractive monopack, its theory had already been developed. However, the two photochemists experienced Eastman Kodak's relative technological backwardness in organic chemistry as a significant constraint. From 1927 on, they conceived a different strategy for the colour development to get around the problem. Unlike other methods, they decided to include the colour couplers into the liquid developer instead of each emulsion layer. Thus the wandering coupler problem would be solved, but not the issue of the wandering sensitising dye.[59] As it will be studied later in section 4.2.2., the photochemist Michele Martinez developed a different technology of *protected couplers* incorporated into the emulsion for Eastman Kodak in the 1940s.

In 1928, the chemist of the Eastman Kodak synthetic chemistry division Leslie Brooker was able to synthesise new dyes which were excellent sensitisers from Frances Hamer's research work. The problem of wandering sensitisers was almost solved. The pooling of Mannes, Godowsky and Brooker's research works eventually constituted innovation because from that stage the monopack concept could move from theory to practice. For Mees, the time to increase the scientific collaboration with Mannes and Godowsky had come.

---

[58] In 1907, Benno Homolka from Hoechst found that it was possible to form coloured images through the creation of dyes in combination with silver images. This discovery was finally patented by Rudolph Fischer with the help of his colleague H. Siegrist in 1912 with their subtractive tripack method including a "colour development". For this process three emulsions were also coated on top of one another, and in each layer chemical substances called couplers were incorporated. These couplers were supposed to provide dyes in the process of development but, such as Schinzel or Homolka, Fischer was unable to realize his process in practice. See Rudolph Fischer, "Process of making photographs in natural colors," US Patent 1,055,155, filed July 1, 1912, and issued March 4, 1913; Coote, *The Illustrated History of Colour Photography*, 134-135; Friedman, *History of Color Photography*, chapters 9 and 22.

[59] James, *A Biography-Autobiography of Charles Edward Kenneth Mees*, 166; Douglas, *The Story of Kodak*, 211.

> In 1930 I realized that the new dyes that we could now make would solve the problem of making Mannes' and Godowsky's proposed color process work. (…) So we asked Mannes and Godowsky to join us here, where they worked happily with us for ten years, and we all set to work and made the new color process work.[60]

The agreement seemed an easy one. Mees's offer was finally revealed much later by Eastman Kodak in 1989.[61] The manufacturer offered to pay a lump sum of $30,000, whose $20,000 would be used to repay the Kuhn, Loeb and Company loan, and annual salaries of $7,500 each. The film manufacturer also accepted that Mannes and Godowsky would receive royalties on all patents filed before the collaboration with Kodak.[62] The two independent researchers accepted the offer and became incorporated in the Kodak research organisation in November 1930. As the Kodak Collection archive at the British Library keeps a copy of the original agreements between Eastman Kodak and Mannes and Godowsky, I compared the above information with the formal data enclosed in this confidential document, not only to confirm the sums in play but especially to ascertain the terms of trade between the parties for this scientific collaboration. Thus, the analysis clarifies the nature of the research work that was requested from Mannes and Godowsky. It is also clear about the ramifications of ownership pertaining to potential scientific knowledge produced from the collaboration.

The original exclusive patent license agreement and an option agreement, both dated 1 November 1930, are the most critical documents for this argument. The exclusive patent license agreement is a contract in which the two inventors agreed to grant Eastman Kodak the right to produce, use and sell products and processes relating to their invention. To define this invention, the agreement provided a list of five previously granted patents of Mannes and Godowsky from 1925 to 1930 all related to colour processes. As their research work was experimental and not finalised, this set of patents was therefore used to ascertain the purpose of the agreement. Usually, the

---

[60] Mees, *An Address to the Senior Staff of the Kodak Research Laboratories*, 37.

[61] *Journey: 75 years of Kodak Research*, 50. The information was taken up later by Collins and Coote.

[62] Coote, *The Illustrated History of Colour Photography*, 139. Douglas, *The Story of Kodak*, 211.

exclusive patent license agreement is offered in return for royalties during the patent life only and unsurprisingly that was also the case for the present agreement. The contract clearly stated exactly what Eastman Kodak requested. To obtain “exclusive license, with the right to sublicense others, to make, use and sell products, apparatus and processes” Kodak agreed to pay 2,5% of the net selling price of "such motion picture film of all widths" involving the inventions and 3,5% of the net selling price of "all other such sensitized products", principally the colour photographic products.[63] These terms were very favourable to the inventors. In 1982 the royalty figures were not known but Milanowski has already pointed out that “both Mannes and Godowsky received extremely excessive royalty/contracts which paid over a million dollars per year to each man at different points in the time.”[64] Beyond financial matters, the experimental technology of Mannes and Godowsky was far from the production stage, and a paragraph of the agreement mentions that a separate contract of employment had also been established for the same period. The two inventors were therefore hired by Eastman Kodak as well and incorporated to the Rochester Research Laboratory. This incorporation was realised in two phases. From 1 November 1930 to 1 June 1931, Mannes and Godowsky worked in New York "the equivalent of four and one-half full working days per week" to develop their inventions and each received a salary at the rate of $3,500 and a flat royalty at the rate of $2,500 per year. After 1 June 1931, they started working at Kodak Park and their salary rose to $5,000 per year including the same flat royalty. The exclusive patent license agreement does not include information about the lump sum of $30,000 offered by Eastman Kodak. But it does not mean that this transaction was not made between the film manufacturer and the young

[63] Exclusive license agreement between Leopold D. Mannes and Leopold Godowsky, Jr., and Eastman Kodak Company, November 1, 1930, ref. A1736, box 153, KCA-BL. The Eastman Kodak Company representative was the vice-president Franck W. Lovejoy.

[64] Stephen R. Milanowski, “Factors Influencing the Neglect of Color Photography 1860 to 1970,” (MSc in Visual Studies diss., Massachusetts Institute of Technology, 1982), 40, 135. The author obtained this information during an interview of Ron Emerson, former curator at George Eastman House, the same year. Emerson mentioned a conversation between Louis Condax, a Kodak researcher and Godowsky probably during the 1950s about the subject.

photochemists. In fact, this lump sum was crucial for Mannes and Godowsky due to the necessity of paying back the Kuhn, Loeb loan.

As for the option agreement signed the same day of 1930, its study clarifies the parallel activities of Mannes and Godowsky in 1928. The agreement is focused in particular on the technology of natural color photography involving a “layer process”, which was disclosed in two patents and in one application for letters patent of the two inventors.[65] During the 1920s, the major competitor of Mannes’ and Godowsky’s work was the Technicolor Motion Pictures Corporation and the prolific activities of its director of research Leonard T. Troland. The option agreement reveals that Mannes and Godowsky had already entered into a legal agreement with Comstock and Wescott, Inc. and the Technicolor Motion Picture Corporation in February 1928. From this agreement they were able to acquire rights “under any patents resulting from certain applications of Leonard T. Troland, Serial Nos. 377,755, filed April 30, 1920 and 499,425, filed September 9, 1921, relating to color photography”. Comstock and Wescott, Inc. relates to the industrial research and development company formed in 1912 by the two MIT professors Herbert T. Kalmus, Daniel F. Comstock and the mechanical expert W. Burton Wescott. The three associates created the Technicolor Motion Picture Corporation in Boston two years later and the first two-colour motion picture process was released in 1916. The photochemist Edward J. Wall helped solve technical issues encountered with colour sensitising film.[66] Troland was then approached in 1918 by Comstock and Wescott, Inc. and was associated with the scientific engineering firm as an expert consultant. At the same time he also become chief engineer and then director of research in 1925 of the Technicolor Motion Picture Corporation and worked on the improvement and development of two and three-

---

[65] The first granted patent is the US Patent 1,516,824 and had been already studied earlier. The second is a patent about “Color photograph and method for producing same”, US Patent 1,659,148, filed August 4, 1923, and issued February 14, 1928. The US application “Color photography” No.531,356 raised a problem as it was filed January 24, 1922 but only issued April 9, 1935 (US Patent 1,997,493). This late date coinciding with the official release of new Kodachrome indicates that the corresponding patent was fundamental to secure the new process.

[66] Coote, *The Illustrated History of Colour Photography*, 116.

colour processes.[67] In this position he undertook an important patent work to secure his inventions in the field of both imbibition processes and monopack layered processes. In the unpublished paragraph above one understands that to further develop their own processes, Mannes and Godowsky could not avoid using some of Troland's technology. Even if it concerns only two patent applications, it represented a potential threat to the further development of Mannes' and Godowsky's processes. The option agreement was thus made in order for the *inventors* to confirm that "they have right, title and power to convey the rights herein conveyed and intended to be conveyed." But as the validation of an application to a granted patent was subject to the technical study of an independent examiner of a national patent office, Eastman Kodak viewed the three eventual options for the future : no patent would be finally issued from Troland applications, one patent would result from one application or two patents would be granted from both applications. According to the result, Eastman Kodak agreed to do the necessary actions to secure any application or patent of the two inventors through the payment of licenses or the payment of foreign patents provided that they took care of their patented inventions in the way a patentee should normally act. It means in particular that Mannes and Godowsky were supposed to inititate a possible prosecution following any interferences involving their precedent applications or patents.[68]

In reality, the two Troland applications created a major problem to both Eastman Kodak and the young photochemists. The application No. 499,425 by the prolific Troland, that was in part a continuation of the prior application No. 377,755, was finally accepted ten years later and a patent granted in June 1931. Troland had incorporated the impressive number of 234 claims into his application. According to Friedman, Mannes and Godowsky had suggested one equivalent formation of the

---

[67] Bryan Dye, Caryn Hannan, and Jennifer L. Herman, *Connecticut Biographical Dictionary* (Hamburg, MI.: State History Publications, 2008), 526; J.G. Beebe-Center, "Leonard Thompson Troland : 1889-1932," *The American Journal of Psychology* 44 (1932): 817-820.

[68] To this end, the two photochemists had to provide all evidence, documents, drawings or applications necessary for the possible prosecution. They also were supposed to pay the renewal fees referring to their patents, as it will be clarified at the end of section 4.2.2. with the Martinez case.

monopack in their patent application work during the 1920s but due to the anteriority of Troland's application, he was given priority to later work in the field.[69] Of course, Troland had never stopped working during this decade and had made some additional findings.[70] In September 1931 he sent an application for reissuing the same patent and increased the number of claims by five. On 5 April 1932, Troland signed the final patent document. On 27 May 1932, he died in a tragic accident while hiking but, as the application had been signed and processed, the Comstock and Wescott, Inc. was finally granted the well-known patent reissue 18,680 on 6 December 1932 (see Figure 7).[71]

[69] Friedman, *History of Color Photography*, 96-97.

[70] However, most of Troland's research work on layered process was already completed ten years earlier when he signed his application No. 377,755 on 7 September 1921 with the 234 claims. Concerning the industrial research undertaken by the Technicolor Corporation involving imbibition processes during the 1920s, see Ulrich Ruedel, "The Technicolor Notebooks at the George Eastman House," *Film History* 21, no. 1 (2009): 47-60.

[71] Leonard T. Troland, "Color photography," US Patent Reissue 18,680, application for reissue filed September 24, 1931, and reissued December 6, 1932. The original patent was "Color photography," US Patent 1,808,584, filed September 9, 1921, and issued June 2, 1931. For Troland's life and death, see Dye, Hannan, and Herman, *Connecticut biographical dictionary*, 525-527.

18,680 21

230. The method of producing a color photograph which comprises forming latent complemental images in different strata of emulsion on the same side of a film while restraining interpenetration of the images by an intermediate stratum, developing the images and coloring them different colors.

231. The method of producing a color photograph which comprises forming latent complemental images in different coatings of emulsion on the same side of a film while restraining interpenetration of the images by an intermediate coating, developing the images in the same developing operation and coloring them different colors.

232. A photographic film for making color pictures comprising a base having on the same side a plurality of coatings including one coating which is sensitive to a color to which a second coating on the entrant side of said first coating is substantially insensitive and the second coating being sufficiently absorptive of other colors substantially to restrict the exposure of said first coating to light of said first color.

233. A photographic film for making color pictures which comprises a base having on the same side a plurality of coatings including one coating which is sensitive to a reddish color to which a second coating on the entrant side of said first coating is substantially insensitive and the second coating being sufficiently absorptive of colder colors to cause said first coating to record an image of the reddish color aspect of an object field to which the film is exposed from said entrant side.

234. A photographic film comprising a support and two coatings on the same side thereof, one coating being sensitive to light of a color to which the other coating is substantially insensitive and the latter coating constituting a filter.

235. A photographic film comprising a support and two coatings on the same side of the support, one coating being sensitive to light of a color to which the other coating is substantially insensitive and the latter coating constituting a filter.

236. A photographic film comprising a support and two coatings on the same side thereof, one coating being sensitive to light of a color to which the other coating is substantially insensitive and the latter coating constituting a filter for absorbing light of complementary color.

237. A support having a photographic emulsion sensitive to a portion of the spectrum, a second support having a photographic emulsion sensitive to another portion of the spectrum, said emulsions being placed in close relation between the two supports and one emulsion having fast to its surface a coating of substantial thickness containing coloring matter which absorbs a part of the spectrum.

238. A support having a photographic emulsion sensitive to a portion of the spectrum, a second support having a photographic emulsion sensitive to another portion of the spectrum, said emulsions being placed in close relation between the two supports and one emulsion having on its surface a coating of substantial thickness containing coloring matter which absorbs light to which the emulsion preceding this coating is sensitive.

239. A photographic film for making color pictures comprising a base having on the same side a plurality of coatings, including one of substantial thickness which is permeable to developer and which absorbs substantially completely a color to which another coating on the entrant side of said first coating is sensitive but which transmits other light.

Signed by me at Los Angeles, California, this 5th day of April, 1932.

LEONARD T. TROLAND.

Figure 7. Last page of Troland's US Patent Reissue 18,680 mentioning the last claims from 230 to 239.

Friedman pointed out that in only a few general claims could a connection between the structure of the Kodachrome and the structure of a Troland monopack be traced. According to Coote, the reissue 18,680 aimed more at "a single emulsion layer that had been differentially sensitised by controlled penetration of sensitising dyes rather than a material requiring the superimposition of two or more emulsion coatings."[72] However, due to Troland's monumental patent, Eastman Kodak had no alternative and was forced to purchase a license from Technicolor Motion Picture Corporation. This license also contained a specific condition : should Kodak market a motion picture film in colour in 35mm size or wider, Technicolor had a limited period during which it would become the exclusive processor of such film. The initial license opened a period of agreements between Technicolor and Kodak that only came to an end at the beginning of the 1950s.[73]

Finally the third and last legal document in the Kodak Collection archive is a later supplemental agreement between Mannes, Godowsky and Eastman Kodak made in June 1934 and that took into account the existence of Troland's patent reissue 18,680. It confirmed the terms of the option agreement of 1930 and links Troland's former applications to the resulting reissued patent. It also clarified that if the license acquired by Kodak became non-exclusive, the company would agree to grant to "any designee of the Inventors" a non-exclusive license under the Troland reissue patent and any other patents "relating to color processes involving a single photographic element having upon the same side thereof two differentially color sensitive strata."[74] Therefore this agreement clearly referred to a two-colour film and it tallies with the known narrative about the Kodachrome process.[75]

Finally employed by Eastman Kodak, Mannes and Godowsky probably had to adapt their research methods to the collaborative work with the Kodak Research

---

[72] Friedman, *History of Color* Photography, 119; Coote, *The Illustrated History of Colour Photography*, 137.

[73] "In considerable measure the government viewed Eastman as the victim of Technicolor demands based on the Troland patent rights, including demand that Eastman not offer a monopack film. It is obvious that Eastman preferred the license to litigation." George E. Frost and S. Chesterfield Oppenheim, "A Study of the Professional Color Motion Picture Antitrust Decrees and their Effects," *The patent, Trademark, and Copyright Journal of Research and* Education 4, no. 1 (1960): 2, 4, 7.

[74] Supplemental agreement between Leopold D. Mannes and Leopold Godowsky, Jr., and Eastman Kodak Company, June 25, 1934, ref. A1736, box 153, KCA-BL, 2.

[75] As it is mentioned in the next paragraph, Mannes and Godowsky developed a two-colour cine film in 1934, just before the development of three-colour Kodachrome process.

Laboratory's staff. However this period is not well documented and it is difficult to ascertain the research work done and the practical terms of the collaboration. It is also not clear whether or not the Harrow Research Laboratory and the Kodak-Pathé Laboratory to a lesser extent played a partial role in the initial development of the Kodachrome. In 1955 Mees remembered that "Mannes and Godowsky did a great deal of the work, but a great deal of it was done by our own people and particularly by the Emulsion Research Laboratory, which had all the responsibility for the sensitizing, coating, and so on."[76] From 1930 on, the two inventors focused on processes involving mono-layer and mixed grain coatings to avoid the use of a multi-layer coating and its potential problems.[77] As Mannes and Godowsky had a three-year contract terminating at the end of 1933, and as the results of their research were not visible enough, Mees had to insist with some members of Kodak Management that they should be given another chance for one more year. They finally developed a concrete two-colour cine film in 1934, "working practically around the clock, day after day."[78] As the production of the new film was delayed due to some complications, Mannes and Godowsky were able to perform additional research and modified the two-colour into a three-colour process. Some evidence of this research period has been found in a correspondence folder between the Patents and Trade Marks Department at Kodak Limited and the engineer Busch of Kodak A.G. at Cöpenick. The subject was the processing of the application for the two-colour process of Mannes and Godowsky in Germany. It appeared that the process was never patented in the United States, however it was granted a British patent in April 1935.[79] To take equivalent action in Germany, in February 1935 the officer of Kodak Limited requested a sample of the two-colour

---

[76] Mees, *An Address to the Senior Staff of the Kodak Research Laboratories*, 37.

[77] Coote, *The Illustrated History of Colour Photography*, 140.

[78] James, *A Biography-Autobiography of Charles Edward Kenneth Mees*, 166-167.

[79] Kodak Limited, "Improvements in colour photography," British Patent 427,516, filed September 21, 1933 (in United Kingdom), and issued April 23, 1935. Kodak Limited was designated as "assignees" of Mannes and Godowsky in the introduction.

process from his American counterpart at Rochester. The answer was partially negative.

> Mannes & Godowsky do not have any film made in the manner described for making the negative one frame having the blue records and the next frame with red and blue-green records. As they are extremely busy now preparing the new Kodachrome method for the market (…), they would have to take time from their regular work (which is extremely pressing) to furnish such a sample and, in view of its present lack of commercial interest, we believe it is not worth the trouble.[80]

The American office finally sent another sample of two-layer film but using a different method. The pressure put on Mannes and Godowsky bore fruit. Finally the new Kodachrome process in its 16mm version for colour movie was announced in April 1935. The first technical description of the process was published in the *Journal of the Society of Motion Picture Engineers* in July 1935.[81] As the film consisted of five layers of emulsion and gelatine it was nicknamed the "quintuplet" film by *Science* magazine.[82] Three layers were devoted to the recording of the blue, green and red spectrums. Between each sensitive layer a thin layer of clear gelatin was coated, used as a margin of safety during the development process and the use of the controlled diffusion bleach. It was thus possible to bleach two layers and not the bottom layer. But the first development process was very long and involved in all 28 steps.[83] As it will be demonstrated in the next sections, the 1935 Kodachrome process was not fully

[80] Perrins to Branch, "Re: Mannes-Godowsky German Appn. K.131598," February 20, 1935, ref. A1729, box 152, KCA-BL. The German patent office granted Kodak Limited the patent DE661678 related to the two-colour process on 14 April 1938 under the title "Verfahren zur Herstellung eines Dreifarbennegativs unter Verwendung eines an sich bekannten Zwischenfilms".

[81] Leopold Mannes and Leopold Godowsky, Jr, "The Kodachrome Process for Amateur Cinematography in Natural Colours," *Journal of the Society of Motion Picture Engineers* 25, no. 1 (July 1935): 65-68.

[82] "The resulting quintuplet "sandwich" of gelatine and light-sensitive emulsions separates the light rays entering the camera into the three primary colors, red, green and blue-violet, because of the presence of three layers which absorb these colors only. Under the three layers is the transparent supporting base on the back of which is the customary layer, known as antihalation backing, which prevents any back scattering of light that might overexpose the film." "Home Color Movies May Be Made without Camera Filters," *The Science News-Letter* 27, no. 732 (April 20, 1935): 246.

[83] Coote, *The Illustrated History of Colour Photography*, 142; Coe, *Colour Photography: the First Hundred Years, 1840-1940*, 128.

accomplished and the Research Laboratory and the production facilities of Kodak Park at Rochester managed its great complexity only with difficulty.

We have seen so far how across-the-board and also opportunistic industrial research was conduct by Eastman Kodak in search of a viable colour process. What we do not know yet is how Eastman Kodak structured its research around colour photography following the introduction of three-colour Kodachrome in 1935 and how the scientific knowledge was practically built up through the patent system within the framework of collaborations with independent photochemists. In the next sections, I will first clarify the development of colour research from 1935 in the Kodak Research Laboratory at Rochester. I will then analyse the drafting process of patent applications between two European independent inventors and Kodak Limited to demonstrate to what extent this unpublished primary source can clarify the process of fundamental research.

4.2. Patent strategies for colour photography technologies

4.2.1 In-house innovation to tackle colour problems

When Mees pointed out in 1955 that an important part of the development work for the new Kodachrome process had been realised by the Eastman Kodak technicians and photochemists at Rochester, it was perfectly true.[84] Kodak Park anticipated the production of Kodachrome film before the official release of the new product. The Engineering and Maintenance Department had to build new machines to produce and process the coming batches of Kodachrome film. A new building was erected especially for the production of large quantities of the necessary chemicals by the Synthetic Organic Chemicals Department.[85] However, the correct development processing for the new Kodachrome film was not at all ready in April 1935. This situation was critical. It was possible to expose some 16mm Kodachrome reels but it was still impossible to get a neutral colorimetric rendering of the developed slides. Mees had to organize and supervise an exceptional program in extreme circumstances; the theoretical technology of Kodachrome had to confront the practical side of the laboratory.

In one of his notebooks, the researcher Phillips detailed this critical period of intense research for a satisfactory development process.[86] Phillips, a member of the Harrow Research Laboratory, was already visiting and working at Rochester in November 1934. He had probably been requisitioned to help the American scientists and assist Mannes and Godowsky. In April and May 1935, he was testifying to the intensive work undertaken in the Research Laboratories. The teams were working nearly all day long with infrequent breaks in a desperate quest for better Kodachrome processing. On 10 May, Phillips noted that "a man (Pringle) was sent to the Medical Dept having been made sick with fumes from acetone-alcohol mixture while cleaning racks from the b-g

---

[84] Mees, *An Address to the Senior Staff of the Kodak Research Laboratories*, 37.

[85] "The Romance of Kodachrome," *The Photographic Journal* 125, no.8 (August 1985): 367.

[86] The research work of Franck B. Phillips has already been introduced in the precedent chapter in section 3.3.3 through the study of his notebooks.

developer."[87] One day, Phillips reported that the general tendency of the experimental work was the development of Kodachrome with green neutrals. The photochemists tested several solutions to reduce the colour cast but, as the writer noted, the "results were very erratic."[88] On 16 May the situation had evolved towards the blue colour, and the depletion of the chemical solutions was suspected. The team decided to use additional replenishers and to improve the forming of the yellow dye into the layer to counterbalance the blue colour cast.

> Godowsky showed that less carbonate in the yellow increased the [deposit] of yellow dye & this was agreed. The carbonate in the yellow was reduced by 50%.[89]

Phillips added as well that on Mannes' initiative the stop bath after the magenta bleach was changed as it was polluted by this bleach with blue-green dye. However, despite many additions "made all night" with several developer and bleach solutions the results remained poor. There was always a blue-green colour cast in excess. Four days later, the situation was better and the developed Kodachrome films at last reached a correct neutrality in the grey. The magenta bleach had been acidified with hydrochloric acid to reduce the residual blue-green dye. This acidification was criticised by Godowsky but Phillips disagreed in his notebook.

> Godowsky pointed out that we must avoid heavily acidified film entering the carbonate stop bath on account of CO2 bubble formation. However this was never encountered.[90]

For Phillips, the developing standards had been fixed for the high densities of the characteristic curve and the researchers could focus on other chemical issues.

This evidence of research teamwork illustrates well the complexity of the new Kodachrome process. However this tendency toward technological complexity was from that time the rule and increased up to the Second World War and beyond. The

[87] Franck B. Phillips, "1934/35", personal notebook, ref. A1270, box 96, KCA-BL, 71. The b-g developer means the solution of blue-green (or cyan) colour developer.

[88] Ibid., Tuesday May 14, 1935, 75.

[89] Ibid., 77.

[90] Ibid., 79.

era of the master emulsion makers was over and an independent photochemist or an industrial researcher was no longer able to conceive a complete colour process on his own from the theory to the adjustment of layers and the selection of sensitising dyes and chemicals. With multilayered emulsion of monopacks the competition was also tough. In 1936, the I.G. Farbenindustrie A.G. at Wolfen in Germany managed to develop a technology of anchoring colour couplers to individual emulsion layers. This way a process of selective colour development by controlled diffusion used by Mannes and Godowsky was no longer necessary. The colour couplers could be incorporated into the monopack film, and not during the developing process of the exposed film as suggested by Rudolf Fischer in 1912. The Agfa patent clarified that the diffusion of the dyestuff components could be stopped "by using as the component in the manufacture of the photographic silver halide emulsion a dyestuff compound which has in the molecule an aliphatic carbon chain of more than 5 carbon atoms."[91] As the molecule had a long-chain structure, its movement was almost entirely blocked. The Agfa Research Laboratories at Wolfen undertook a long-term project to synthesise possible dye-forming couplers and experimental colour emulsions. Besides the laboratory activity an extensive patent work was undertaken to secure every colour technology produced in the Research Laboratories.[92] Finally, after a satisfying selection of couplers for each of the three layers, Agfa introduced in October 1936 the Agfacolor Neu film including a multi-layer reversal technology.

For Eastman Kodak, the elegant solution of the Agfacolor Neu was a technological and economical threat even if the colour rendering of the Kodachrome film was slightly better. The technology used by Agfa was far simpler and rendered the 28 steps necessary to the processing of Kodachrome films obsolete. Another issue was the

---

[91] Gustav Wilmanns et al., "Manufacture of photographic silver halide emulsions," US Patent 2,186,849(A), filed August 5, 1936 (United States of America), filed August 7, 1935 (Germany), and issued January 9, 1940. Mentionned by Coote, *The Illustrated History of Colour Photography*, 152. The author did not provide the reference of the patent but a textual research in patent databases online provided the American patent reference.

[92] Coote indicated that in 1935 alone, Agfa filed 450 patents relating to colour photography. Coote, *The Illustrated History of Colour Photography*, 153.

relative instability of the chemical dyes used in the layers of Kodachrome.[93] Kodak's first action was to develop a simpler processing for the Kodachrome films. It was not before 1938 that they released this new processing. The controlled diffusion bleach was replaced with selective re-exposure for each colour-development step. In this way the total number of steps was reduced to 18.[94] As new sensitisers were available that would not wander in adjacent layers, it was now possible to selectively re-expose the blue and red sensitive layers with blue and red light and to treat them by yellow and cyan color developer. As for the third and last green sensitive layer, it was treated with a fogging agent to make it developable again.[95]

In James' memoires, we learn that the enigmatic Lot Spaulding Wilder, a researcher of the Rochester Laboratory, was the inventor of the Kodachrome processing simplification.[96] After the release of the Kodachrome monopack, Mees decided to create an experimental department for colour photography including Wilder, Ralph M. Evans and Wesley T. Hanson. Mannes and Godowsky also played an important role for scientific and patent work during the period up to the outbreak of the Second World War. James quoted one phrase of Mannes stressing Wilder's research skills.

> Lot Wilder, Mannes said, "was one of the most gifted inventors I've ever known, and also one of the finest men." He played a major role in simplifying Kodachrome processing, which was reduced from 28 to 18 steps.[97]

Wilder's research work is difficult to identify in the British archive. In 1936 he was apparently not working on Kodachrome processing yet the Communication n°605 of the Kodak Research Laboratories suggests he jointly worked with Capstaff and Miller

[93] Brian Coe, *Colour Photography: The First Hundred Years, 1840-1940*, 128.

[94] *Journey: 75 years of Kodak Research*, 52.

[95] Coote, *The Illustrated History of Colour Photography*, 145-147. See also Annette Roulier, "A Short History and Concepts of Color Photography," *Imaging and Media Lab*, Swiss Virtual Campus, 2008, http://www.abmt.unibas.ch/SKRIPTEN/ScriptColor/color_photography_history.pdf , 23.

[96] Surprisingly Friedman remained entirely silent about Wilder's research work in his *History of Color Photography* published in 1944.

[97] James, *A Biography-Autobiography of Charles Edward Kenneth Mees*, 169.

on the projection of lenticular colour films, such as the first Kodacolor process.[98] Fortunately, in his last notebook Phillips reported a meeting with Wilder in the laboratory on 4 February 1938. The discussion was naturally about the new Kodachrome processing, noted by Phillips as the selective reversal process. If the processing steps of February 1938 are compared with the later literature about the new 1938 Kodachrome processing, it is clear that Wilder was on the right track and that he had almost developed the final processing that would be used from the end of that same year. As Phillips summarized, the new process "depends on exposing each layer after negative development, to fogging light of the colour to which that layer was sensitized, & then developing the layer in a complementary colour coupling developer."[99] After the negative development and the removal of the backing, the film was exposed through the base with a red light and re-developed in a cyan developer. It was then exposed through the base with a white light and re-developed in a magenta developer to treat the green sensitive middle layer. The fourth step was an exposure through the top of the film with white or blue light and another development in a yellow developer. The silver present in all three layers was removed with a bleach treatment by a Farmer's reducer and the film was fixed and washed. Phillips also drew the structure of the Kodachrome film in his notebook. He reported the details discussed with Wilder as the sequence was not entirely satisfactory. The application of an UV coat was not successful as it interfered with the gelatine. The nature of the yellow filter between the blue sensitive and green sensitive layer had to be adjusted to be fully removed during the fixing. A "dry over-coat" layer, present into the initial Kodachrome film between the green sensitive layer and the yellow filter layer had been eliminated. To sum up, Wilder and Phillips stated that the first exposure in red was correct but that their indecision about the spectral quality of the two last exposures generated some errors on the final colour rendering of the film. "Wilder

[98] The communication was presented during a meeting at Rochester in the autumn 1936 and a copy sent to the *Journal of the Society of Motion Picture Engineers*. See Capstaff, Miller and Wilder, "The Projection of Lenticular Color-Films," *Journal of the Society of Motion Picture Engineers* 28, no. 2 (February 1937): 123-135.

[99] Franck B. Phillips, "1938", personal notebook, ref. A1270, box 96, KCA-BL, 1.

agrees [and] points out that in parts where the effect comes in only the red light is theoretically absorbed by the varying b-g dye & this does not put the green sensitive layer anyway."[100] It is important to note that Wilder's processing was secured in an application filed jointly with Mannes and Godowsky on 19 January 1938 in the United States, and in Canada on 24 March of the same year. The equivalent patents are identical and involved two exposures of the monopack with white light after the initial exposure in red, such as in Phillips' notebook.[101] Wilder, hired by Eastman Kodak at an unknown date, possessed an academic background in mathematics. It is possible that his theoretical abilities necessary for the study of mathematical concepts was engaged in the development of the new Kodachrome processing. At this stage, the structure of the processing could be defined theoretically, such as the solving of a matrix made of three sensitive layers. The challenge was to simplify the initial matrix and to get a red dye in the film from a red photographed object and the like. Wilder was finally able to find the correct spectral nature of the two lights for green and blue sensitive layers.

[100] Ibid., 3. "B-g" means blue-green or cyan.

[101] Leopold D. Mannes, Leopold Godowsky, Jr., and Lot S. Wilder, "Reversal process of color photography," US Patent 2,252,718, filed January 19, 1938, and issued August 19, 1941. Same authors, "Colour photography," Canadian patent 415,999, drawings certified March 24, 1938, and issued October 26, 1943. It is difficult to clarify whether Mannes and Godowsky really took part in Wilder's research work or if they were granted the co-authorship of the invention due to their long-term research about the 1935 Kodachrome process.

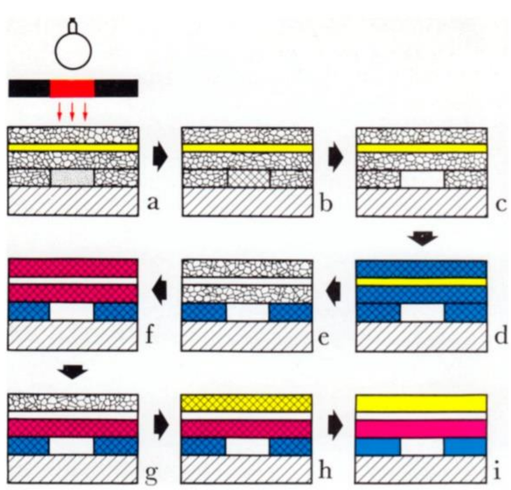


Fig. 14. Old Kodachrome processing: (a) exposure from red patch; (b) black-and-white negative development; (c) first bleach to remove metallic silver; (d) cyan development using residual silver halide in all layers; (e) bleach to remove dye and regenerate silver halide in top two layers; (f) magenta development using regenerated silver halide; (g) bleach to remove dye and regenerate silver halide in top layer; (h) yellow development using regenerated silver halide; (i) final bleach and fix to remove silver throughout.

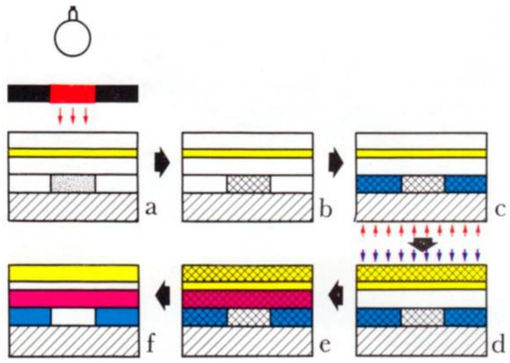


Fig. 15. New Kodachrome processing: (a) exposure from red patch; (b) black-and-white development; (c) red exposure (through base) and cyan development using newly exposed silver halide; (d) blue exposure (from top) and yellow development using newly exposed silver halide; (e) fogging magenta development using residual silver halide (which is left only in green-sensitive layer); (f) silver and yellow filter layer removed by bleach and fix.

Figure 8. First Kodachrome processing (1935-1938) compared with new Kodachrome processing (from 1938).[102]

The final process was described by Friedman in 1944. The photo-historian deduced the principle of the processing from the study of a published communication of the Kodak research Laboratories by Mees in 1942.[103] The new processing was equivalent up to the exposition with red light and the development in cyan developer (see Figure 8). The next step was to expose from the top of the film the blue sensitive layer with a blue light, and to develop with a yellow-coupler developer. Then the middle layer

[102] Arnold Weissberger, "A Chemist's View of Color Photography: How Does Color Photography Work? What is Required of the Light-Sensitive Material? What is the Origin of the Image Dyes?" *American Scientist* 58, no. 6 (1970): 651. Dr. Weissberger was an organic chemist at Eastman Kodak and was Associate Head of the Color Photography Division of the Kodak Research Laboratories at Rochester when he retired in 1964. Weissberger's description of new Kodachrome processing corresponds to the description made by Friedman in 1944. See next footnotes below.

[103] Kenneth Mees, "Direct Processes for Making Photographic Prints in Color", *Journal of the Franklin Institute* 233, no. 1 (January 1942): 41-50. This paper corresponds to the Communication no. 832 from the Kodak Research Laboratories.

magenta sensitive was exposed to white light or treated by a fogging agent such as methylene blue or thiourea. This layer was developed with a magenta-coupler developer and the rest of the processing was similar to Wilder's solution of February 1938.[104] The move from theory to production was unsurprisingly tough, as confirmed by Mees.

> This process offered very considerable difficulties when it was first attempted but, in view of its advantages, they were overcome, and it is the method by which the Kodachrome film is now processed.[105]

Wilder continued working on the improvement of layer technologies applied to Kodachrome at least up to 1945. In 1941, he filed another application with Mannes and Godowsky about a new technology of integral mask.[106] Between the yellow filter thin layer and the green-sensitive layer, the researchers added a slow blue-sensitive layer that was converted during processing into a mask to obtain colour correction. This technology was released to compensate for the imperfect nature of chemical dyes used into the emulsions and to provide in particular a better colour neutrality for the reproduction of colour film.[107] Furthermore, three patents have been identified with Wilder as the only inventor. In two of them, the author showed his profound knowledge of the multilayer technology used in monopack films. The US patent 2,275,710 introduced a technology to combine sound and picture film, with the addition of an infra-red sensitive, yellow dyed layer between the blue and green

[104] "The newer method was to utilize the residual color sensitivity of the layers after they had been exposed and developed, to effect a layerwise separation of the complemental images." Friedman, *History of Color* Photography, 122. In her digital publication, Roulier reversed the position of the expositions and colour-coupler developments of the red and blue sensitive layers. See Roulier, "A Short History and Concepts of Color Photography," 23. However, the correct processing seems to be the one as outlined by Mees, Friedman and Coote.

[105] Kenneth Mees, "Direct Processes for Making Photographic Prints in Color," *Journal of the Society of Motion Picture Engineers* 42, no. 4 (April 1944): 234.

[106] Mannes ceased his collaboration with Eastman Kodak in 1939. The same year, Godowsky left the Kodak Research Laboratory but still worked on colour photography as a consultant in a small personal laboratory in Westport, Connecticut, nicknamed "Kodak Park Westport". See *Journey: 75 years of Kodak Research*, 54.

[107] Leopold D. Mannes, Leopold Godowsky, Jr., and Lot S. Wilder, "Integral Mask for multicolor film," US Patent 2,258,187, filed May 15, 1941, and issued October 7, 1941.

sensitive layers. As Wilder clarified in his specification, his solution was the improvement of the gold toning process suggested by Mannes and Godowsky in 1939, producing a film "not of highest quality" due to unwanted density in the sound track area.[108] Later in 1943, Wilder filed an application for a complex monopack colour film involving five colour-sensitive emulsions, a yellow filter layer plus the film base. The two additional layers were a green-sensitive emulsion with magenta coupler and a red-sensitive emulsion with cyan coupler. This feature of adding a non-diffusing coupler into an emulsion was very innovative for Eastman Kodak during this period, and only used by Agfa in the Agfacolor Neu film. The purpose of the invention was "to provide a multi-layer film containing couplers, which produces maximum dyes densities." For this work Wilder used the previous American patent 2,306,410 by Karl Schinzel that I discuss later in this chapter in section 4.2.3.[109] This very important shift towards the incorporation of colour couplers in the monopack film ought not to evade the collaborative work of Wilder with other researchers at Eastman Kodak. Apart from the joint work with Mannes and Godowsky, Wilder produced patents with Paul W. Vittum, Scheuring S. Fierke, Deane S. Thomas, Edwin E. Jelley, Arnold Weissberger and Kent C. Brannock.[110]

[108] Lot S. Wilder, "Combined sound and picture film," US Patent 2,275,710, filed November 9, 1940, and issued March 10, 1942. Does the origin of the invention reveal a spirit of competition between Wilder and Mannes and Godowsky? One can point out that it was a great chance for a young researcher such as Wilder to tackle the two famous inventors.

[109] Lot S. Wilder, "Color photography," US Patent 2,376,217, filed April 6, 1943, and issued May 15, 1945.

[110] It is not possible to study the complete set of patents within the framework of my research. See Wilder's collaborative patent literature in US 2,266,456, US 2,292,306, GB 557,750, GB 557,802, US 2,322,005, CA 418,533, CA 419,015, US 2,401,713, US 2,403,722, US 2,435,616 and US 2,507,183. See also Kelley Wilder, "Kodak and Photographic Research," in *American Photography: Local and Global Contexts*, ed. Bettina Gockel (Berlin: Akademie Verlag, 2012), 264. Lot Wilder died in 1951 and his sudden death could explain why this skilled researcher remained in the shadows of the Kodak pantheon. I would like to thank Kelley Wilder and her father for this biographical data about Wilder's death.

4.2.2. "Win-win" scientific collaboration with the independent photochemist Martinez

One understands from the study of this research period in colour photography that the most important challenge for the Kodak researchers was to invent a process to prevent the couplers from wandering into the adjacent layers of the monopack films. It was necessary that this innovation not interfere with the German technology of long-chain molecules, which was protected by dozens of patents. Although Wilder used an approximate solution as has been seen above, he is not the author of the solution secured by Kodak Limited and used later for the new Kodacolor negative film. As Friedman wrote, "Kodacolor evidently is based upon the disclosures of M. Martinez". Martinez's American patent 2,269,158 details a solution in which the coupler was dissolved in a resin, and the result was dispersed into the emulsion. Martinez also suggested dispersing the silver halide grain in the resin as well in a later American patent 2,284,877.[111] This one brief sentence was all Friedman had to say about Martinez's case, and the photochemist has been given the same treatment by other historians of colour photography, if he was treated at all.[112] From Kodak's point of view, this technology of "protected couplers" had been progressively developed by in-house researchers such as Vittum, Weissberger or Evans. Martinez was not mentioned in 1989 except for the remark that from his initial research an early Kodacolor process was released in 1941 but with poor colour rendering and stability.[113] Coote's *History* gives more information about this independent chemist Dr. Michele Martinez, an Italian living in the United Kingdom during the Interwar period. First of all, two of Martinez's patents lay behind the development of the Vivex process of colour printing. The company Colour Photographs Limited was formed in 1928 to purchase the British

---

[111] Friedman, *History of Color Photography*, 123. Martinez is also briefly mentioned p. 392.

[112] See for instance Weissberger, "A Chemist's View of Color Photography: How Does Color Photography Work?" 656. The author did not mention Martinez's name concerning the technology of dissolution of a coupler in a resin binder. However, a concise mention of the research work of the *free-lance inventor* Martinez was found in Gallafent, "The Direction of Photographic Research," 118.

[113] *Journey: 75 years of Kodak Research*, 57-58.

and foreign rights in Martinez's process as described in his patents.[114] Coote also mentions that a decade later, in 1939, it was Vittum and Jelley who discovered a technique of mixing colour couplers with "oil formers" to fix them in the emulsion. But he also clarified that Martinez had already received a patent in 1937 for the incorporation of a colour coupler in a resinous binder. Coote also added an important piece of historical information.

> In 1940, while he was in an internment camp of the Isle of Man, Martinez was granted another patent for a mixed grain monolayer colour film, and Kodak must have considered that because the proposed procedures were sufficiently close to what they expected to do, they should obtains rights to the Martinez patents.[115]

The Patents and Trade Marks Department of Kodak Limited together with the Harrow Research Laboratory carried out long-term collaborative work with Martinez to file several patent applications and to draw up some exclusive license agreements. This activity was necessary to be able to use an innovative technology developed by an independent researcher like Martinez in exchange for royalties and to add it to Eastman Kodak's patent folders and scientific assets. The terms of scientific collaboration followed the "ally" model recently suggested by Hintz, as mentioned in section 1.2.5.2. This model stipulates that independent inventors develop and license their patent to firms on a royalty basis in maintaining a bilateral flow of scientific information between the two parties.[116] As the Kodak Collection archive holds some important correspondence folders about Martinez, this is an unique opportunity to study the methodology used by the Kodak representatives from the initial contact with Martinez in the 1920s in England to the patent's expiration after the Second World War. It shows how inventions or *scientific facts* produced in a personal laboratory were converted into the official jargon of patents by which they became real for the

---

[114] Coote, *The Illustrated History of Colour Photography*, 78. The author did not provide the references of the patents, but it appears that they are GB 280,053, "Improvements in colour photography," complete accepted November 11, 1927, and GB 280,252, "Improvements in in the manufacture of photographic surfaces," complete accepted November 17, 1927. In 1928, Martinez became a member of the Royal Photographic Society of Great Britain and used the first name *Michael*.

[115] Coote, *The Illustrated History of Colour Photography*, 157.

[116] Hintz, "The Post-Heroic Generation," 739-741.

scientific community. I have already mentioned at the end of section 4.1.4. that the invention, characterised by a technical or scientific fact, was hidden in the patent's jargon and in its claims. A large part of the patent can explain these facts and makes them travel outside the industrial research laboratory. It is worth adding that in Laet's view, as clarified in section 1.2.5.2, the patent is also a vehicle, a carrier of technical and scientific fact that can take an active part in the transfer of knowledge. This concept can be juxtaposed with Morgan's view about the notion of facts, their existence and circulation. I argue that the patent used by Martinez as a tool to identify and confirm the nature of scientific facts he found through experimentation can be compared with Morgan's "good companion" necessary for a scientific fact to travel well and with integrity.[117] The patent is not a part of the scientific fact but this fact is embedded into the patent which acts as a protective "companion" and enables the scientific fact to travel through scientific communities and industrial competition.[118] It is now possible with Martinez's case study to clarify the real substance of an innovation connected to a scientific fact through the study of the drafting of a patent application, in the framework of a scientific collaboration with an independent photochemist.

The first abundant folder of Martinez points out his inventive nature during the 1920s in England. It confirms that when Martinez released the technology of couplers incorporated in resin in 1937, he possessed the profile of a prolific independent inventor. The first document linking him to Kodak Limited is a non-disclosure agreement dated back to 1924, which entailed neither scientific collaboration nor bilateral exchange of knowledge. Martinez had filed an application in 1923 for a colour photographic process and Kodak requested "the sole right to purchase all or any of the rights under the patents enumerated in the Schedule", which enumerated the

---

[117] Peter Howlett and Mary S. Morgan, *How Well Do Facts Travel? The Dissemination of Reliable Knowledge* (Cambridge: Cambridge University Press, 2010), 26-27.

[118] The protective nature of the patent is therefore similar to Morgan's metaphor about technology: "[...] we can understand technologies as embedding facts, much as ancient pottery jars carry facts about the nature of the goods stored within them, be it wine or oil." Ibid., 19.

applications filed by the inventor in England, the United States, Germany, France and Switzerland. He was also requested to provide any and all improvements in the process which he may have made up to the granting of the patent. The agreement was made in exchange for a lump sum of £250 and it was the opportunity for the manufacturer to avoid having Martinez disclose or sell his technology to a competitor.[119] It was a real possibility that Martinez might to deal with other manufacturers of the photographic industry and this is what occurred several years later. A second agreement indicates that Eastman Kodak "did obtain from Martinez an option to acquire a full and complete assignment of certain inventions patents and applications" in 1930 in exchange of a certain sum.[120] But some other agreements in the folder demonstrate that before being granted his well-known British patent 505,834 in 1939 about couplers and resin, Martinez approached the company Elliott & Sons Limited and offered an option for six months from 20 December 1937 on processes that could be developed from the potential patent.[121] The agreement also clarified that this option was given on the consideration of the payment of a lump sum of £300 and that Elliott & Sons[122] agreed to pay Martinez "a royalty commission on sales of five per centum calculated on the retail selling prices of all articles concerned with a guaranteed minimum sum of £500 per annum."[123] After the complete specification was accepted and the British patent 505,834 granted, the situation with the British competitor was still tense as Elliott & Sons purported to have exercised its

[119] Agreement between M. Martinez and Kodak Ltd., May 1, 1924, ref. A1737, box 153, KCA-BL, 1. The following patent was granted in England the same year: "Direct colour photography," British patent 222,523, filed April 5, 1923, and issued October 6, 1924. The patent involved a complicated printing process in colour from the theoretical side with 16 claims.

[120] Option Agreement between M. Martinez and Eastman Kodak Company, July 1, 1932, ref. A1737, box 153, KCA-BL. The period of rights for Kodak was extended in exchange of a lump sum of £150.

[121] Charge agreement between M. Martinez and C.C. Rawlinson and J.H. Bruce, March 11, 1938, ref. A1737, box 153, KCA-BL. Of course, as the patent was not granted on March 1938 yet, the agreement mentioned the corresponding provisional specification n°26966. But it also mentioned another specification n°24423 that apparently did not produce any patent.

[122] The company Elliott & Sons was established in Barnet near London. Initially a printing works, the factory started manufacturing photographic plates and paper from the end of the nineteenth century onwards.

[123] Charge agreement between M. Martinez and C.C. Rawlinson and J.H. Bruce, 1.

right to purchase Martinez's technology. It is the reason for another agreement in which Martinez "contends that there is no binding agreement affective upon him in respect of such rights." In return for a lump sum of £250 plus £370 if the option was fulfilled, Martinez granted to Kodak the option to acquire the "said patent and patent applications".[124] It is clear that the two competitors were struggling to secure Martinez's technology and incorporate it in their respective assets. Finally, Kodak Limited managed to contain its competitor's ambitions and an agreement was signed between the two companies through which Kodak granted an exclusive and royalty-free license to Elliott & Sons in exchange of a specific remuneration.[125]

The fact that Martinez generated competition between Kodak and Elliott & Sons for the purchase of his technology could have been a strategy of the inventor to secure a possible agreement with one of these companies and to ensure some source of income. In this strategic sense, the necessary procedures for the completion of a patent helped the inventor to attract the interest of potential investors. Time management was crucial for the procurement of the patent, not only with regards to the prior art and to the other possible applications already filed, but also concerning the custom of *provisional specification*. Martinez used this subterfuge for most of his patent applications and was therefore able to claim priority on an incomplete invention. He then had to provide a *complete specification* to the patent office within the time limit allowed.[126] For example, Martinez sent the provisional specification related to his British patent 505,834 which did not contain any claims on 5 October 1937, and the complete specification with 17 claims on 5 October 1938. The definition of his invention was now clear as the nature of the process in the first claim points

[124] Agreement between M. Martinez and Eastman Kodak Company, November 21, 1939, ref. A1737, box 153, KCA-BL.

[125] Agreement relating to British Patent No. 505,834 […] between Kodak Ltd. and Messrs. Elliott & Sons Ltd., March 4, 1941, ref. A1737, box 153, KCA-BL.

[126] For patent policy and intellectual property institutions in Britain see for example Nicholas, "Cheaper patents," 331.

out.[127] Both documents were enclosed in the final patent that was granted some months later, on 18 May 1939.

The incident may be why Kodak Limited seemed to have been wiser in securing Martinez's second patent. However, the situation was also different and after the outbreak of the war, Martinez's personal situation was complicated due to his Italian nationality. A set of letters from 1939 to 1941 stresses that Martinez was also collaborating closely with Kodak Limited. During the spring 1941 he requested and received from the manufacturer a lump sum of £2,000 in consideration of his British Patent application n°9657/39 and foreign rights. The sum was sent to his wife in London as the Italian inventor had already been detained in an internment camp. The first evidence of Martinez's detention comes from a memorandum dated 27 January 1941 written by L.E.T. Branch of the Patents and Trade Marks Department of Kodak Limited.[128] Branch reported his discussion with Martinez when he met him at the internment camp of Oratory Schools in South Kensington. This camp appears to be a transitional location where civilian German, Austrian and Italian aliens were screened before either being released or sent to one of the internment camps on the Isle of Man. After the Italian declaration of war on the Allies on 10 June 1940, the British Italian community was treated as a potential enemy.[129] Martinez who had emigrated to England at least fifteen years before suffered from this anti-alien policy and was arrested together with other Italian residents at an unknown date. In his memo,

---

[127] "A process of colour photography employing colour formers for producing different colours in different parts of a photographic material, which includes localising the action of the colour formers by means of a natural or artificial resin or gum resin not chemically combined with the colour former but in intimate physical association with it." Michele Martinez, "Improvements in or relating to colour photography," British Patent 505,834, filed October 5, 1937, issued May 18, 1939, 3. The equivalent American patent is the number 2,269,158 as mentioned by Friedman in 1944 (see footnote 113 above).

[128] Leslie Ernest Thomas Branch, Deputy Manager of the department. His immediate superior was Raymond Edwin Crowther, with the title of Manager of the department. This information was retrieved for the year 1940 from the statutory declarations of Branch and Crowther, 20 and 18 March 1940, ref. A1251, box 89, KCA-BL. It seems that Branch had a background in mechanical engineering as demonstrated by some of his early patents (see GB 38,335, GB 372,565 and GB 366,273 in 1932).

[129] Terri Colpi, "The impact of the Second World War on the British Italian Community," in *The Internment of Aliens in Twentieth-Century Britain*, eds. David Cesarani and Tony Kushner (London: Frank Cass, 1993), 167.

Branch unveiled a vast project of ten provisional specifications filed by Martinez and sent in a letter to Mees on 4 June 1940. Branch discussed each case with Martinez, pointing out that some specifications were not interesting at all for Eastman Kodak. As a first reaction, Martinez declared that "whoever buys the applications must buy all ten or none", but he finally reduced his request to four applications 9657/40, 9651/40, 9653/40 and 9556/40.[130] The reference of these four applications is important as only the application 9657/40 would lead to the second of Martinez's British patents, number 543,606 about technologies of colour coupler incorporation into the emulsion. Martinez was conscious that Kodak Limited had already secured the principle of a method of colour film manufacturing with the couplers into the layers, and agreed to limit his claims accordingly.[131] After all, Martinez was not in a dominant position and could not access his personal laboratory anymore for further experimentation. On the contrary, in Rochester some researchers had already checked the validity of Martinez's specifications.[132]

But Martinez did not lose courage while interned on the Isle of Man and continued to be a prolific inventor.[133] In a communication sent to Crowther in April 1941 to be shared with Rochester, he provided six photographic relief processes involving the use of colloid-metal salts in combination with heat treatment. Such inventions could contribute to several technologies like sound records on cinematograph films or

---

130 L.E.T. Branch, Memorandum of discussion with Dr. Martinez at the Internment Camp, Oratory Schools, South Kensington, January 27, 1941, ref. A1728, box 152, KCA-BL.

131 Branch to Martinez, January 28, 1941, ref. A1728, box 152, Kodak Collection Archive, British Library. Indeed in their British patent 524,154, the Kodak researchers had found "that if a colour coupler is dispersed in a water-insoluble but water-permeable binder, such as cellulose ester – for example, cellulose nitrate- and if this is then surrounded by a water-soluble binder such as gelatine, there is little or no tendency for the coupler to diffuse from the water-insoluble binder into the water-soluble binders." Kodak Limited, "Improvements in colour photographic materials," British Patent 524,154, filed January 23, 1939, and issued July 31, 1940, 1. Mannes and Godowsky used this technology and improve it in their American patent 2,304,939 issued in 1942.

132 "9653/40: Dr. Staud points out that the compounds usually desensitise […]." Branch, Memorandum of discussion with Dr. Martinez at the Internment Camp, 1.

133 About everyday life of Italian internees on the Isle of Man see Lucio Sponza, "The internment of Italians 1940-1945," in *"Totally un-English"?: Britain's internment of "enemy aliens" in two world wars*, ed. Richard Dove (Amsterdam ; New York : Rodopi, 2005), 153-163.

ribbon-like materials, typewriter equipment, Dictaphone or telegraphic machines. It indicates some evidence of scientific collaboration between Martinez and the Research Laboratory at Rochester.[134] In the letter accompanying his communication Martinez reminded Crowther that his relief process had already been studied by the American Kodak researchers and that "it proved successful even to making the castings for the lenticular colour process." He also emphasised the ability of the invention to contribute to the making of geographical maps in relief. His idea was to help to the war effort, as a large number of maps was required. For Martinez, it was also the opportunity to ask for help.

> If we put ourselves together and I am allowed to work with your people in your factory, in no time we could produce good samples for trials for the military and the Air Force, and in no time we could organize production in large scale.[135]

The Italian inventor had probably overestimated Kodak's power over military authorities, and his situation did not change.[136]

For Eastman Kodak, more than innovative technologies of photographic relief, application 9657/40 remained high on the priority list. However, Martinez's personal situation complicated the bureaucratic initiatives of the British Kodak staff.[137] In fact Branch and Crowther were working in close collaboration with their American

---

[134] "Colour reliefs. Dr. Alexander Murray, who worked [at] this relief of mine in Rochester, expressed the opinion, which Dr. Mees shared, that just relief still pictures, colourless or black and white, were not possibly a proposition of commercial importance, but that if colour could be added, then the proposition would become of real magnitude. I have evolved in full the process to obtain this, but although it is still incredibly simple in manufacture and in use […] I am unable to write it fully in conditions obtaining in camp, nor would I risk to put down in an abridged form or in haste the novel principle involved." Michele Martinez, "A communication to Messrs Kodak Ltd and to the Eastman Kodak Company of U.S.A.", April 24, 1941, ref. A1737, box 153, KCA-BL, 8-9.

[135] Martinez to Crowther, Metropole Internment Camp n°2 in Douglas, Isle of Man, April 24, 1941, ref. A1737, box 153, KCA-BL.

[136] The supply to the military during the Second World War would be an interesting line of arguments to follow. The Kodak Collection Archive may contain other evidence of such potential collaboration with the American military. However, this subject goes beyond the scope of my thesis and cannot be studied here. Concerning the supply to the American military during the First World War, we have more information available. See for example Mees, *From Dry Plates to Ektachrome Film*, 55-57.

[137] From 1940, the sudden interest and hostility of the British government toward Italian immigrants, whatever their particular background, caused many problems to the international exchange of knowledge. As part of my study, the patent system was affected in particular.

counterparts at Rochester. In Rochester, Newton Perrins was the Head of the Patent Department of Eastman Kodak and the three men frequently corresponded.[138] The flows of their exchange of knowledge can be summarised in Figure 9. At the end of March 1941, Perrins requested Martinez's signature from Branch for the American and Canadian applications concerning the British application 9657/40. Crowther had to write directly to the Commandant of the Metropole Camp to get the papers signed and formalised.[139] In June 1941, Branch started to prepare the complete specification from the provisional specification already provided by Martinez. He expressed some hesitation as to the correct method necessary to change the initial explanations of the inventor. "Shall we "clean-up" the pro[visional]. (…) Martinez might accuse us of something if we alter his wording at all."[140] Branch had also some difficulties understanding Martinez's rationale through his *provisional*. He provided a draft of the *complete* to Crowther but with some reservations. "At the places marked in red I either cannot understand at all what he means or am doubtful whether my amendments are correct. Can you specially consider these."[141] Finally the application 9657/40 was sent for approval by Kodak Limited to the British Patent Office but Martinez received a negative answer in July 1941. The examiner objected to the initial title of the application, requested a reference to the literature about some processes and chemical compounds and also refused the presence within the text of some

[138] Newton M. Perrins was hired by Eastman Kodak as an assistant patent attorney in 1917. He directed the Patent Department of the Company from 1928 to 1949, when he relinquished the active management to Daniel I. Mayne. In 1947 he was named a member of the National Patents Council. He died in 1953 at the age of 69. See "Newton M. Perrins," *Journal of the Patent and Trademark Office Society* 35, no. 12 (December 1953): 887; "Kodak man appointed to U.S. Patents Council," *Kodakery* 5, no. 25 (26 June 1947): 2.

[139] "The papers for both the applications should be signed by Dr. Martinez before a Notary Public. As there is no United States Consulate in the Isle of Man, the papers will have to go to Liverpool for legalisation of the Notorial signature at the Consulate there." Crowther to the Commandant of 2 Metropole Camp, Douglas, Isle of Man, April 15, 1941, ref. A1728, box 152, KCA-BL. See also Perrins to Branch, March 28, 1941, ibidem.

[140] Branch to Crowther, "Martinez British 9657/40," June 4, 1941, ref. A1728, box 152, KCA-BL. The *pro* means the provisional specification.

[141] Branch to Crowther, June 10, 1941, ref. A1728, box 152, KCA-BL.

registered trademarks such as Ozobrome, Agfacolour or Dufaycolour.[142] In October 1941 the application was changed and re-sent to the Patent Office but the examiner still refused it for similar reasons.[143]

In the meantime, Martinez insisted during the summer 1941 that Eastman Kodak consider his other applications 9651/40, 9653/40 and 9656/40 again. For Martinez, the invention contained in the application 9651/40 would solve every drawback of the Chromatone process, a method of colour printing developed by the Defender Photo Supply Corporation.[144] Martinez summarized the others applications under three inventions. The first was a colour process derived from the principles of the colour inherent to relief that the inventor wanted to apply to processes working with fast bromide emulsions. The second was a new photographic paper providing constant sepia colour after development independent of the exposure time and strength of the developer. The third invention involved an anticipatory technology of dry development of photographic materials.

> Absolutely dry, not semi-dry, and nothing to do with mercury vapours nor with ammonia fumes. A revolution, literally, […] of which I cannot sufficiently emphasize the repercussions specially on the cinematograph processing trade.[145]

Martinez also clarified that these inventions were based on experiments made in the past several years and still fresh in his memory. To finish the research work he requested a collaboration with the Kodak researchers and a short stay at Rochester: "Oh, if only I could go to U.S.A. for a short time. It should be possible for Dr. Chapman

---

[142] Patent Office to Martinez, July 20, 1941, ref. A1728, box 152, KCA-BL.

[143] Patent Office to Crowther, October 28, 1941, ref. A1728, box 152, KCA-BL. It is difficult to speculate on the potential politics played by the patent office and the examiner. Martinez was collaborating with a British subsidiary of an American company, but his Italian nationality may have worked against him.

[144] "The people in the E.K.Co. in Rochester must not have tried the true-colour processing contained in my 9651/40 and further detailed in the notes I attached to it […]." Martinez to Crowther, August 21, 1941, ref. A1728, box 152, KCA-BL, 2.

[145] Ibid., 4. It is unfortunately impossible to determine the innovative technology of dry development proposed by Martinez as he did not want to reveal its principles into his correspondence.

to obtain that, through the diplomatic representatives here, if he really desired it."[146] Martinez also expressed a fear of watching his inventions *pillaged* by enemy countries during this period of war, and suggested postponing the disclosure of the patent relating to the application 9657/40. "Would it not be preferable to record matters at present, for you to keep in option but in abeyance until the world and patents are safe ?"[147] Crowther forwarded Martinez's letter to Perrins and Chapman and the inventor's proposal was followed, and the publication delayed. But it appears that Eastman Kodak did not try to arrange a visit to Rochester for Martinez in the following months. Despite Martinez's supplication, he was forced to remain captive on the Isle of Man during much of the Second World War.[148]

In any event, Crowther and Branch's mission still remained to present an amended application 9657/40 to the British Patent Office. To this end Branch requested some additional explanations to Martinez in November 1941 as the examiner himself could not understand a specific point of the application. It concerned the example 2 for which three layers produced after the initial development a yellow plus silver image, a red plus silver image and a silver image. The film was then bleached and treated with a colour coupler developing solution. Branch thought that the result should be a yellow plus blue-green, a red plus blue-green and blue-green, thus giving an incorrect colour reproduction as described before in the application.[149] Martinez replied to Branch by providing a clearer explanation of the theoretical mechanisms of the process. In fact, following the development of Martinez's emulsion with a colour agent, the quantity of

[146] Ibid., 5. During the war Dr. Albert Kinkade Chapman (1890-1984) was the vice-president and general manager of the Eastman Kodak Company. In 1951 he became president and chairman of the board from 1962 to 1967. This time again, Martinez's wish was not fulfilled.

[147] Ibid., 6.

[148] In the same letter, Martinez stressed the advantages of an improved scientific collaboration at Rochester: "Again I wonder, is it not possible for me just to have only a few months' work in U.S.A., or simply personal communications with the E.K.Co., so that I may do, show and say all I have to do, show and say? Personal contact only, and discussion, can give the measure of innovations of real value. I have not the slightest doubt that it would be very relevant the advantage to the E.K.Co. I have no desire to force myself on the Company, only give them benefit of what I have of paramount importance." Ibid., 6.

[149] "However, if you could send us an explanation which would satisfy the Examiner, we could reinsert Example 2." Branch to Martinez, November 19, 1941, ref. A1728, box 152, KCA-BL.

silver formed in the location of the colour agent was entirely insignificant. Thus after the bleach the results in the layers would be "yellow with negligible traces of blue-green, if any, […], red with again traces of blue-green, if any […]; blue-green."[150] As a result, example 2 was reinserted and later accepted by the Patent Office examiner. The last set of correspondence regarding the application 9657/40 was an increasingly fastidious discussion about specialised terminology in chemistry and physics. For instance one hesitation was about the terms *hydrophilic* and *hydrophobic* used in a claim, following a request from the examiner.[151] Crowther suggested another terms such as *water repellent* or *with a tendency to absorb water*.[152] In another discussion, Branch juggled with the subtle art of patent writing in which the inventor should not provide too much key data or, to achieve the same ends with a different method, should give a long list of chemicals that could potentially be used in a process. In this way the competitor would have to perform lengthy experimental work to be able to reproduce the equivalent process with the correct components.[153] As a result of these revisions, the examiner[154] was finally satisfied with the amended complete specification and the British Patent Office accepted it in February 1942.[155] The document received the number 543,606 and it was legalised on 5 March.[156] The narrative of this patent drafting process shows the connection of specific vocabulary

---

[150] Martinez to Branch, November 27, 1941, ref. A1728, box 152, KCA-BL.

[151] "Dr. Davey gave us the opinion that ordinary collodion emulsions do absorb water to some extent, even if a very small extent. If this is correct it would perhaps seem that the words are not really suitable for the claims." Branch to Crowther, December 19, 1941, ref. A1728, box 152, KCA-BL.

[152] Crowther to Branch, December 23, 1941, ref. A1728, box 152, KCA-BL.

[153] "In case "ammonium" is all that will work, I do not favour, substitute it by potassium, but say "alkali" which probably includes it." Branch to Crowther, January 15, 1942, ref. A1728, box 152, KCA-BL.

[154] It is critical to understand the role of the examiner during the patent process because he is the third expert interlocutor as part of a scientific collaboration in the patent drafting process. Although I found sometimes the identity of these state employees through correspondence in the Kodak Collection Archive, further research would be necessary within the Patent Offices archives, if available, to increase our understanding of the examiner's role. Such research goes beyond my own collection of data during my PhD.

[155] "We (…) have pleasure in informing you that the Examiner is now satisfied with the specification and it will be accepted finally today." Branch to Martinez, February 3, 1942, ref. A1728, box 152, KCA-BL.

[156] Michele Martinez, "Improvements in colour photography," British patent 543,606, filed June 3, 1940, complete specification filed July 3, 1941, and issued March 5, 1942.

formation to difficulties in clarifying the technical aspects of the patent and to the lengthy process of issuing patents. It also shows the difficulty for Martinez, source of the invention, to transfer his scientific knowledge to Branch and Crowther despite their knowledge of the photographic process.

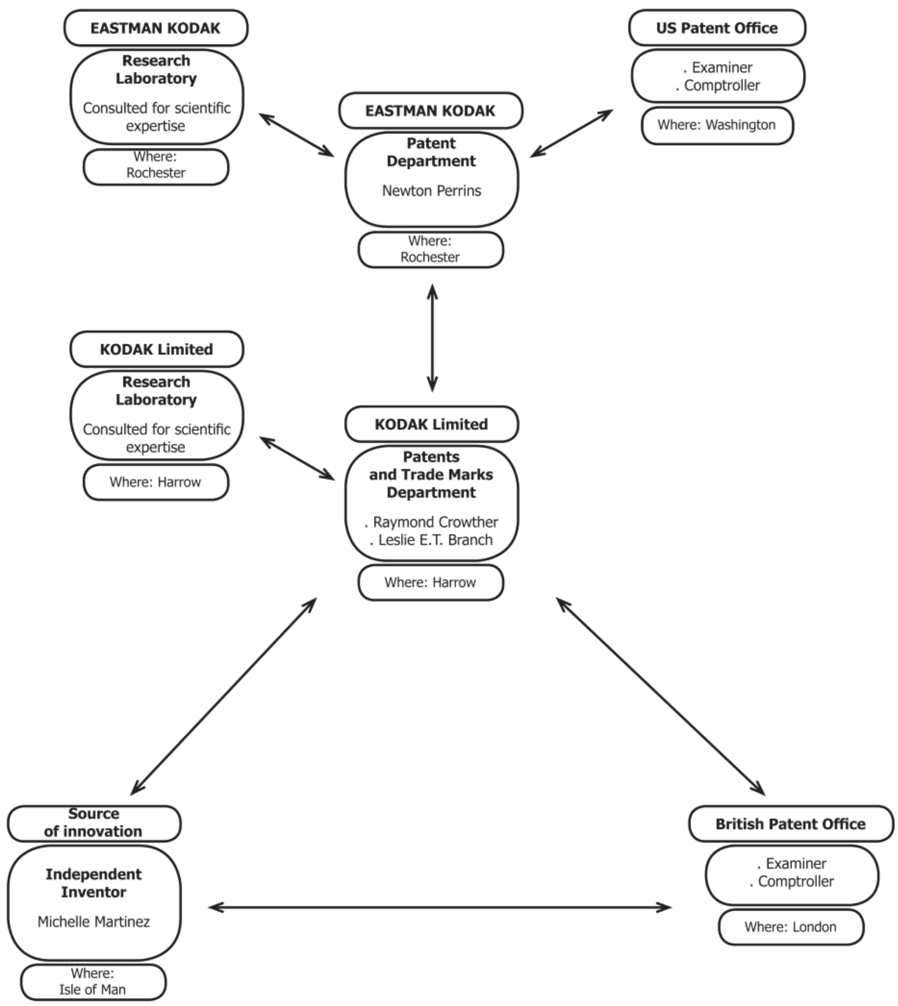


Figure 9. Scientific collaboration and exchange of knowledge during the drafting process of British patent 543,606 and its related American patent US 2,284,877.

The final action in parallel with the British patent was to monitor the patent application in the United States of America, from the application signed by Martinez in March 1941 on the Isle of Man. This application was submitted in May 1941 and not long after obtaining the British patent it was also patented in 1942 by the United States Patent Office. When one compares the British and American patents, it is clear that the texts are slightly different. Although the examples and the photochemical description of the invention remain similar in substance, the total number of claims was reduced from 16 to 8 claims for the American patent. This change was made at the discretion of Perrins and his subalterns, who were responsible for the patent application in their country on behalf of Martinez. That difference proves that it was necessary to adapt the British patent literature to the American Patent Office and to its editorial practices. It also points out that the state of the art pertaining to Martinez's technology likely differed between the two countries. For the inventor, his new invention embedded in the British patent 543,606 changed the previous technology of *insulation* of the sensitive grains, for which colour reactions occurred through *localized* particles as disclosed in the British patent 505,834.

> The object of my present invention is achieved by precipitating silver halide in the presence of a synthetic or natural resin, gum, or gum-resin, or similar substance, preferably of water-repellent properties, in such a way that the silver salt is formed within or in close physical association with the resin, which is the insulator of the grain so formed […].[157]

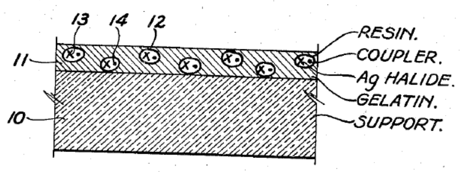


Illustration 9. The resin acting as an insulator for the silver salt and the colour couplers in Martinez' American patent 2,284,877.[158]

This *insulator* as seen in Illustration 9 above, dispersed into the gelatin, then incorporated the colour couplers and the silver halide.

[157] Michele Martinez, "Light sensitive color element," American patent US 2,284,877, filed May 22, 1941, and issued June 2, 1942, 1. This description used the adjective *water-repellent*, a terminology also suggested later in the year 1941 by Crowther as seen above.

[158] Ibid., cover.

In the Kodak Limited archive, there is a license between Martinez and the Eastman Kodak Company that was made and signed in April 1943. The inventor, namely the *licensor*, gave the *licensee*, that is Eastman Kodak, the sole and exclusive license related to the British patent 543,606 “in consideration of the sum of $2,000.”[159] However it is not clear whether Martinez had been released from the Isle of Man or not. In any case the British government did not detain him after 1944, as the Metropole Camp in Douglas was closed the first week of November 1944.[160] After the war, Martinez reappeared, writing a letter to Branch from a hotel in New York. The deputy manager at Kodak had requested a simple authority with signature concerning Martinez’s patents. The Italian inventor had a new address in Los Angeles but was residing temporarily in New York for business. In his letter, Martinez expressed his sadness to Branch because he had been informed about Crowther’s death by Perrins some time ago.[161] In January 1947, Martinez also sent to Branch a priority assignment signed and legalised by notary, for the Patents and Trade Marks Department to be allowed to fill a patent application in Czechoslovakia corresponding to the invention in patent GB505834.[162] In the following years, all trace of Martinez’s was gradually lost. In 1954, the time had come to think about the renewal of the Martinez patents. Branch wrote to Daniel Mayne, Perrins’ successor, with a short list of important British patents to consider. In the opinion of Branch, as Kodak Limited has “*not made or imported into England any material made according to*” the Martinez patent GB505834, it would be very difficult to convince the British Patent Office to extend the lifetime of the patent.[163] Alongside this patent, Branch also considered the patent GB507841 of

---

[159] License between Michele Martinez and the Eastman Kodak Company, April 1, 1943, ref. A1737, box 153, KCA-BL.

[160] Connery Chappell, *Island of Barbed Wire: Internment on the Isle of Man in World War Two* (London: Robert Hale, 1984), 181.

[161] “What a loss! Crowther was the man I admired most. Not knowing it, I had in him the greatest friend I ever had. I cannot tell you adequately how I feel.” Martinez to Branch, Hotel New Yorker, August 5, 1946, ref. A1728, box 152, KCA-BL.

[162] Martinez to Branch, Beverly Hills, January 27, 1947, ref. A1728, box 152, KCA-BL.

[163] Branch to Mayne, “Extension of terms of British Patents,” January 14, 1954, ref. A1728, box 152, KCA-BL.

Mannes, Godowsky and Wilder for the original Kodachrome selective reversal process.[164] In June 1954, the Patents and trade Marks Department of Kodak Limited sent two letters to Martinez regarding the decision not to renew his patent GB543606. Should the inventor want to keep the patent in force, he was asked to pay the renewal fee directly. Both letters were returned and the Department never managed to contact Martinez.[165]

The last section of Chapter 4 introduces the research work of Karl Schinzel, having provided some scientific milestones to Eastman Kodak in the development of the Kodacolor system through the establishment of patents. It is important to introduce the scientific collaboration between Schinzel and Eastman Kodak at the end of this chapter because it complements the history of colour research undertaken by Eastman Kodak following the launch of three colour Kodachrome. The nature of the relationship between the inventor and Kodak was also different due to Schinzel's Czech roots and his restless character, far from Martinez's personality.

[164] This is the equivalent of the American patent US 2,252,718 already studied in this chapter, in which Wilder described his first improvement of the Kodachrome process as disclosed to Phillips during his stay in Rochester in 1938.

[165] The second letter sent to the Martinez's address at Los Angeles was returned on 18 July 1955 with the mention "moved, left no address." It appears that this is the last track of the Italian inventor in the Kodak archive at the British Library. Martinez's dates of birth and death are unknown. Through the European Patent Office, I found his probable last patents. The British patent 770,959 was filed with the complete name "Michele Pasquale Luigi Martinez". It entitled "Improvements in a photographic iron-silver color process" and the patent was granted on 27 March 1957. The last patent of the same M. P.L. Martinez is the American patent US 2,886,435 about the similar iron-silver color process. It was granted on 12 May 1959 and it was noted that Martinez was the assignor to the Panacolor, Inc. Company. For more information about Panacolor, see Roderick T. Ryan, *A History of Motion Picture Color Technology* (London: Focal Press, 1977), 218.

4.2.3. Scientific collaboration with Karl Schinzel and the Kodak Research Laboratory project in Switzerland

The scientific collaboration between Schinzel and Eastman Kodak is a rich, lengthy and complex story, involving the project of creating an additional research laboratory in Europe. It goes beyond the preceding collaboration between Martinez and Eastman Kodak to better clarify the nature of innovation performed by the film manufacturer through its industrial research structure in Europe at the end of the 1930s. It confirms that some practices were similar to those used within the scope of “Open Innovation”, a concept that was defined in the introduction in section 1.2.5.3. It also complements our understanding of colour research undertaken by Kodak following the launch of three colour Kodachrome. For Eastman Kodak, Schinzel was alternately an independent photochemist like Martinez, an employed researcher at Rochester like Mannes or Godowsky and even the director of a new Kodak Research Laboratory project like Clark or Abribat. The large quantity of archive materials relating to Schinzel’s research work over a long period in the Kodak Collection archive confirms that the photochemist worked on the further improvement of colour photography from the release of the three-colour Kodachrome in 1935 onwards.

It makes it all the more difficult to understand why Schinzel has been so absent in the history of Kodak research up to now. During his lifetime, Schinzel was granted 4 entries in Wall’s *History of Color Photography* in 1925 and 18 entries in Friedman’s book about the same topic in 1944. The two historians and photochemists pointed out that Schinzel was the first to suggest the technology of the monopack for the reproduction of colour in 1905.[166] But this was only one aspect of Schinzel’s work in photochemistry. Before collaborating with Eastman Kodak he undertook independent research for instance about colour development, chemical toning, three-colour printing or mixed type emulsion with silver chloride and silver bromide. Friedman specified that in 1936

[166] Wall, *History of Three-Color Photography*, 432, 433, 440, 497; Friedman, *History of Color Photography*, 94, 95, 96, 115, 119, 312, 366, 368, 380, 381, 399, 400, 406, 407, 408, 410, 411, 414.

and 1937, Karl and his brother Ludwig Schinzel published a series of papers in the German journal *Das Lichtbild* in which they discussed the chemistry of primary colour development. The innovative technology provided by the papers was secured by Schinzel in a series of patent applications and assigned to Eastman Kodak.[167] Recently, Rogers clarified that through one of these publications Schinzel was even the first to disclose the concept and mechanism of instant photography, which led to the innovative products of Polaroid Corporation.[168] In the older literature, Douglas A. Spencer was one of the few Kodak managers to recognize Schinzel's scientific contribution. In the Maxwell Centenary Discourse Spencer gave in 1961, the author provided a concise list of pioneers of colour photography. Schinzel was in this list for his theory of integral tripacks disclosed in 1905 beside Young, Maxwell, Ducos du Hauron, Traube, Fischer and Mannes and Godowsky.

> Schinzel was a sort of Austrian counterpart to the Frenchman, Du Hauron. In over 50 patents he described in outline the various pathways along which this form of colour photography could be developed, but could do little more with the facilities available to him : colour photography had become a problem for chemists and engineers rather than physicists.[169]

Spencer, who joined the Research Laboratory of Kodak Limited in 1939 and became managing director of the company in 1957, was the first professional scientist to hold this position and was therefore acutely aware of photographic research matters. He had worked before as a chemist at Colour Photographs Limited to improve the printing process of the company and knew the corresponding patents of Martinez, as has already been mentioned.[170] Therefore it was no surprise that Spencer was perfectly aware of Schinzel's research work in colour photography. However, the information

---

[167] Friedman, *History of Color Photography*, 366.

[168] David Rogers, *The Chemistry of Photography. From Classical to Digital Technologies* (Cambridge: Royal Society of Chemistry, 2007), 202. The reference mentioned by Rogers was Karl Schinzel and Ludwig Schinzel, *Photographische Industrie* 34 (1936): 942.

[169] Douglas A. Spencer, "The first hundred years of colour photography," *The Photographic Journal* 101 (September 1961): 269, 272.

[170] Coote, *The Illustrated History of Colour Photography*, 78-82. Gauntlett, "A History of Kodak Limited", 86.

about Karl Schinzel and his brother has only come from the patent literature and the analysis of periodicals up to now. Very little is known about Schinzel's biography and above all about the period of collaboration with Eastman Kodak. It is worth further study to clarify the research work on colour photography through the prism of Schinzel's life in the 1930s and around the Second World War, because it will ascertain the real contribution of Schinzel to Kodak Research from archival materials.

They are only two fragmented but recent biographies of Karl Schinzel.[171] The most complete one was published in the Czech magazine *The Heart of Europe* in 2006 on the occasion of the 120th anniversary of Schinzel's birth.[172] Due to his Czechoslovakian roots, Schinzel was cited as having the first name Karel.[173] When he patented his monopack process of *Katachromie* in 1905 he was only 19. Transferred to the Vienna branch of Hell & Co., a German chemical group, Schinzel was able to attend lectures on chemistry at the University of Technology and some evening courses. In 1912 he finally gained the title of engineer. He served in the Army during the First World War and resumed his education at the end of the conflict by working on a doctoral dissertation. In 1919, he received a doctorate in technical sciences about the manufacture of explosives at the University of Technology of Vienna. It is very likely that Schinzel attended some lectures of Joseph Maria Eder at the Research Institute of Graphic Art in Vienna.[174] However, the author of the biography clarified that in 1922 Schinzel was

---

[171] The first biography is from Gert Koshofer, "Schinzel, Karl," *Neue Deutsche Biographie* 23 (2007): 1, accessed February 2, 2015, http://www.deutsche-biographie.de/ppn139578617.html. See also Gert Koshofer, *Farbfotografie 2* (München: Laterna magica, 1981), 11-15.

[172] Ludek Wünsch, "Karel Schinzel, An Inventor Crossed by Fate," *The Heart of Europe*, no. 4 (2006): 16-19.

[173] Born in 1886 at Edrovice in the actual Czech Republic in a modest family, the young Schinzel moved ten years later for the bigger city of Opava, in the heart of Czech Silesia. He started a two-year business school as he was supposed to take over the small family business. However, when he discovered the photographic medium in the beginning of the twentieth century, he developed a passion not only for the visual art but also for the photochemical mechanisms of the photographic process. He then worked as an accountant at Hell & Co., a chemical and drug manufacturer in Troppau. At this time he could not access a scientific education at the university but devoted most of his free time to the self-learning study of photographic processes, analysing the French, German and English literature on the topic.

[174] According to Koshofer, Schinzel was the assistant of Eder from 1920 to 1922. Koshofer, "Schinzel, Karl," 1.

unsuccessful in a scientific proposal to a committee of experts for improving his monopack process. After this failure, Schinzel returned to Opava and began to work independently on colour photography with the help of his brother Ludwig, who assisted him for his photographic experiments. He worked for more than a decade on theoretical and experimental work on colour photography in a personal laboratory, without any link to academic circles or photographic film manufacturers.[175]

The Schinzel brothers suddenly became renowned and respected photochemists in 1936 after Ludwig convinced his brother to publish most of his many findings in 14 papers in the German journal *Das Lichbild*.[176] Coote briefly mentioned Schinzel's contribution to colour photography and cited an article published in the *British Journal of Photography* in November 1939. In this article a list of forty patent specifications equivalent to around 200 printed pages was mentioned and for the author, "the specifications as a whole form an encyclopedia of information on materials for colour photography".[177] Unsurprisingly Schinzel's research work attracted the attention of Eastman Kodak as well as its German competitor Agfa. Mees and his research team needed to react promptly to prevent the loss of Schinzel's technology to Germany. It is unclear whether Schinzel was contacted first by Kodak Limited or directly by Rochester. Crowther and Branch stated later that they had known Schinzel since the autumn of 1936.[178] According to Wünsch, Schinzel was finally invited at Kodak Park in Rochester in December 1936 and later to London.[179] There is some evidence of Schinzel's visit to Eastman Kodak at this date in some administrative files of the Kodak Collection archive. A retainer agreement between Schinzel and Eastman Kodak

[175] Wünsch, "Karel Schinzel, An Inventor Crossed by Fate," 16-17. I contacted by electronic message the author who is apparently the curator of the photographic collection at the Silesian Museum in Opava to get more information about his references. However, no reply has been received up to now.

[176] Koshofer, "Schinzel, Karl," 1. Some papers were also published in the German journal *Photographische Industrie*, such as the first paper in vol. 34 (1936): 942. See Friedman, *History of Color Photography*, 366.

[177] Coote, *The Illustrated History of Colour Photography*, 147.

[178] Statutory declaration of Raymond E. Crowther and of Leslie E.T. Branch, n. d., ref. A1251, box 89, KCA-BL.

[179] Wünsch, "Karel Schinzel," 18.

mentioned the employment agreement offered to the inventor and was signed on 23 December 1936. Schinzel committed to begin work at the Kodak Research Laboratory from 1 July 1937. In return the manufacturer agreed to pay him the sum of £9164 "with interest thereon at the rate of five percentum (5%) per annum from the date hereof to the date of payment […]."[180] It is likely however that Schinzel came to work with the Kodak researchers only at the end of 1937, as his salary suggests.[181] Before this close collaboration in the laboratories at Kodak Park, Schinzel had secured his findings by means of preliminary patent work.[182] In the first part of 1937, Kodak researchers at Rochester studied the many applications that Schinzel had filed in Austria in May and July 1936. Schinzel's work, although promising, was highly theoretical and it had to be integrated into the scientific and technological knowledge of the Kodak laboratories. Perrins reported this work of patent analysis from the Patent Department at Rochester in a letter to his counterpart Crowther from Kodak Limited. He also clarified the future strained relationship between Mannes, Godowsky and Schinzel at Kodak Park. As the inventors of Kodachrome were mentioned in the first article of Schinzel in *Das Lichtbild* as "zwei eingewanderten polnischen Musikanten", Perrins noticed that the terminology was rather pejorative and the biographical data wrong.[183] In September 1937, Branch visited his counterparts at Rochester. He reported that he was still working on Schinzel patent cases together with Vittum, Petersen and Wilder.[184]

---

[180] Retainer agreement between Eastman Kodak Company and Dr. Karl Schinzel, September 1, 1938, ref. A1251, box 89, KCA-BL, 1.

[181] Schinzel received a salary from Eastman Kodak from 1 January to 30 September 1938 for his laboratory work at Rochester. See the correspondence after Karl Schinzel's death in 1951 between Eastman Kodak and the descendants in the file ref. A1251, box 89, KCA-BL.

[182] This patent work will be analysed at the end of this section.

[183] The diplomatic Perrins concluded finally: "while I am not intimating that [Mannes and Godowsky] are not giving the best of their advice and opinions in order to obtain the best protection we can on what Dr. Schinzel has disclosed, they are not at all enthusiastic about his work from a practical standpoint." The German mention "*zwei eingewanderten polnischen Musikanten*" means *two immigrant Polish musicians* but with a pejorative sense. Perrins to Crowther, "Off the record", April 20, 1937, ref. A1251, box 89, KCA-BL.

[184] Branch to Crowther, September 21, 1938, ref. A1715, box 291, KCA-BL.

The research work of Schinzel done at Rochester is unfortunately not well documented in the Kodak Collection archive. In his later correspondence and scientific notes one can find some evidence of Schinzel's mutual work with Kodak researchers such as Vittum, Petersen, Mannes and Godowsky.[185] Finally, it seems adapting to teamwork was difficult for the temperamental Schinzel. Therefore a new kind of collaboration was progressively conceived and eventually proposed to Schinzel. The idea was to send the photochemist to pilot a new Research Laboratory in Europe. Apparently Schinzel was keen on this innovative concept and accepted the proposal. An agreement was made between him and Eastman Kodak, stating that he was "retained by Kodak not as an employee but as an independent researcher and consultant." The contract specified Schinzel's professional duties.

> D. Schinzel agrees that he will at once establish and will […] maintain and operate a laboratory in a European country satisfactory to Kodak and that he will in such laboratory faithfully and diligently devote his best efforts during said research period to such research and experimental work on color photography and chemical and photographic processes related thereto as he may be instructed by Kodak in writing to perform, and that he will devote thereto weekly the number of hours customary with research workers employed in industrial laboratories in such countries.[186]

The researcher committed to preparing some samples and to providing some data, evidence or advice to the patent agents preparing the patent applications. Schinzel also committed to report "fully in writing to Dr. C.E.K. Mees, Director of Research from Kodak" about all experimental work, research, discoveries and inventions relating to colour photography carried on or made by him, his brother or any person employed by either of them.[187] At the same time, Schinzel was supposed to grant to Kodak a non-exclusive right and license relating to any potential invention and discovery for which he would have filed some patent applications or already received a patent. His brother Ludwig or potentially the employees of the laboratory would also be required to

---

[185] See for instance the analysis of Schinzel's correspondence to Branch in the next paragraph.

[186] Retainer agreement between Eastman Kodak Company and Dr. Karl Schinzel, September 1, 1938, ref. A1251, box 89, KCA-BL, 2-3.

[187] Ibid., 5.

comply with these rules. Finally, Schinzel committed to never disclosed an invention or discovery "to any third party" without Kodak's permission. He also agreed that "he will not publish any articles about photographic subjects or chemical subjects related in any way to photography without first obtaining Kodak's consent and approval in writing, signed by Dr. C.E.K. Mees […]."[188] These structural constraints point out the strategic role of confidentiality in photographic invention as well as the protection gained from the patent system. A letter from Perrins the same year provided the financing agreed by Kodak to establish the new Research Laboratory. Schinzel was granted an annual salary of $6000 plus the expenses of his laboratory up to $4000. This rate was agreed for a period of five years but could be extended up to ten years. After this period of five or ten years Schinzel would be employed as a consultant at an annual salary of $2500. For any invention made during the period of agreement, Schinzel was granted a royalty of 2,5%.[189] Perrins did not provide a complete explanation about this agreement but this rate was comparable to the rate obtained by Mannes and Godowsky in 1930, the value being equal and it is possible that it concerned 2.5% of the net selling price of motion picture films as well. The content of the agreement proves first that Eastman Kodak considered the collaboration with Schinzel in the very long-term, possibly over more than 10 years, anticipating all the potential of his theoretical inventions. Secondly, it points out that Eastman Kodak treated Schinzel on a level with Mannes and Godowsky. Therefore it is not only due to personal difficulties between him and the scientific staff of the Kodak Research Laboratory that Schinzel returned to Europe, as suggested by Koshofer in 2007.[190]

Schinzel left Rochester on 29 November 1938 for Zürich in Switzerland where he had planned to open the Research Laboratory. Time passed, and the organisation of the new structure was not well advanced the following months. During the first semester

---

[188] Ibid., 6, 10.

[189] Perrins to Page, November 29, 1938, ref. A1251, box 89, KCA-BL.

[190] Koshofer, "Schinzel, Karl," 1. Information given by Wünsch about Schinzel's stay in Rochester does not match with the archive material found in the Kodak Collection archive as well. See Wünsch, "Karel Schinzel, An Inventor Crossed by Fate," 18.

of 1939 Schinzel was working in close collaboration with Branch of Kodak Limited on patent applications and this additional scientific work may have diverted the independent researcher from his new supervisory function. First Branch and L.E. Jones, a chartered Patent agent in Liverpool working with Kodak Limited, met Schinzel in Zürich for three days in January 1939. From February to April Branch and Schinzel maintained an exhaustive correspondence about the patent applications. The correspondence between Schinzel and Branch in the first months of 1939 shows practically how an independent inventor transferred his knowledge of chemistry to the Kodak Patents and Trade Marks Department and to the Kodak Research Laboratory at Rochester. The letters also clarify the rationale and the strategy of the patent drafting process and the research activities required for that purpose.

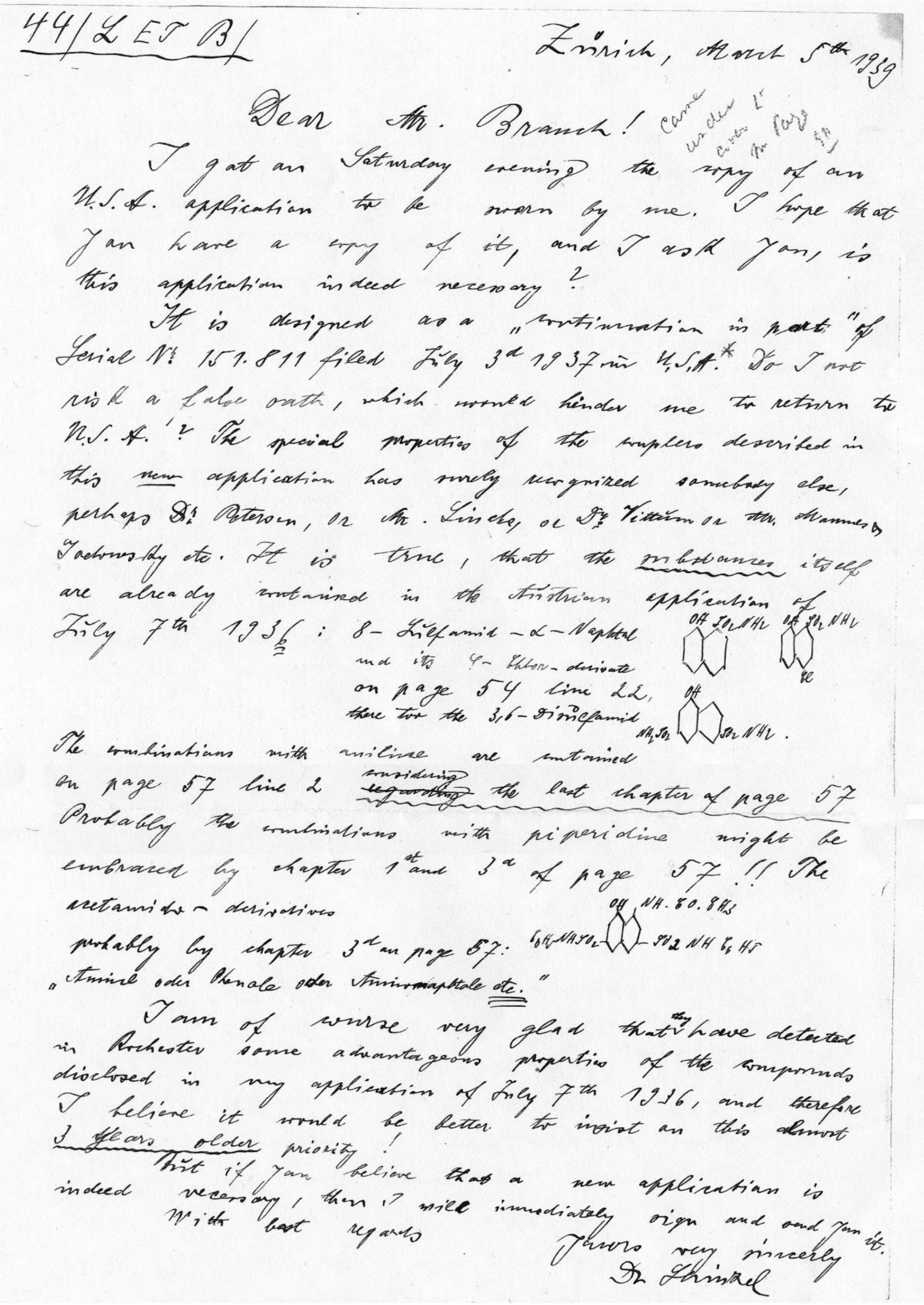
The Kodak Collection archive holds 14 letters written by Schinzel and sent to Branch from 4 February to 4 April 1939.[191] Branch's letters to Schinzel are not included in the file and it is unclear whether the set of Schinzel's letters are complete or not. Schinzel was still in Switzerland, residing at the Hotel Plattenhof in the center of Zürich. The main topic of the letters was the filing of some patent applications for which Schinzel was the inventor, and at least two discussions about application work have been identified from the corpus of letter. The first one relates to one patent application in German and concerns more than the half of the corpus. According to my analysis of Schinzel's patents, this German specification corresponds to the invention disclosed in British patent 498,663 on the development of multilayer photographic colour films. After the original British patent, a decision was taken to patent the technology in the United States of America and in Belgium, France and in the Netherlands.[192] Due to the disruption of World War II, the German specification was probably not accepted as no

[191] Karl Schinzel's correspondence to Leslie E.T. Branch, 4 February to 4 April 1939, ref. A1726, box 152, KCA-BL. Some letters were labelled as "44/LETB/ IS" possibly by Schinzel himself. The last letter was labelled as "Schinzel letters RE503752" most probably by an archivist at Kodak Limited at an unknown date.

[192] This multi-patenting strategy represented an exception in the patent work done by Schinzel and Eastman Kodak. As it will be stress in the analysis of Schinzel's patents, most of his inventions were patented in Great Britain and/or in the United States of America only.

corresponding patent was found in my research. The second discussion identified was about the request from Eastman Kodak for the signature from Schinzel of an American application. The request would finally lead to the American patent 2,249,542 about phenolic and naphtolic couplers, which represent the last patent granted and identified from the collaboration between Eastman Kodak and Schinzel.[193]

[193] Karl Schinzel, "Phenolic and Naphtholic Couplers containing Sulphonamide Groups," US 2,356,475, filed March 24, 1939, and issued August 22, 1944. Schinzel is writing about this application on 5 and 6 March 1939.


44/LET B/

Zürich, March 5th 1939

Dear Mr. Branch!

I got on Saturday evening the copy of an U.S.A. application to be sworn by me. I hope that you have a copy of it, and I ask you, is this application indeed necessary?

It is designed as a „continuation in part" of Serial No 151.811 filed July 3d 1937 in U.S.A.* Do I not risk a false oath, which would hinder me to return to U.S.A.? The special properties of the couplers described in this new application has surely recognized somebody else, perhaps Dr. Peterson, or Mr. Lincke, or Dr. Vittum or Mr. Mannes, Jachowsky etc. It is true, that the substances itself are already contained in the Austrian application of July 7th 1936: 8-Sulfamid-α-Naphtol and its 4-Chlor-derivate on page 54 line 22, there too the 3,6-Disulfamid.

The combinations with aniline are contained on page 57 line 2 considering the last chapter of page 57. Probably the combinations with piperidine might be embraced by chapter 1st and 3d of page 57.!! The acetamide-derivatives probably by chapter 3d on page 57: „Amine oder Phenole oder Aminonaphtole etc."

I am of course very glad that they have detected in Rochester some advantageous properties of the compounds disclosed in my application of July 7th 1936, and therefore I believe it would be better to insist on this almost 3 years older priority!

But if you believe that a new application is indeed necessary, then I will immediately sign and send you it.

With best regards

Yours very sincerely

Dr. Schinzel

Illustration 10. Schinzel's letter to Branch on March 5, 1939, concerning the filing of an application.[194]

[194] Schinzel to Branch, March 5, 1939, ref. A1726, box 152, KCA-BL.

In his letters, Schinzel mentioned that he was not sure whether the filing of the application was necessary or not (see Illustration 10).

> It is designed as a "continuation in part" of Serial No. 151.811 filed July 3rd 1937 in USA. Do I not risk a false oath, which would hinder me to return to U.S.A. ? The special properties of the couplers described in this new application has surely recognized somebody else, perhaps Dr. Petersen, or Mr. Lin[…], or Dr. Vittum or Mr. Mannes or Godowsky etc.[195]

Indeed all the patent work related to Schinzel's letters was still issued from the initial Austrian applications that the inventor had filed in 1936, before leaving for Rochester. In 1939, even if most of Schinzel's inventions were already patented through the collaboration with Eastman Kodak, the Austrian applications were still the "working document" from which Branch and Schinzel were frequently referring. Thus the first application 151.811 mentioned by Schinzel above was filed in July 1937, from the Austrian application filed in July 1936, and resulted in the patent US2249542 in July 1941. Finally, Schinzel carefully inspected his Austrian application from 1936 and changed his mind: "I have found, that practically all the contents of the intended USA application is already contained in the mentioned Austrian application, so that I can sign with good conscience before the U.S.A. Consul (…) and I return you this application."[196]

Schinzel's correspondence not only provides evidence of administrative patent work however. Through the letters, one also better understands how the inventor conceived his applications and what his practical constraints were during this period of intense political tension. In Zürich, he had no access to a photographic laboratory to work on the behaviour of certain chemical compounds through experimentation. But he was able to confirm the theory of his inventions by studying at the library and he

---

[195] Ibidem.

[196] Schinzel to Branch, March 6, 1939, ref. A1726, box 152, KCA-BL. The mention of the American patent 2,249,542 echoes the label "Schinzel letters RE503752" on the last Schinzel's letter. Indeed the British patent 503,752 related to the American patent 2,249,542 according to the European Patent Office archive. The British patent 503,752, whose complete specification was accepted on 11 April 1939, can be described as one of Schinzel's masterpieces with 42 pages of data about processes and chemical compounds. See the final table of Schinzel's patents.

sometimes worked there before answering Branch's request about chemical elements.[197] The first letter is instructive because Schinzel, while discussing the methods of developing reversal colour films, made reference to his collaborative work at Rochester. He was for instance aware at the time of writing that the researcher Dr. Petersen was experimenting with some colour couplers at Kodak Park at the same period, in particular high molecular coupling components. As to the filter dyestuffs used in each layer, he reported that Vittum had advised him against using titanic ferrocyanide because it was not intense enough and Schinzel mentioned that uranyl ferrocyanide may be a better compound for this process. Apparently, the chemical fogging of layers had not been studied enough at Rochester according to Schinzel.

> All the fogging methods were denied by M[ess]rs. M[annes]. & God[owsky]., and they had already worked out a complicated process with intense green blue illumination from behind for the middle image. I must come to demonstrate within some weeks, that pure fogging is the best method […].[198]

Three days later, Schinzel got in touch with Branch again about the fogging with ferrocyanide. Again, the letter contains evidence of Schinzel's scientific collaboration at Rochester and proves the intense exchange of chemical knowledge between the most prominent actors of the American Kodak Research Laboratory and the independent photochemist.[199] In the letters Schinzel also discussed the subtle strategy of the patent system. The inventor, despite his extensive experience with patent work, feared the possible risk created by the time gap between the filing of the provisional specification and the filing of the complete one.

[197] "Aniles and other compounds decomposable by acids, I have studied yesterday and to-day in the library, not very easy as volumes are lent out." Schinzel to Branch, February 4, 1939; "I have in the library carefully studied your 1-14, but I did not find amino-derivate, which would yield by hydrolyse non-diffusing couplers, they are all too low-molecular." Schinzel to Branch, March 2, 1939, ref. A1726, box 152, KCA-BL.

[198] Schinzel to Branch, February 4, 1939, ref. A1726, box 152, KCA-BL, 2. It is interesting to recognize here the selective re-exposure method used in the reversal process as secured by Mannes, Godowsky and Wilder in 1938 through the patent US 2,252,718 and already studied above in section 4.2.1.

[199] "I had great hopes for titanic-ferrocyanide, Dr. Mees was very enchanted of its intense colour in the test-tubes, but Dr. Vittum told me, it is by far not so intense as colloidal Ag ; I hope, that he is not mistaken." Schinzel to Branch, February 7, 1939, ref. A1726, box 152, KCA-BL. "Ag" is the symbol of the silver chemical element.

> I have remarked in the London Patent Library, there is a huge literature and uncertainty as to the "legal development" if in the meantime, before filing the complete specification, another is filing an application, comprising the new material contained in the complete specification.[200]

In fact, some of his inventions were similar to the technology disclosed in two German patents that Agfa gained in May and June 1937. To avoid an infringement of the Agfa patents and the possible refusal of his application in Germany, he proposed to Branch to add a disclaimer to exclude the substances already described in the Agfa patents. Schinzel's strategy was also to study the claims published in the Agfa patents to provide some additional innovation in his own claims. "Agfa has forgotten in claim 1 line 16 : …stage an insoluble or almost or totally non-diffusing dyestuff component… I believe, my claim 3 in Austrian 7.7.36 is much more distinct !"[201] Finally Schinzel suggested to Branch to start an opposition procedure against the Agfa patents due to its remarks about chemical elements. He also justified the possibility of opposition because he had published some of his findings in *Das Lichbild* before than Agfa sent its complete specification to the British patent office. Thus Agfa could have theoretically used Schinzel's findings for its own British patent 468,946. This striking example of time management applied to patent strategy illustrates well the difficulties for an inventor or a research organisation to control the legal and official property of its own inventions. Apparently, as it has been previously discussed, all the patent work provided in the letters regarding the Schinzel patent application in Germany was unfruitful and no corresponding German patent was gained.

During the summer 1939 Schinzel came to London to work with Branch and L.E. Jones. The inventor went back to Switzerland in August 1939. As Branch testified later, he "last saw Karl Schinzel during August 1939 when [he] left London to go to France".[202] But on 16 September 1939, Schinzel sent a letter to Eastman Kodak from Germany indicating that he had been surprised there by the outbreak of the war and that he

[200] Schinzel to Branch, March 23, 1939, ref. A1726, box 152, KCA-BL, 2.

[201] Ibid., 2. Schinzel was referring to the Agfa British patent 465,823 issued on May 13, 1937.

[202] Statutory declaration of Leonard E. Jones and of Leslie E.T. Branch, n. d., ref. A1251, box 89, KCA-BL.

might be obliged to perform military service.[203] As a consequence, the Eastman Kodak managers finally decided to use an article of the retainer agreement signed with Schinzel to reduce his annual salary from $6000 to $2500.[204] The probable failure of the creation of the Research Laboratory was not the only problem. The European Kodak network was unable to locate Schinzel, and the signature of the Schinzel brothers was still necessary to file nearly 22 divisional patent applications in Great Britain.[205]

After Schinzel's disappearance at the end of the year 1939, Perrins expressed his discouragement and suggested to stop "writing up these applications which could not be filed", as it seemed impossible to have them signed by the inventor.[206] On the other hand, the request to file the 22 divisional applications from the many claims of the original patent was a way for Eastman Kodak to secure the specific unclaimed inventions. As this patent work was postponed, the risk was that the original patent would be granted while the unclaimed inventions could be disclosed in applications filed by other researchers or companies. For his part, Branch suggested getting the signature of Ludwig, the brother of Karl Schinzel, through the German and Czechoslovakian subsidiaries of Eastman Kodak.[207] However Schinzel reappeared in March 1940, by sending an application signed in a simple letter to the Dutch correspondents of the patent agent L.E. Jones in Liverpool. The form was dated the first March 1940 in Karl Schinzel's handwriting and dispatched from Holland on 26th March.[208] In April 1940, L.E. Jones was also informed that Schinzel sent a letter to their

[203] Thomas J. Hargrave to Nils Bouveng, November 10, 1939, ref. A1251, box 89, KCA-BL. Hargrave was the head of the Legal Department of Eastman Kodak and became president of the company in 1941.

[204] "We naturally cannot forecast what the circumstances may be at the end of the war, but if Schinzel is available then and wants to proceed with the laboratory project, Dr. Mees at the present moment is of the opinion that he should do so. However, the whole color picture may change by then." Hargrave to A. D. Page, November 10, 1939, ref. A1251, box 89, KCA-BL.

[205] Perrins to Hargrave, January 11, 1940, ref. A1251, box 89, KCA-BL.

[206] Ibidem.

[207] Branch to Jones, March 5, 1940, ref. A1251, box 89, KCA-BL.

[208] Jones to the Patents and Trade Marks Department of Kodak Ltd., March 29, 1940, ref. A1251, box 89, KCA-BL.

German correspondents M. Breitung & Marsch in Berlin including an assignment signed and a new postal address in Vienna.[209] A few weeks later, the Dutch correspondents L.E. Jones provided the 22 application forms signed by Schinzel, received in Holland from M. Breitung & Marsch.[210] There was renewed hope at Eastman Kodak then and Branch planned to have other pending documents signed by Schinzel despite the procedural difficulties. This optimism was short-lived however. In the summer 1940, Mr. Sutherland of Kodak S.A. in Lausanne forwarded a letter from Schinzel clarifying the possibilities of communication with foreign countries.

> I beg to inform Kodak Limited in London that it is useless to send me anything to sign, because I should not be able to return it, all communications, also the indirect ones through neutral country being prohibited under the most severe penalties.[211]

Perrins from the Patent Department at Rochester had also sent many papers for Schinzel to sign and, in the same letter, the inventor confirmed he had sent in May 1940 nine American applications signed to Eastman Kodak. This exchange was still allowed as the United States of America had not yet entered the war.[212] Branch reacted quickly to Schinzel's remark, arguing it could be theoretically possible for an inventor in enemy territories to communicate through the British Patent Office to get documents signed. But he also suggested a second option to Perrins, that is to "get a Power of Attorney from Schinzel to sign on his behalf all patent applications in countries outside the United States". With this subterfuge they could stop chasing the Schinzel brothers throughout most of Europe.[213] Some days later Perrins confirmed that Rochester had received one power of attorney signed by Karl and Ludwig Schinzel in favour of a colleague of the chartered Patent agent L.E. Jones in Liverpool. Further paper work was thus made easier. From this point on, Schinzel's correspondence with the Eastman Kodak agents during the Second World War discontinued, and the fate of

[209] *Vereenigde Octrooibureaux* to Jones, April 10, 1940, ref. A1251, box 89, KCA-BL.

[210] Branch to Perrins, April 22, 1940, ref. A1251, box 89, KCA-BL.

[211] Perrins to Hargrave, Branch and Chapman, July 15, 1940, ref. A1251, box 89, KCA-BL.

[212] Ibidem.

[213] Branch to Perrins, August 15, 1940, ref. A1251, box 89, KCA-BL.

all Kodak correspondents becomes almost impossible to clarify from an analysis of the archive. Schinzel's own fate will be revealed at the end of the section but most important, a clarification of his scientific contribution to colour photography has to be done through the analysis of his numerous patents. Doing so not only complements the prior research work of Mannes, Godowsky, Wilder or Martinez studied before but also stresses the crucial fact of gathering scientific knowledge through the making of patents.

The complete study of the full patent work of Karl Schinzel has never been done before. The rare references citing Schinzel and his research work give only a partial list of patents obtained between 1939 and 1944 in England and in the United States of America.

Patent number	Inventor	Convention date (Austria)	Application date (in UK)	Granting date	Title (complete)	Eq. US Patent
GB498663	Karl Schinzel	09/05/1936	10/05/1937	10/01/1939	Improvements in Processes for the Production of dye images from photographic silver salt images	US2295013 US2172262
GB498869	Karl Schinzel				Process of Colour Photographic Development	-
GB498870	Karl Schinzel				Process of Colour Photographic Development	-
GB498871	Karl Schinzel				Process of Colour Photographic Development	-
GB498874	Karl Schinzel				Improvements in Colour Photographic Elements	-
GB498875	Karl Schinzel				Process of Colour Photography	-
GB499185	Karl Schinzel	-	09/05/1936		Process of and Materials for Colour Photography	-
GB500716	Karl Schinzel	09/05/1936	10/05/1937	10/02/1939	Method of Colour Processing a Colour Photographic Element	-
GB500717	Karl Schinzel				Improvements in Colour Photographic Elements and Processing thereof	-
GB500718	Karl Schinzel				Improvements in Colour Photographic Elements	-
GB500719	Karl Schinzel				Improvements in the Production of multi-layer Colour Photographs by Reversal	-
GB500720	Karl Schinzel				Improvements in Processes for the Production of dye images from photographic silver salt images	-
GB500721	Karl Schinzel				Improvements in and relating to Three-Colour Photography	-
GB500793	Karl Schinzel				Process of and Materials for Colour Photography	-
GB500794	Karl Schinzel				Method for the Production of Colour Photographs	-
GB500795	Karl Schinzel				Improvements in Colour Photographic Elements	-
GB500796	Karl Schinzel				Improvements in and relating to Colour Photography	-
GB500826	Karl Schinzel				Process of and Materials for Colour Photography	-

GB501000	Karl Schinzel				Process of Colour Photography	-
GB501001	Karl Schinzel				Process for Colour Photography	-
GB501002	Karl Schinzel				Process of and Materials for Colour Photography	-
GB501003	Karl Schinzel				Process of Colour Photography	-
GB501040	Karl Schinzel			not accepted	Improvements in Colour Photographic Development	-
GB503752	Karl Schinzel				Process of Colour Photography	US2249542
GB503814	Karl Schinzel				Improvements in Three-Colour Photographic Materials	
GB503815	Karl Schinzel				Improvements in the Production of Natural Colour Photographs by Colour Development	-
GB503816	Karl Schinzel				Improvements in Sensitive Material for Three-colour Photography	-
GB503817	Karl Schinzel				Improvements in Sensitive Material for Three-colour Photography	-
GB503818	Karl Schinzel				Improvements in Sensitive Material for Three-colour Photography	-
GB503819	Karl Schinzel				Improvements in Sensitive Material for Three-colour Photography	-
GB503820	Karl Schinzel				Improvements in Sensitive Material for Three-colour Photography	-
GB503821	Karl Schinzel				Improvements in Sensitive Material for Three-colour Photography	-
GB503822	Karl Schinzel	07/07/1936	07/07/1937	11/04/1939	Process of Colour Photography	-
GB503823	Karl Schinzel				Improvements in Materials for Colour Photography	-
GB503824	Karl Schinzel				Process of Colour Photography	-
GB503825	Karl Schinzel				Process and Materials for Colour Photography	-
GB503826	Karl Schinzel				Process and Materials for Colour Photography	-
GB503827	Karl Schinzel				Process and Materials for Colour Photography	-
GB503939	Karl Schinzel				Improvements in Three-Colour Photographic Materials	-
GB503940	Karl Schinzel				Improvements in the Production of Colour Photographic Picture Films having Sound Tracks	-
GB503941	Kodak Limited				Process and Materials for Colour Photography	-
GB512559	Karl Schinzel	03/12/1936	03/12/1937	20/09/1939	Improvements in and relating to Colour Photography	US2249541
GB512752	Karl Schinzel			25/09/1939	Improvements in and relating to Colour Photography	
GB516719	K. and L. Schinzel[214]	10/04/1937	09/04/1938	10/01/1940	Improvements in Colour Prints by multiple Colour Development	US2266442
GB516536	K. and L. Schinzel	25/06/1937	27/06/1938	04/01/1940	Photographic Films especially Colour Films bearing Sound tracks	US2246013
GB520173	K. and L. Schinzel	-	27/06/1938	16/04/1940	Photographic Films especially Colour Films bearing Sound tracks	
GB523296	K. and L. Schinzel	-	06/09/1938	11/07/1940	Process and Material for the Production of Colour Photographs	
GB521746	K. and L. Schinzel			30/05/1940	Production of Coloured Pictures	US2227981
GB521833	K. and L. Schinzel			31/05/1940	Production of Coloured Pictures	
GB521834	K. and L. Schinzel	22/10/1937	22/10/1938		Production of Coloured Pictures	-
GB521835	K. and L. Schinzel				Production of Coloured Pictures	-
GB521836	K. and L. Schinzel				Production of Coloured Pictures	-

214 Karl and his brother Ludwig Schinzel.

GB521837	K. and L. Schinzel				Production of Coloured Pictures	-
GB521888	K. and L. Schinzel			03/06/1940	Production of Coloured Pictures	-
GB524552	K. and L. Schinzel	23/12/1937	23/12/1938	08/08/1940	Process of Making Natural Colour Photographs	-
GB524553	K. and L. Schinzel				Process for Making Natural Colour Photographs	-
GB525808	K. and L. Schinzel			04/09/1940	Process for Making Natural Colour Photographs	-
GB525810	K. and L. Schinzel				Process of Making Natural Colour Photographs	-
GB533568	Karl Schinzel	-	16/06/1939	17/02/1941	Improvements in and relating to Colour Photography	US2276254

Table 9. Karl Schinzel British patent work from 1936 to 1941.

Patent number	**Inventor**	**Convention date (Austria)**	**Application date (in US)**	**Granting date**	**Title (complete)**	**Eq. British Patent**
US2295013	Karl Schinzel	09/05/1936	29/04/1937	08/09/1942	Method of Developing Multilayer Photographic Color Films	GB498663
US2172262	Karl Schinzel			05/09/1939	Ultraviolet Filter in multilayer Film	
US2249542	Karl Schinzel	07/07/1936	03/07/1937	15/07/1941	Rehalogenation process of color photography	GB503752 GB503814
US2249541	Karl Schinzel	03/12/1936	02/12/1937		Production of natural Color Photographs by Intermediate Dye Coupling	GB512559 GB512752
US2266442	K. and L. Schinzel	10/04/1937	07/04/1938	16/12/1941	Color Print by multiple Color Development	GB516719
US2246013	K. and L. Schinzel	25/06/1937	18/06/1938	17/06/1941	Color Sound Film	GB516536 GB520173
US2227981	Karl Schinzel	22/10/1937	21/10/1938	07/01/1941	Method of Preparation of Natural Color Pictures	GB521746 GB521833
US2276254	Karl Schinzel	-	14/06/1940	10/03/1942	Color Photography	GB533568
US2193011	Karl Schinzel	09/05/1936	30/12/1938	21/03/1940	Colored Photographic Image	-
US2206126	Karl Schinzel		29/04/1937	02/07/1940	Photographic Color Developer	-
US2226639	Karl Schinzel		29/04/1937	31/12/1940	Color Photography	-
US2231684	Karl Schinzel	-	29/04/1937	11/02/1941	Monopack Film sensitized with layers containing different silver halides	-
US2306410	Karl Schinzel	07/07/1936	03/07/1937	29/12/1942	Color Development	-
US2263012	Karl Schinzel	23/12/1937	17/12/1938	18/11/1941	Process for making Natural Color Photographs	-
US2266443	Karl Schinzel	09/05/1936	08/12/1938	16/12/1941	Semipermeable Layer for multi-layer Film	-
US2213745	K. and L. Schinzel	06/09/1937	19/08/1938	03/09/1940	Making Silver-free Three-Color Prints	-
US2356475	Karl Schinzel	07/07/1936	24/03/1939	22/08/1944	Phenolic and Naphtholic Couplers containing Sulphonamide Groups	-

Table 10. Karl Schinzel American patent work from 1936 to 1944.

Apart from the secondary sources already cited, the recent *Timeline of Historical Film Colors* published online by Barbara Flueckiger was helpful as a start for an incomplete set of Schinzel's patents. Some of the patents were listed in a publication by Adrian Cornwell-Clyne in 1951. For the rest of the patents attributed to Karl Schinzel alone or with his brother Ludwig, I analysed the database of the European Patent Office also available online. I performed a double search for which Schinzel was either the applicant of the patent, or the official inventor. In this manner the list of Schinzel's patents was completed and the inventions for which a British patent as well as an American patent were granted were also identified.[215]

In almost all Karl and Ludwig Schinzel's patent literature, some mention was made of a "convention date" in Austria, which always pre-dates the specification application (see Tables 9 and 10). In the patent system, this "convention date" makes reference to the Paris Convention priority right of the inventor.[216] This procedure allows the claimant to file an application in a contracting State of the Paris Convention so that the filing date will be recognised by all the other member countries. Then the inventor has to file a subsequent application within a specific period from the first filing in the countries where he wants to request a patent. Practically, Schinzel used this method in Austria when he started to publish the description of his research work in *Das Lichtbild* in 1936. This way his inventions were secured, provided that he kept on working on the writing of the patent applications. As Schinzel's Austrian applications were filed before the inventor was invited by Eastman Kodak to Rochester, and due to the large amount of scientific findings, Schinzel's strategy was highly risky. It is unlikely that Schinzel, operating alone without the collaboration of the staff of the Eastman Kodak Patents and Trade Marks Departments, would have been able to produce this extensive patent

---

[215] Barbara Flueckiger, "Kodachrome Reversal," Timeline of Historical Film Colors, University of Zurich, accessed September 20, 2015, http://zauberklang.ch/filmcolors/timeline-entry/1277/#; Adrian Cornwell-Clyne, *Colour Cinematography* (London: Chapman & Hall, 1951), 427-451; European Patent Office, "Espacenet Patent Search," http://worldwide.espacenet.com/advancedSearch?locale=en_EP.

[216] The treaty of the Paris Convention for the Protection of Industrial Property was signed in Paris on 20 March 1883. The contracting member countries constitute the Union for the protection of industrial property. The United Kingdom became a member in 1884, the Austria in 1909 and the United States of America in 1887. The treaty is still in force today with 176 members as of 2014.

literature. In an ontological sense, the teamwork with Eastman Kodak acted as a collaboration revealing Schinzel's research work and inventions. It is peculiar that despite this mutual development of scientific facts and inventions in the field of colour photography, Schinzel's contribution to photographic science has not emerged and has remained confined within the paragraphs of patents.

Admittedly, Schinzel's theoretical work that could be found in his Austrian applications was not within the reach of midrange photochemists dealing with standard black and white photography. In fact the inventor synthesised years of photographic research by compiling specialised literature, photographic patents and his own chemical experimentation in the laboratory. Schinzel represents a turning point in understanding the activities of the Kodak Research Laboratories. From his contribution to colour photography the understanding of his research work becomes more difficult and the degree of expertise rises significantly. The patents and work of Mannes, Godowsky, Wilder or Martinez for instance were more intelligible in comparison for the *interactional* expert, whereas Schinzel's work requires an analysis from a *contributory* expert, according to the definition of Collins and Evans.[217] My interactional expertise was enough as well to analyse the many Harrow Research reports and to sort them out into several categories in chapter 3. But the Schinzel literature, principally made of pure scientific knowledge, exceeded the limits of my own expertise to be able to state whether or not an innovation that can be found in a patent is significant to colour photography. Thus this in-depth analysis from a contributory expertise will not be undertaken within the framework of my research and I will rather clarify some scientific and technological processes involved in Schinzel's patents that echo the methods and processes used at that time by the Kodak Research Laboratories.

A tally of the British patents resulting from the Austrian applications filed on 9 May and 7 July 1936 proved that Coote's reference in 1993 was right[218] : 41 patent documents

[217] Collins and Evans, *The third wave of science studies*, 254. Interactional and contributory expertise have been studied in sections 1.2.4. and 3.2.1.

[218] Coote, *The Illustrated History of Colour Photography*, 147.

were found, one patent receiving the British number 501,040 but with the mention "*application void*" and the specification refused. From this batch of British patents, only three resulted in American patents. It does not necessarily mean that only these later American patents would have been used for the production of colour film. Indeed the existence of the patent is not always linked with the immediate need of its embedded invention for production, but also to protect innovative technology from use by an industrial competitor. In the first British patent 498,863, Schinzel disclosed a method of removing the metallic silver during the colour development without removing the dye associated with it. The dye was rendered insoluble and was prevented from diffusing through the adjacent layers by treating the image with a precipitant for the dye before removal of the silver.[219] In the related American patent 2,172,262 Schinzel studied in particular the selective development of a colour photographic element with three gelatino-silver halide emulsion layers and additional filter layers absorbing ultra-violet, within the framework of a three-colour reversal development. The purpose was to be able to expose the element to ultra-violet light to develop a particular layer with no incidence in the other ones. The yellow and ultra-violet filters were used to divide of the spectrum in the intermediate layers. Schinzel also provided some examples of re-exposures with lights of different nature (red, blue, yellow, ultra-violet, X rays etc.). The invention was used to improve the colour rendering of the colour monopack.

[219] The precipitant could be phosphotungstic acid for weakly basic dyes, or inorganic or organic bases for acid dyes.

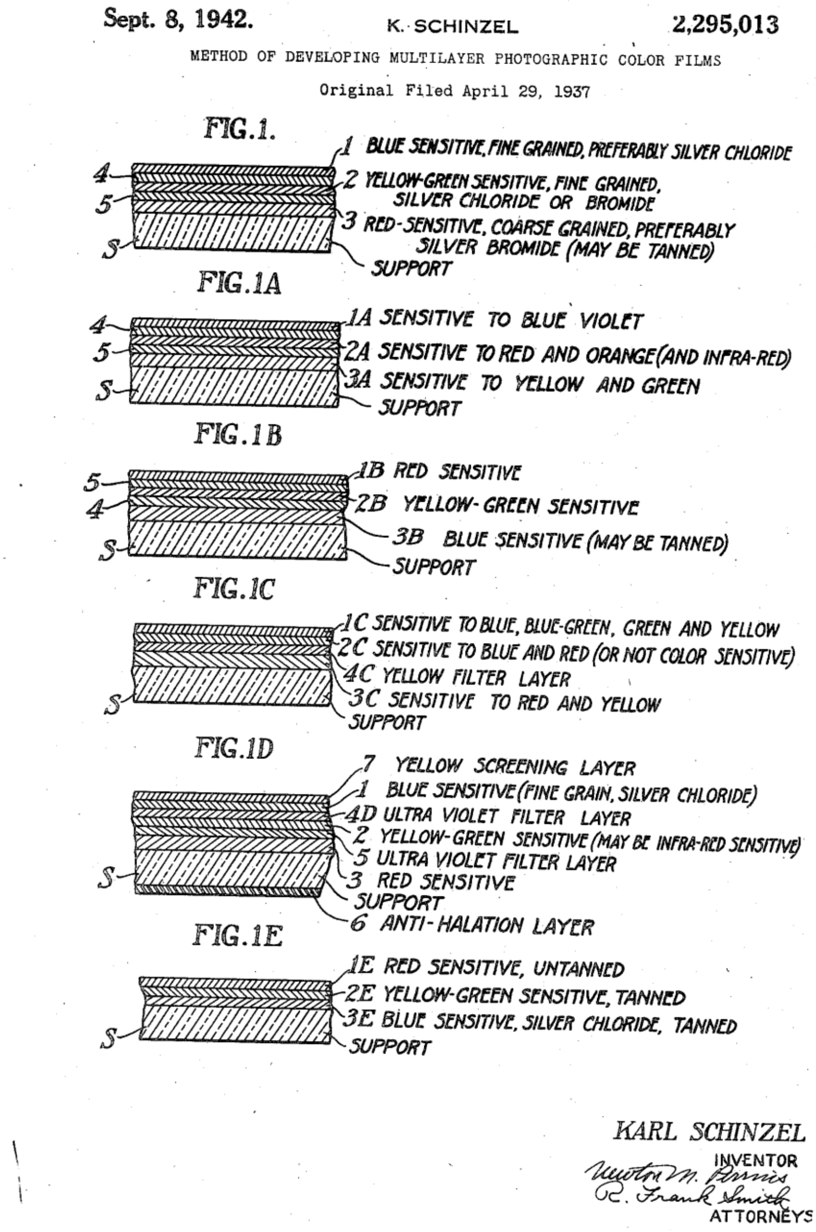


Illustration 11. Drawings of Schinzel's American patent US 2,295,013, on the cover.

In the related American patent 2,295,013 the technology of selective re-exposure within the same context of reversal development is defined even better.[220] However in all

[220] "The steps of re-exposing one of the exterior layers to light of a color absorbed by the filter between the re-exposed layer and the middle layer, developing an image in color in such re-exposed layer, re-exposing the other of the exterior layers to light of a color absorbed by the filter between such other layer and the middle layer, developing an image in a second color in such re-exposed layer, rendering the middle layer developable by chemical means and developing an image in a third color in said middle

claims the middle layer was always rendered chemically developable and Schinzel did not disclose a similar technique with particular light exposure (see Illustration 11). In this latest of Schinzel's inventions there is a similarity with the selective reversal process studied and worked out by Wilder, Phillips and other Kodak researchers in 1938. Therefore it is necessary to point out that Wilder's research work on the new colour processing of Kodachrome in 1938 was influenced by Schinzel's technology of selective re-exposure in particular.[221] This remark confirms the significant role of the patent system in the transfer of scientific knowledge. It also stresses that the development of an innovation can be enriched by preceding innovations.

In the British patents that also resulted from the first batch of Austrian applications, Schinzel disclosed some data about the chemical nature of the developing agents applied to colour development (498,869, 498,871) and discussed the principle of colour development itself, which consists in converting a colour component silver salt image into a dye image with a developing solution (498,870). In the British patent 498,874 Schinzel provided a new development of the selective re-exposure process of either reverse silver halide images or silver salt images obtained by reconversion of silver images.[222] With this innovation, the other emulsions were unaffected during the re-exposure of the specific emulsion. To this end Schinzel insisted on the use of an infra-red sensitiser. Concerning the nature of the dyes, the inventor also disclosed his findings about a special developer consisting of an alkaline solution or suspension of a leuco vat dye. This developer, as explained in the British patent 498,875, was used to convert a colour component silver salt image into a dye image. The leuco form of the dye was colorless and water-soluble but became coloured and insoluble after oxidation. Thus

layer." Karl Schinzel, "Method of developing multilayer photographic color films," American patent US 2,295,013, filed April 29, 1937, and issued September 8, 1942, 11.

[221] It is a pity that the Kodak Collection Archive did not reveal some evidence of teamwork between Wilder and Schinzel, during Schinzel's stay at Rochester.

[222] "This is done by giving one of the emulsions a sensitivity to light outside the region it is destined to record and to which it is sensitized, such as to infra-red light, by means of another sensitizer which is stable to developing or developing and oxidizing baths." Karl Schinzel, "Improvements in colour photographic elements," British patent 498,874, filed May 10, 1937 (in United Kingdom), and issued January 10, 1939, 1.

after the residual silver was removed the dye remained in the layer. The British patent 500,716 disclosed the use of organic mercaptans and coloured mercaptides, some innovative chemical components of the period that proved useful for the production of coloured images.[223] The mercaptides produced were orange-coloured and Schinzel stressed that the invention did not require the exposure of the silver halide to light in the middle layer, which was particularly convenient for a monopack made of three differentially coloured sensitised silver halide emulsions coated on a single support. This patent was followed by 14 other British patents all granted the same day on 10 February 1939.

The subsequent set of 18 patents provided from the second set of Austrian applications filed on 7 July 1936. The first British patent 503,752 is remarkable as it clarified partially the Schinzel's research method. The inventor disclosed chemical formulas of developers and coupling components necessary for the colour development of double or triple layers monopacks. The patent document contains no less than 42 pages including some tables that "give examples of compounds indicated", and references to publications in which the specific compound was studied.[224] These endless lists of examples, issued from years of literature review, were also a way of submerging the reader with chemical formulas and to make a convenient selection of chemical compounds almost impossible to a competitive researcher. It is sometimes difficult to understand the relationship between British and American patents, since for instance the situation of the British patent 503,752 above was linked by the European Patent Office to the American patent 2,249,542. It involved a method of multilayer monopack colour development rather than a list of developers and couplers. The author provided some information only about the coupling developers and also some examples about the chemical nature of the

[223] "It has now been found that the coloured mercaptides formed by reaction between metallic salts, especially silver salts, and organic mercaptans or their alkali metal or ammonium salts are suitable for the production of coloured images useful in the colour processing of a multi-layer colour photographic element […]." Karl Schinzel, "Method of colour processing a colour photographic element," British patent 500,716, filed May 10, 1937 (in United Kingdom), and issued February 10, 1939, 1.

[224] The journals were publications issued from five National Patent Offices and eleven journals in chemistry.

couplers. For this process the couplers were integrated in the photographic layers and not added during the development. It was made of insoluble or non-diffusing compounds that formed “a colored image by coupling with the oxidation product of a primary aromatic amino coupling developing agent”.[225] Schinzel hid from the reader that it was necessary for the process that the couplers did not diffuse during the coating of the emulsions or during the development. This information points out the theoretical character of this invention.

Sixteen other British patents issued from the Austrian applications of July 1936 follow. All relate to Schinzel’s research work before his collaboration with Eastman Kodak. It is more interesting to go over to the set of British and American patents from the Rochester period in 1937-1938, because it is directly linked with Schinzel’s period of scientific collaboration on-site. It represents 17 British patents and 4 American patents and for the majority of them, Ludwig Schinzel is also mentioned with his brother as the co-author of the invention.[226] In the American patent 2,249,541 Schinzel disclosed new information about the colour development of a monopack film including the couplers in the layers. In 17 pages the inventor illustrated all the possibilities of chemical reactions with the detail of the chemical compounds used. The couplers were in fact coupling derivatives of a dye compound and for Schinzel the definition of these critical elements in the colour process was important for the comprehension of the invention.[227] Another patent clarified the nature of some of these couplers and pointed out the difficulty of adding those made of insoluble salts into the emulsion as

[225] Karl Schinzel, “Rehalogenation process of color photography,” American patent US 2,249,542, filed July 3, 1937, and issued July 15, 1941, 1.

[226] Although Ludwig Schinzel probably assisted his brother Karl during the Interwar period for laboratory work and or publications in journals, his faithful contribution did not interfere with Karl Schinzel’s pure research work. All indications lead to believe that Ludwig was not with Karl at Rochester between 1937 and 1938 and it is therefore peculiar to find his name in the patents of that period. One reason of this co-authoring could be the direct receipt of sums relating to patent rights in a European bank through Ludwig Schinzel.

[227] Schinzel described couplers as “dyes or dye derivatives such as the reduced form of anthraquinone which are combined with, or contain, a group which couples with the oxidation product of an aromatic amino photographic developer.” In several claims, the photographic developer was the paraphenylene diamine. Karl Schinzel, “Production of natural color photographs by intermediate dye coupling,” American patent US 2,249,541, filed December 2, 1937, and issued July 15, 1941, 16.

they can crystallize.[228] Furthermore Schinzel did not neglect to undertake research on the sound track and its development in a colour monopack. In the American patent 2,246,013, the strategy was to control the diffusion of the developing solutions through the nature of the gelatin. Two general layers were used. In the first one made of soft gelatin and containing silver chloride the picture image was printed and developed in a weak developer. In the second one made of harder gelatin containing sensitive silver bromide the sound track image was printed and developed in a strong developer. One understands from these descriptions of Schinzel's technologies that at that time the photochemist had to deal with several recurring characteristics of the chemical compounds. First of all their nature which implies their selection or rejection according to the advance of organic and colloidal chemistry. Secondly their solubility in pure water or other aqueous substances, and the ability to fix a compound in a layer or remove it during the development. But also the physical nature of the compound was important to control, that is to say its colour: beyond its intrinsic spectral sensitivity, a chemical compound also performed in some processes as a colour filter, for instance blocking some of the visible spectrum to remove any lighting effect on the adjacent layers. All this, including the presence or absence of coupling compounds into the layers, generated a new science of colour photography that very few scientists were able to master and develop.

From the set of patents above, Branch mentioned at the end of 1939 four British patent applications that would result in four of these patents. At this time, the Kodak staff had no news from Schinzel and in his statutory declaration, Branch testified to Schinzel's faithfulness towards Eastman Kodak.[229] In the Schinzel patents inventory, the last identified British patent specification was signed by Schinzel in June 1939 and

---

[228] In the American patent 2,266,442, Schinzel disclosed the nature of some couplers: an aryl hydrazide including its chemical structure, an aryl hydrazide of aceto-acetic acid, an aryl hydrazide of α-naphtol carboxylic acid or some insoluble salts of varied compounds.

[229] "He often had informed me that he wishes to continue to work for the E.K.Co. Karl Schinzel made it clear to me beyond all doubt that he wished W.P. Thompson & Company to file application 31061/39 (Case 5)." Statutory declaration of Leslie E.T. Branch, n. d., ref. A1251, box 89, KCA-BL. Leonard E. Jones, the chartered Patent agent of Kodak Ltd., was working at W.P. Thompson & Company. The British patents concerned are 520,173, 521,746, 521,888 and 525,808.

the equivalent patent 533,568 was granted in February 1941. The related American patent 2,276,254 was granted in June 1942 and its specification filed in June 1940. In a brief letter, Perrins informed one Kodak Limited chartered patent agent that he had received from Kodak Lausanne the corresponding US patent application signed by Schinzel on 22 May 1940.[230] Although the patent work seemed to continue from the Schinzel specifications during the Second World War, no additional Schinzel patent was identified as later than the American patent 2,276,254. Branch, Perrins and the rest of the Kodak staff did not know if Schinzel would survive the war. But after all, work on his specifications was not wasted time according to Crowther.

> I feel our appeal (…) would be considerably strengthened if we could put before Schinzel, at the appropriate time, the evidence of our acts of goodwill in piloting his Patents through in his absence and of doing everything we could to keep them alive.[231]

Of course this work was not done unselfishly and the objective was the gaining of exclusive licenses under Schinzel's patents. But paradoxically the terrible constraints of the war and the arm-wrestling contest about intellectual property of Schinzel's inventions allowed a successful conclusion to the inventor's patent work.

Karl Schinzel survived the Second World War. Some letters in the Kodak Collection Archive clarify the fate and role of the photochemist during the war, from his point of view. In the summer 1939, he left London for Rotterdam with a Dutch steamer to better comprehend "the development of the political situation". Suspected as a German spy by the Dutch harbour police, he was deported to Germany with two German professors of the University of Oxford and London. After this he remained under the control of the German authorities.[232] According to Wünsch, he worked for the manufacturer Zeiss-Ikon in Berlin in 1942 but, as the city was regularly bombed by the Allies, he was allowed to go back to Vienna in 1943.[233] As soon as the war came to

[230] Perrins to Thompson, June 7, 1940, ref. A1251, box 89, KCA-BL.

[231] Crowther and Branch to Perrins, January 29, 1940, ref. A1251, box 89, KCA-BL, 5.

[232] Schinzel to Branch, August 28, 1947, ref. A1251, box 89, KCA-BL.

[233] Wünsch, "Karel Schinzel, An Inventor Crossed by Fate," 18-19.

an end, Schinzel contacted Kodak Limited again and sent a first letter to the deputy chairman William Webb in July 1945. He never gave up the idea of the new Research Laboratory and wanted to express his complete loyalty towards the pre-war project.[234] However, the situation had dramatically changed after the war. Schinzel was informed that Webb suddenly died in April 1943 and his many requests in July 1945 were sent to Hargrave, the new president of Eastman Kodak from 1941.[235] Cash reserves of industries like Kodak and its subsidiaries were much reduced and it seems that the Swiss Research Laboratory project was progressively abandoned, and no definite answer was sent to Schinzel. Even worse for the inventor, his personal laboratory and his specialised library in the family house in Baden near Vienna were vandalised and partially destroyed by the Russian army in April 1945. Schinzel lost years of data collection in the field of photography. As he remained in contact with Kodak Limited up to his death, he regularly requested some photographic journals or patents from Branch. In 1949, Schinzel was still working on a new process. In a letter to the inventor, Branch indicated that he had studied the corresponding applications with the Dutch Patent agents of Kodak Limited for what he named the *elimination coupling process*. As Schinzel had suggested to Branch some experiments about the process, the Kodak manager confessed his helplessness in this matter.

> We are not allowed to do colour research at Harrow without first asking Rochester, because this work is centralised in the laboratories in Rochester, which is the only place having the proper facilities. However, I wrote to Rochester last week explaining in full our difficulties and I think that they will help us to solve them […].[236]

This last research was apparently never fulfilled. Karl Schinzel died suddenly on 23 November 1951 and over the following years his brother Ludwig corresponded from

[234] "Please to make yourself a petition to the Swiss Government in Bern, that your House has a great interest that a Research Laboratory should be established for the inventor of the modern Kodachrom film, which was planned already before the war, and the respecting petition was filed be me 1. May 1939." Schinzel to Webb, July 26, 1945, ref. A1251, box 89, KCA-BL, 1.

[235] Page to Schinzel, September 17, 1945, Page to Hargrave, September 17, 1945, ref. A1251, box 89, KCA-BL.

[236] Branch to Schinzel, April 28, 1949, ref. A1251, box 89, KCA-BL.

time to time with Branch, requesting some copies of Karl's letters to his Kodak Limited quasi-colleagues. This was the end of a long-term scientific collaboration.

4.3. Conclusion of Chapter 4

Chapter 4 opened with a chronological and technological narrative about the all-round research of a subtractive tripack during the Interwar years. I argued that Kodak research was not limited to the in-house work of the Kodak Research Laboratories scientists. Unlike traditional views concerning not only the history but the business and industrial research of Kodak, the development of new products came frequently within the scope of external technologies often theorised but not applied to the production side.[237] To this end, photographic research was increasingly correlated with the patent system and its subsequent protection of intellectual property and innovation from 1920. Scientific discoveries and inventions were hidden in patent jargon and in its claims. Thus the patent played an increasingly active part in the process of innovation and invention. Sometimes the research period was disconnected from the date of the patent's award due to the strict control process of the patent application, such as the Troland's case and the patent reissue 18680.[238] For the photochemists Mannes and

[237] Jenkins described in detail how Kodak Research was organised from 1912 on, using George Eastman correspondence and Kenneth Mees most significant publications. But he did not investigate other archival materials to understand how Kodak Research really worked in the first years of the Research Laboratory. See Jenkins, *Images and Enterprise*, chapter 14, section "Eastman Kodak. Research and Development," 300-318. For his conference paper Sturchio also used Mees's publications and academic literature about business and industrial research as well, but did not consider the administrative production of the Kodak Research Laboratory at Rochester. See Sturchio, "Experimenting with Research: Kenneth Mees, Eastman Kodak, and the Challenges of Diversification," 7-19. However, one could think that Sturchio and Thackray might have been able to consult the Rochester research reports, when they worked in close collaboration with the Kodak researchers at the end of the 1980s for the publication of *Journey: 75 Years of Kodak Research* in 1989.

[238] Troland's reissued patent 18,680 is a good example of the use of a specific jargon in patent literature. For instance, the claim 232 mentioned "a photographic film for making color pictures comprising a base having on the same side a plurality of coatings including one coating which is sensitive to a color to which a second coating on the entrant side of said first coating is substantially insensitive and the second coating being sufficiently absorptive of other colors substantially to restrict the exposure of said first coating to light of said first color." Troland, US Patent Reissue 18,680, 21.

Godowsky, who undertook long-term research of a subtractive bi-pack and tri-pack in collaboration with Eastman Kodak, the patent was a bureaucratic tool to announce their many innovations to the competition as much as a major constraint embedded in the research process and with which they had to deal.[239] Some of the best evidence for the importance of the patent system in the photographic industry is the *History of Color Photography* published by the photochemist Joseph Friedman. The author was able to write his long narrative of technological systems of photographic reproduction in natural colour mostly from the expert analysis of hundreds of patents, frequently quoting various descriptions and formulas. As Friedman never worked for Eastman Kodak, the analysis of the patent literature was critical in ascertaining the state of the fundamental and industrial research for some Kodak processes such as the new Kodachrome or the wash-off relief process.[240] Indeed, Eastman Kodak strengthened its use of the patent system as a strategic tool concerning fundamental research in colour photography during the Interwar years.

Another section of chapter 4 dealt with the period that followed the release of the tri-colour Kodachrome in 1935. Unlike official histories of photography, this product's launch was far from an accomplishment. On the contrary, it represented a new beginning in colour research because the technology used was highly complex and ultimately required a simplification of its developing process. The research and development work at Kodak Park and the collaboration of the Harrow Research Laboratory was fundamental in improving the general characteristics of the Kodachrome process as well as protecting the innovation produced by the use of

[239] Collins placed great emphasis on Mannes and Godowsky and their scientific collaboration with Eastman Kodak, but did not mention that they were affected by constraints of already patented technologies related to photochemical compounds. See Collins, *The Story of Kodak*, 205-215.

[240] The only biography of Friedman can be found in the second edition of the *History of Color Photography* published in 1968. The author of the introduction was the photographic consultant and expert Lloyd E. Varden, who was one of Friedman's friends. Friedman gained his PhD in chemistry at the University of Chicago in 1926. Between 1928 and 1929 he assisted Edwin H. Land to develop his polarizer sheet and obtained his first patent together with the later founder of Polaroid. In 1929 Friedman joined the research laboratories of the Technicolor Corporation and worked there several years before to leave for different positions in the photographic industry. In 1943, he took a position in the Ansco research laboratories. Such as Wall, he always remained out of the Eastman Kodak "silver curtain". Joseph S. Friedman, *History of Color Photography*, 2nd ed. (London: Focal Press, 1968), viii-xiii.

patents. The scientific contribution of certain researchers at the Research Laboratory in Rochester had been underestimated as well, such as the colour research work of Wilder, Vittum or Jelley. Through analysis of the British archive and from his corpus of patents, the scientist Lot Wilder progressively emerged as a central figure of the in-house research about colour photography at Rochester up to the end of the Second World War. He invented a new developing process for Kodachrome in 1938 and reduced the many steps from 28 to 18. He also patented an innovative process by which colour couplers were incorporated into the monopack film, unlike the Kodachrome process. There were some major technological constraints, however. The most important challenge for the Kodak researchers at that time was the development of a new solution to prevent the couplers from wandering into the adjacent layers of the monopack films. It was necessary that this innovation refrain from infringing on the German technology of long-chain molecules, which was protected by dozens of patents.

Although Wilder suggested an approximate solution as seen above, it was the independent inventor Michele Martinez who authored a decisive invention secured by Kodak Limited and used later for the new Kodacolor negative film. The description of the scientific collaboration with Martinez, including the joint elaboration of a patent, clarified this fundamental innovation method used several times by Eastman Kodak. This unpublished account of such collaboration demonstrated that independent inventors were not always hired by the American manufacturer, like Mannes and Godowsky in 1930. When Eastman Kodak decided to collaborate with the Italian inventor, the Patents and Trade Marks Department of Kodak Limited was on the frontline, becoming the only interface between him and the Kodak Patent Offices. During this collaboration the Department outshone the Kodak Research Laboratories that were still used however as a *task force* necessary to support and validate the inventor’s assumptions. Thus, Martinez’ story ascertains the crucial role of Kodak Limited in the development of colour technologies in the 1930s and during the Second World War. This is particularly meaningful in the new understanding of how Kodak research really worked. Unlike Mannes and Godowsky’s story, Kodak also identified and collaborated with independent inventors on a temporary basis without recruiting them, in the style of “Open Innovation”.

Kodak Limited started to collaborate with Martinez as early as 1924, through a non-disclosure agreement referring to a colour photographic process. During the drafting of his first significant patent from 1937 onwards, Martinez not only approached Kodak Limited but also the British competitor Elliott & Sons from Barnet near London. Kodak Limited managed to strike a deal with Martinez and acquired the rights to his British patent 505,834. In this patent, the Italian inventor disclosed a physical solution to prevent the transfer of colour couplers into the adjacent layers during the chemical development of a monopack. His strategy was to localise the action of the colour former with a natural or artificial resin. This material would unite with the colour former “in a purely physical way” and not through a chemical combination. From the outbreak of the Second World War, Martinez continued to work on the improvement of his technology of localisation but also on new colour and printing processes. His work led to the British patent 543,606 that was obtained with the collaboration of Kodak Limited. For this new photographic process, the resin binders not only contained the colour former but also the silver halide that had been precipitated in close physical association with it. The resin binder, acting as an insulator for the silver salts and the colour couplers, itself spread into the gelatin of the emulsion.

The rest of chapter 4 analysed the lengthy development work necessary for the British patent 543,606, which took place in 1941 and 1942. This scientific collaboration between Martinez and the team of the Patents and Trade Marks Department of Kodak Limited faced a major constraint. The Italian photochemist was arrested in January 1941 and sent to one of the internment camps on the Isle of Man. Despite Martinez’s internment, he corresponded regularly with Branch and Crowther of Kodak Limited and they worked jointly on the specifications corresponding to the future British patent 543,606. The narrative of their scientific collaboration demonstrated that despite exceptional circumstances both the inventor and his correspondents at Kodak Limited managed to produce patent literature and to take the necessary steps to obtain the required patent. It also stressed that both Branch, Crowther and the Kodak Research Laboratories underestimated the potential of the many other inventions proposed by the prolific Italian inventor.

I introduced in the last section of chapter 4 the research work of Karl Schinzel, another prolific photochemist, and his contribution to Kodak Research. Schinzel provided some scientific milestones to Eastman Kodak in the development of the Kodacolor system through the establishment of patents. As with Martinez, a crucial scientific collaboration took place between Schinzel and Eastman Kodak. The structure of this collaboration was important because it took several forms, from the first relationship with the independent inventor and the purchase of his patent rights, through the scientist employed and incorporated in the research structure at Rochester to the external consultant commissioned to spread industrial research in Europe via the creation of a new Research Laboratory. From the analysis of the legal agreements between Schinzel and Eastman Kodak it has been possible to ascertain the use of the modern concept of “Open Innovation” to develop new processes and inventions through Schinzel’s consultancy. The identification, classification and analysis of Schinzel’s complete patent work demonstrated that his scientific contribution was fundamental to Eastman Kodak within the framework of industrial research surrounding colour photography. By collating the specific jargon of the patent literature, the photochemical expressions used with Schinzel’s correspondence and archival materials issued from the Eastman Kodak Patent departments, it was possible to follow the creation of an invention from the technical discussions and brainstorming of the participants up to the final acceptance by a national Patent Office.

The narrative of Schinzel’s scientific collaboration with Eastman Kodak was also the first account ever written about one of the major but neglected researchers of twentieth century photography. Schinzel briefly worked with Mannes and Godowsky at Rochester in 1937 and his patent work is at least as important as theirs. At the beginning of Schinzel’s collaboration with Eastman Kodak, the researchers from Rochester and Harrow received a formidable set of theoretical inventions, which they had to sort out, validate and possibly use. Like Martinez, Schinzel suffered during the Second World War and was forced to drastically reduce his laboratory and research work. Schinzel's exhaustive correspondence and his legal agreements with Eastman Kodak revealed that without the outbreak of the War, the planned Research Laboratory in Switzerland would have played a major role together with the British and French Kodak Research Laboratories in innovation at Eastman Kodak. From Schinzel's return from Rochester to Europe in 1938, the staff of the Patents and Trade Marks Department of Kodak Limited became the privileged interlocutors of the independent inventor. Through the scientific expertise of Branch and Crowther, some of Schinzel's innovations and inventions resulted in invaluable patents.

It is challenging to understand why the Eastman Kodak press machine neglected talented scientists like Wilder, Martinez and Schinzel. At the end of the 1980s, Kodak decided to put forward Mannes and Godowsky's success story in its own history of photography and innovation and to ignore the three photochemists studied above. Kodak communicators simplified the narrative about colour photography, by claiming Mannes and Godowsky as co-geniuses and the only inventors of the three-colour Kodachrome, in the great tradition of the history of science. The fact that they had benefitted from external innovations developed by Martinez and Schinzel was also contrary to the corporate discourse claiming Kodak research as an in-house source of inventions *per se*. However, we have missed much by listening only to Kodak's own history of innovation and neglecting corporate archives of prime importance such as research reports, notebooks and patent literature. By contrast, the present thesis that has used such archival materials clarified that the release of Kodachrome in 1935 was only one step along the way to improve fundamental and applied research in colour photography for the next decades. This research was governed by international teamwork and knowledge sharing implying key contributions from Mannes and Godowsky of course but also from Wilder, Martinez and Schinzel, as well as from a plurality of other scientists such as Phillips, Vittum, Jelley or Hanson.

In the final conclusive chapter, I will undertake a general analysis of all the findings made during my research on the industrial and scientific research at Eastman Kodak and the contribution of the European Kodak Research Laboratories from 1928 to the end of the Second World War. In the core chapters I identified and clarified the structures used to develop industrial research, the methods of innovation selected to this end and the professional and social relationships between the managers, researchers and technicians that led to the development of a new science of photography within private laboratories or through independent photochemists. Several questions were solved through these chapters. I discussed and clarified the reasons for the creation of two additional Kodak Research Laboratories in Europe during the 1920s. The routine work performed in these laboratories was identified, as well as the nature of innovation favoured for these structures. I pointed out the methods used by the researchers to communicate and to share scientific knowledge together, in-house or through scientific communication. I unveiled the unknown involvement of Kodak Limited members of the Patents and Trade Marks department and their fruitful collaboration with independent inventors in the development of colour photography. I also stressed the importance of the patent system in the innovation methods of the photographic industry and the development of this growing constraint during the Interwar period. The final chapter will be an opportunity to compare the initial research questions and speculations with these results and to discuss about the limitations of this thesis and the suggestions for further research.

Chapter 5: Conclusion

So far, chapter 2 has proven that there was industrial research going on at Eastman Kodak before the opening of the first Research Laboratory in 1912. As early as the end of the nineteenth century, activity in fundamental and applied research was taking place at the Harrow Works while training trips and steady correspondence allowed the exchange of technological and scientific knowledge with the principal Works at Rochester. Chapter 2 also clarified that from 1912, the American Research Laboratory provided a better structure than the previous industrial laboratory to perform fundamental research and extend the knowledge of the photographic process. This initial period of the new research structure was largely characterised by a model of "Closed Innovation" in which researchers made scientific discoveries and produced knowledge within the laboratory. In chapter 3, we have also seen through the analysis of the research reports that the European Research Laboratories made an important contribution to innovation at Eastman Kodak during the 1927-1945 period. This analysis stressed in particular that the Harrow Research Laboratory favoured using "Closed" and "Open Innovations" together. In chapter 4, the study of unpublished correspondence folders from the Kodak Collection archive pointed out how the mutual work of the Patents and Trade Marks Department and Kodak Limited's Research Laboratory was fundamental to scientific collaboration with independent photochemists for the drafting of key patents.

Chapters 2, 3 and 4 offer some conclusions regarding the nature of the constraints faced by Kodak Research, the production and transfer of knowledge in the European Kodak Research Laboratories, the principles of scientific collaborations and the "models of innovation" used by Kodak in Europe during the twentieth century. Consequently, these chapters clarify that the French and British Research Laboratories played an important role in the R&D activities of the firm, at least from their opening to the end of the Second World War, contrary to the official discourse of the company, which has always emphasised the predominance of the Research Laboratory of Rochester over Eastman Kodak innovation. As a matter of fact, this technological journey of the European Kodak Research and by extension of the whole photographic research during the twentieth century has been neglected by scholarly studies. Until recently, the principal reason for this was the lack of existing industrial archives. In this final chapter, I will bring these different strands together by comparing first the findings provided by this study with the initial research questions. Furthermore, I will briefly mention the activities of Kodak European Research in the first years of the twentieth-first century to compare them to the situation of the interwar period, extensively studied in this thesis. I will also reflect on the nature of the research presented here and offer some suggestions for further work.

5.1. Answers to the introductory questions

In the central chapters I identified and clarified the organisations set up by the photographic industry to develop fundamental and applied research, the methods of innovation used to this end and the professional and social interactions between the managers, researchers and engineers that led to the development of a new science of photography within private laboratories or through the collaboration with independent photochemists. In this section I return to my original research questions and discuss the conclusions reached as a result of this research. The original questions were:

1. To what extent did the practice of industrial secrecy in the process of film making restrain the sharing of photographic knowledge?
2. Is there any evidence of basic and industrial research at Kodak Limited before the creation of the first Kodak Research Laboratory in Rochester in 1912?
3. What was the strategy behind Eastman Kodak's opening of two additional Research Laboratories in Europe in 1928?

4. What do the contents of the French and British research reports tell us about the daily work of the researchers, the organisation and methods of industrial research and international scientific collaboration?
5. Is it possible to uncover the nature of Kodak technological research and practices for the transfer of photographic knowledge through the analysis of the notebooks of some researchers?
6. Is it possible to clarify in practical terms the scientific collaboration between independent inventors and Eastman Kodak through the analysis of legal agreements and other corporate documents?
7. How important was the patent system to the innovation process at Eastman Kodak, and how was the patent literature designed from a purely practical point of view?
8. Finally, considering the complete set of data gathered from the archives about the industrial research activities at Eastman Kodak, is it possible to qualify the type of innovation favoured by the company during the interwar years, and to confront it with recent "innovation models"?

I will now revisit each of these questions in turn.

1. To what extent did the practice of industrial secrecy in the process of film making restrain the sharing of photographic knowledge?

The analysis of the archival and primary sources consulted clearly demonstrated in Chapter 2 the negative influence of the industrial secrecy on the sharing of photographic knowledge. The rare specialists of photographic emulsion working outside the main film manufacturing companies could not benefit from their scientific discoveries and practical innovations. During the interwar period, the possible transfer of photographic knowledge was only one-sided, from public research organisations to the research structures of Eastman Kodak, Ilford or Agfa among others. Practices of secrecy also spread among the Departments of the Kodak Research Laboratories and the production facilities thereby delaying the laboratory work and to some extent curtailing potential scientific findings.

2. Is there any evidence of basic and industrial research at Kodak Limited before the creation of the first Kodak Research Laboratory in Rochester in 1912?

Archival sources studied in Chapter 2 also provide answers to question 2. Small-scale fundamental research took place at Kodak Limited involving several modern organisational methods such as the transfer of technological knowledge with Kodak Park at Rochester and scientific collaboration with independent photochemists to develop and adapt the "science of photography" to mass production. In this context, the creation of the first Kodak Research Laboratory at Rochester in 1912 principally represented the deployment of a new organisation of industrial research rather than a serious break from the traditional structure of the industrial laboratory. Staff and budget progressively increased, while the Research Laboratory was used in parallel as a symbol of prestige against the competitors.

3. What was the strategy behind Eastman Kodak's opening of two additional Research Laboratories in Europe in the 1928?

The in-depth historical narrative of the internationalisation of Eastman Kodak Research in 1928 (Chapter 3) provides a clear view of Eastman Kodak's strategy. The creation of the British and French Research Laboratories does not constitute a single strategy, but was instead a result of multiple factors and originated from different causes. For Kodak Limited, the creation of the Research Laboratory took place first of all within the context of the modernisation of the Harrow Works. Secondly, the new structure was designed to improve the transfer of technological knowledge between the Research Laboratory at Rochester and Harrow. Thirdly, it was also intended to compete with the Ilford Research Laboratory by developing basic research on the chemistry of cyanine dyes, used as optical sensitizers. Finally, the new Research Laboratory was organised around the new European Kodak organisation, including the new Kodak-Pathé subsidiary in France and the new Kodak film plant at Cöpenick in Germany.

For Kodak-Pathé, George Eastman had known the capacities for fundamental and applied research of his former competitor Pathé since 1906, in particular for the making of a nonflammable film. French photochemists produced a corpus of scientific knowledge during two decades and it was seen as a valuable company asset when Eastman Kodak merged with Pathé in 1927. The decision was made to continue the development of photographic research at Vincennes and most of the researchers of the former French company were incorporated to this end. Ultimately, Mees's will to establish teamwork between British and French researchers was another reason to develop scientific research in France.

4. What do the contents of the French and British research reports tell us about the daily work of the researchers, the organisation and methods of industrial research and international scientific collaboration?

An analysis of the French and British research reports and their teachings in Chapter 3 provided an intimate look at the daily work of researchers as well as clarifying some aspects of the organisation of industrial research and international scientific collaboration. While a qualitative data analysis in the form of tag clouds applied to the title of 350 research reports did not provide significant results, the expert content analysis of this same corpus covering the period 1929-1935 provided a remarkable source of information about the activities of the Harrow Research Laboratory. Three main categories finally emerged from the global activities of the Harrow Research Laboratory. Standard fundamental research represented 13% of studied reports, standard industrial research and development represented 56% while the collaboration-oriented activities concerned 31% of the corpus of reports. These reports proved to be invaluable archival material for the historical social researcher by revealing the multifaceted nature of Kodak research in Europe. We knew from Kodak marketing discourse that Kodak scientists were partially conducting fundamental research activities, but the analysis of the French and British reports also teaches us that they solved multi-site manufacturing issues as well, conducted technology watch or reverse engineering and used the model of "Open Innovation" by benefitting from external sources of scientific knowledge.

5. Is it possible to uncover the nature of Kodak technological research and practices for the transfer of photographic knowledge through the analysis of the notebooks of some researchers?

As to question 5, using the notebooks of a number of researchers, it was found that content analysis of the selected notebooks provided an invaluable insight into the professional practices of the photochemists, production managers and researchers. Some paragraphs within the notebooks showed that the technological knowledge and the company's know-how was kept, assessed and shared through a restricted community of people who were allowed to consult these collaborative tools. Some limitations of this study appeared as well, such as the rather small sampling of notebooks studied compared with the complete collection of notebooks available at the British Library or the lack of information about the supposed use of these notebooks in the photographic industry.

Illustration 12. Eastman Kodak advertisement in Life magazine in 1943.[1]

6. Is it possible to clarify in practical terms the scientific collaboration between independent inventors and Eastman Kodak through the analysis of legal agreements and other corporate documents?

[1] "Kodak Research Has Made Color Photography a Part of Everyone's Life," *Life*, August 2, 1943, 39. This advertisement points out the Kodak Research path as an exciting adventure punctuated with milestones, although remaining a mysterious black box for end consumers.

The section of Chapter 2 about the agreement between the photochemist Krohn and Kodak Limited, and above all the sections of Chapter 4 about the terms of the agreements between Mannes, Godowsky or Schinzel and Eastman Kodak, answered question 6 by shedding light on the terms of scientific collaboration between independent inventors, employees and the American film manufacturer. Beyond the legal jargon incorporated in these formal documents, study of them demonstrated that they were extremely precise about the rights and duties of each party. This kind of archival source represents invaluable evidence for the study of intellectual property and innovation in the movie and photographic industry.

7. How important was the patent system to the innovation process at Eastman Kodak, and how was the patent literature designed from a purely practical point of view?

In Chapter 4 I clearly demonstrated how the patent system controlled the mechanisms of innovation within the specific framework of basic and industrial research undertaken for the development of a colour photographic process. As in other industries, the patent acted as a major constraint to innovation, which the researchers had to deal with. Furthermore, unpublished documents and correspondence provided a description of the time-consuming negotiating and drafting of several patent documents. These narratives of the whole process up to the final delivery of the patent showed that this procedure was an integral part of the scientific research process.

8. Finally, considering the complete set of data gathered from the archives about the industrial research activities at Eastman Kodak, is it possible to qualify the type of innovation favoured by the company during the interwar years, and to confront it with recent "innovation models"?

Pertaining to question 8, the many case studies processed in my thesis point out that the nature of innovation at Eastman Kodak was heterogeneous during the interwar years. On one side, the creation and activities of the Research Laboratories promoted a culture of "Closed Innovation", for which scientific findings and inventions came from the research capabilities of the company and its subsidiaries. On the other hand, the Harrow Research Laboratory partially used a model of "Open Innovation" by investigating third party innovative technologies locally or in Europe, by partnering with local actors in testing some new materials or by developing scientific collaborations in-house and with independent inventors. The analysis of the structure of the Research Laboratory of Kodak Limited during its first years also revealed its small-scale size in terms of research and development. In this context, I argue that this reduced size forced the company to use the global model of "Hybrid Innovation", as discussed in section 5.1, by mixing "Closed Innovation" and investigations of external sources of technological knowledge. This method of innovation is surprisingly modern and it appears that it led to successful collaborations between in-house researchers or technical experts and independent inventors. The intellectual property of some theoretical inventions was secured this way and new products were eventually launched afterwards. It is worth noting that the findings of this thesis shed a new light on the actual nature of Kodak Research during the twentieth century. Previously unknown activities of Kodak researchers in Europe point out the modern nature of Kodak Research organisation in those days. These findings fill a gap between the official discourse of Eastman Kodak about its history, as seen for instance in Illustration 12, and what really happened in the laboratories.

5.2. The significance of "Open Innovation" to Kodak 1927-1945

From the findings of Chapters 3 and 4, I argue that Kodak European Research was a prototypical modern organisation, partially using the recently developed concept of "Open Innovation". This section clarifies the relationship between Kodak Limited's recent activities and Kodak European Research during the interwar years, in the framework of "Open Innovation".

In the Eastman Kodak publication about the 75 years of Kodak Research mentioned in Chapter 2, it has already been pointed out that the Kodak Research Laboratories in the United States of America were drastically re-organised between 1985 and 1986, to better "fit the new company-wide structure."[2] In fact, the structure of the company had moved to a business-oriented one in November 1984, initially made up of 17 business units. In 1990, the number of business units reached 27 and they were sorted into 5 groups. The Research Laboratories were also affected. "A large central research lab was replaced by several organisationally dispersed research laboratories."[3] The consequences of this reorganisation on the European Kodak Research Laboratories at the end of the twentieth century go beyond the framework of my research. However, one can assume that the business-oriented structure also reshaped the organisation of European research.

More recently, a striking case study about Kodak Research in the United Kingdom created the opportunity to connect the model of "Open Innovation" to my historical research findings about this company. Kodak European Research (KER), an *Open Innovation Centre*, was opened in January 2006 in a regional cluster at Cambridge. This R&D unit was a result of the replacement of research facilities in Harrow, Paris and Chalon-sur-Saône in France.[4] KER was supposed to identify potential partners and to develop scientific collaboration, locally and in the European, African, and Middle Eastern Region (EAMER). In these areas KER established *global pipelines* to access relevant information by identifying knowledge intermediaries. According to Eastman Kodak, KER was closed in 2009 due to the financial crisis. Despite the failure of this innovative outpost three years after its opening, the fact that Eastman Kodak judged

[2] *Journey: 75 years of Kodak Research*, 152.

[3] Rzasa, Philip V., Terrence W. Faulkner, and Nancy L. Sousa, "Analyzing R & D Portfolios at Eastman Kodak," *Research Technology Management* 33, no. 1 (1990): 27.

[4] "In the Picture. Kodak's New European Research Centre on Cambridge Science Park," *Catalyst. Cambridge Science Park Newsletter* (Spring, 2006): 4-5. The article is derived from the interview of the former Kodak European Research Director Sam Weller.

the model of “Open Innovation”, as theorised by Chesbrough in 2003, relevant and useful must be pointed out.[5]

In fact, Eastman Kodak decided to open the KER unit at Cambridge Science Park due to its many potential connections with industries, spin-off companies, universities and research institutes. In such a regional network, spatial proximity increased the transfer of tacit knowledge and the informal exchange of new ideas. The concept of “Open Innovation” was used to supplement the Kodak activities of Technology Intelligence, in order to identify possible threats or opportunities through the regional cluster. In practice, the mission of the rather small staff of 25 technical experts at KER was to identify the local *buzz* created from continuous exchanges and updates of information by companies embedded in the cluster. This information was used to facilitate access to knowledge, to capture the relevant new technological information and to speed up technological advancement.[6] Figure 10 shows how this research work was undertaken practically, from the identification of new technologies and intermediaries to the development of technological collaborations.

---

[5] Concerning the dismantling of KER in 2009, see Elisabeth Goodman, “Deep Visuals Ltd – how Kodak’s knowledge assets did not quite ‘walk out of the door’,” Cambridge Network webpage, 13/10/2009, http://www.cambridgenetwork.co.uk/news/deep-visuals-ltd-how-kodak-s-knowledge-assets-did-not-quite, accessed April 14, 2015.

[6] Rani J. Dang, Letizia Mortara, Ruth Thomson and Tim Minshall, “Developing a Technology Intelligence Strategy to Access Knowledge of Innovation Clusters,” in *Strategies and Communications for Innovations. An Integrative Management View for Companies and Networks*, ed. Michael Hülsmann and Nicole Pfeffermann (Berlin; Heidelberg; New York: Springer, 2011), 51-71; see also Letizia Mortara, Ruth Thomson, Chris Moore, Kallopi Armara, Clive Kerr, Robert Phaal, and David Probert, “Developing a Technology Intelligence Strategy at Kodak European Research: Scan & Target,” *Research Technology Management* 53, no. 4 (2010): 27-38.

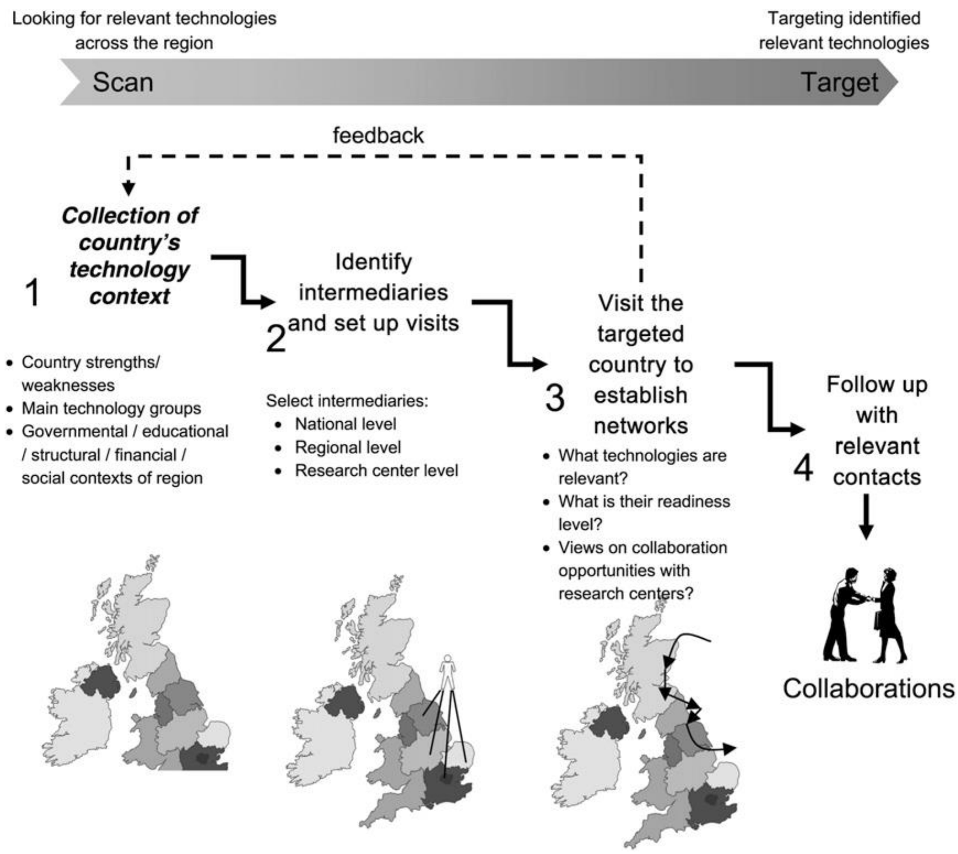


Figure 10. Design methodology of Technology intelligence at KER, moving from Scan to Target.[7]

One of the conclusions given by Dang et al. about the KER experience at Cambridge echoes the situation of the Harrow and Vincennes Research Laboratories for the studied period of my research.

> By interacting with the Cambridge cluster, Kodak became more integrated within the local network as it could directly access relevant local knowledge that was not easily reachable from the headquarters in America.[8]

[7] Mortara et al., "Developing a Technology Intelligence Strategy at Kodak European Research: Scan & Target," 30. Both modes of Scan and Target were used in the Technology intelligence process to source new technologies outside of the organization. The result of the Scan mode was the identification of partners or technologies with high relevance to Kodak while the final Target mode was used to increase knowledge pertaining to these innovative entities, up to the forming of possible collaborations.

[8] Dang et al., "Developing a Technology Intelligence Strategy to Access Knowledge of Innovation Clusters," 66.

For its collaboration-oriented activities, the Harrow Research Laboratory typically demonstrated a similar role of interface between Rochester and local actors and networks in Europe. The researchers investigated new technologies developed by local companies and travelled in Europe to find partners and promising technologies, whereas the staff of the Patents and Trade Marks Department at Harrow established scientific collaborations with Martinez and Schinzel. As to the Research Laboratory at Vincennes, its role as interface was lower because it already represented a unique source of science and technology and a network of contacts including intermediaries and suppliers. In addition, the French Laboratory, like the British Laboratory, exchanged scientific knowledge directly with Rochester.

So, following my in-depth research into the activities of the Kodak Research Laboratories principally during the Interwar period, I can argue that the Harrow Research Laboratory, and to a lesser extent its French counterpart, partially used a similar strategy of "Open Innovation" for their collaboration-oriented activities.[9] Each was acting not only as a "listening post" but also as a regional cluster which supplied the Eastman Kodak headquarters in Rochester with possible innovative technologies, new partners and scientific collaborations with independent photochemists. Just like the KER outpost and its networking activities with the Cambridge cluster, the European Research Laboratories and the other local actors in photochemistry constituted a scientific community during the interwar period that can be assimilated to an innovation network. With the benefit of hindsight, it is therefore possible to define the Kodak European Research structure during the years 1927-1945 as a prototypically modern organisation in terms of the ideas about innovation that were theorised only in the twenty-first century.

Again, this research and its findings, such as the real nature of Kodak European Research, matter as they provide a rare glimpse into the Kodak "black box", relevant to the methods of industrial research used by this international company. From this

[9] As seen in section 5.1, I already argued that the Harrow research Laboratory used a global strategy of "Hybrid Innovation", mixing "Closed" and "Open Innovation", for the whole of their activities.

study, we discovered an entire segment of knowledge about the way photographic processes were invented in the twentieth century by one of the largest photographic and cinematographic firms. Regarding the significance of Eastman Kodak to photography history, it strongly complements our understanding of the Kodak photographic and cinematographic products, because this research was conducted for the first time from the analysis of the scientific production of the researchers and not from the analysis of top management correspondence, or the study of Kodak marketing discourse and advertisements.

But this thesis is also crucial as it complements the history of photography and its evolution in the twentieth century. Scholars in the field have already pointed out the development of the photographic industry, such as Coote, McCauley, or Pritchard.[10] Other academics have stressed the development of a new visual culture following the release of photographic colour processes, such as Bellone and Fellot, Boulouch and Roberts.[11] However, a study of the nature of research and development activities in the photographic industry had never been done before, except Lavédrine and Gandolfo's noteworthy publication about the development of the autochrome process and the history of the Lumière family enterprise.[12] And yet, doing the history of photography in a comprehensive and holistic manner means studying the uses of photography since 1839, but also studying the long-term invention of photography. This last field of the history of photography was and is still active with key studies clarifying the invention and development of the first photographic processes before

---

[10] Coote, *The Illustrated History of Colour Photography*; Elizabeth Anne McCauley, *Industrial Madness: Commercial Photography in Paris, 1848-1871* (New Haven: Yale University Press, 1994; Michael Pritchard, "The Development and Growth of British Photographic Manufacturing and Retailing 1839-1914" (PhD diss., De Montfort University, 2010).

[11] Roger Bellone and Luc Fellot, *Histoire mondiale de la photographie en couleurs : des origines à nos jours* (Paris: Hachette Réalités, 1981); Nathalie Boulouch, *Le ciel est bleu : une histoire de la photographie couleur* (Paris: Textuel, 2011); Pamela Glasson Roberts, *The Genius of Color Photography: from the Autochrome to the Digital Age* (London: Goodman, 2010). See also the more technological publication of Sylvie Pénichon, *Twentieth-century color photographs: Identification and care* (Los Angeles, California: Getty Conservation Institute, 2013).

[12] Bertrand Lavédrine and Jean-Paul Gandolfo, *The Lumière Autochrome: History, Technology, and Preservation* (Los Angeles: Getty Conservation Institute, 2013).

and after 1839, and up to the 1870s. But a similar study was missing for the further inventions of photography in the twentieth century. However, the history of twentieth century photography does not only concern the study of the many uses of photography including his social context, and the analysis of photographic archives or photographers' work. If we want to study photography "as a whole", we need to consider that "doing photography" also means re-inventing the medium by progressively creating new processes in a highly socialised context. Researchers developing photographic processes independently or within the context of the industrial research laboratory in the twentieth century were often the first practitioners of their experimental films. Despite a body of technological, scientific and material constraints, they knew which technical characteristics to achieve and benefitted from a constant spirit of competition due to the consistently high volume of the transfer of scientific knowledge from the patent literature and from the specialised periodicals. Scientists and photochemists had the desire for photography, at least the desire to create new analogue photographic processes which would change the visual culture of the popular imagination, including memories in colour, from their release into the market. When Karl Schinzel theorized a subtractive monopack process he called *Katachromie* in 1905, he was unable to develop this first concept of a multi-layered photographic process, which was only a brilliant idea at the time. But he had the desire to produce it one day. When Mannes and Godowsky experienced the poor colours of a movie using a four-colour additive process in 1917, they also wished for a new cinematographic film to be able to provide a better reproduction of natural colours. These situations were similar to Talbot's disappointment, while drawing the panorama of Lake Como in 1833, wishing to create a process able to mechanically reproduce and fix the image displayed by the *camera lucida*.[13] The present thesis stressed this notion of social desire regarding the further inventions of twentieth century photography.

[13] Sophie Hedtmann, Philippe Poncet, and Marie-Laure Cazin, *William Henry Fox Talbot* (Paris: Les Editions de l'Amateur, 2003), 81.

This research also points out that photography and cinematography historians have many topics of common interest and should therefore share their research and findings, since most big film manufacturing companies worked for both markets in the twentieth century. This remark was particularly relevant with regard to the conference I attended in December 2015, at the Fondation Jérôme Seydoux-Pathé in Paris, about the studies made so far from the Kodak-Pathé research notebooks.[14]

This thesis contributed to the field of history of technology as well, having clarified Eastman Kodak's contribution to the development of industrial research internationally, the company's use of industrial secrecy and its parallel use of patent strategy. Regarding Kodak's industrial research, the thesis complements the existing studies of large-scaled organisations mentioned in section 1.2.3. such as General Electric, AT&T, Du Pont and Philips. In particular, it clarified the management of multi-site industrial research, split into three main research laboratories and the related circulation of scientific knowledge. This research went beyond previously existing studies about patented technologies of the photographic industry, such as Corcy and Schimmelman on inventories of patents.[15] It not only inventoried patents in a specific photographic technology, but also clarified the drafting of several patents and the production and transfer of related scientific knowledge. This unique narrative of the patent "in the making" helped to understand the specific moment of the creation of an invention and scientists' rationale.

This research also addressed the field of business history, as there was always a connecting lead between Kodak industrial research and the marketplace. It showed how the industrial research structure was progressively set up, how Mees conceived its organisation and how and why two additional research laboratories were opened at

[14] See Stéphanie Salmon, ed., *Les Cahiers De Recherche Pathé (1904-1930)* (Paris: Fondation Jérôme Seydoux-Pathé, forthcoming).

[15] Marie-Sophie Corcy, *Inventaire des brevets du relief optique : dépôts français 1852-*1998 (Paris: Prodiex, 2001); Janice G. Schimmelman, *American Photographic Patents 1840-1880: The Daguerreotype and Wet Plate Era* (Nevada city: Carl Mautz-Publishing, 2002); see also Franz Schmitt, *Dictionnaire des brevets cinématographiques français : des origines à 1929* (Paris: Prodiex, 1996).

the end of the 1920s. Furthermore, the thesis clarified how Eastman Kodak innovated practically. From the very first invention to the release of a final product, Kodak mixed in-house fundamental and applied research and the use of external sources of knowledge. This is particularly relevant for the recent field of innovation studies and a source of instruction for existing large companies.

Finally, the study was made "from the inside" in this thesis, while answering Latour's call, as seen in section 1.2.4., also echoed the epistemological concerns of Science and Technology Studies scholars, when they address the nature of scientific knowledge and of scientific practice. My analytical method used for the study of the Harrow Research reports could benefit academic laboratory studies in other industrial sectors, by investigating scientific archives with a similar combination of Grounded Theory with the concept of interactional expertise, as introduced in section 3.2.1., to make it possible to identify the origins of industrial research strategies, the organisation of the work and its social dimension.

5.3. Limitations of this study

It is worth remembering that this thesis constitutes one of the first academic studies using Kodak corporate and scientific archives only recently available to scholars. The understanding of the Kodak Collection Archive and of the Kodak-Pathé Archive as a whole still remains. Therefore, further research on these archives might provide findings which could complement some of the conclusions of the present thesis.

In particular, it was not possible to study in the thesis the impact of the German defeat in 1945 and the subsequent transfer of Agfa technologies to Eastman Kodak and other film manufacturers. This was due not only to the lack of documentation in the British and French Kodak archives, but also to the large amount of time spent on the analysis of the research reports and the Martinez and Schinzel files. For the same reasons, I did not study the American activities of Kodak during the Manhattan Project and the possible contribution of Kodak Limited.

As regards methodology, some initial tracks studied during the literature review process were not used in the thesis, such as the concept of critical discourse analysis (CDA) conceptualised by Norman Fairclough or the method of corpus linguistics.[16] However, CDA or corpus linguistics techniques could be of benefit to the analysis of the Harrow research reports or the Vincennes research notebooks, as these large bodies of literature follow a homogeneous editorial standard. Such analysis techniques could be used once all or part of the corpora have been digitised and deciphered with optical character recognition software. For my research, I did not pursue this option finally, notably because of the strict regulations at the British Library pertaining to the reproduction of special collections materials.

Furthermore, I decided to study only the first part of the Harrow research reports corpus due to the large amount of documents available. Thus, the findings about the activities of the Harrow Research Laboratory cover only the years 1929 to 1935.

5.4. Further research

As a consequence of the final limitation outlined above, it would be logical to extend the data collection and analysis of the Harrow Research Laboratory up to 1940 and beyond, to study the impact of the Second World War on Kodak industrial research in England, in particular.

It would also be necessary to inventory and study the complete corpus of the personal notebooks available in the Kodak Collection archive, as it was not entirely identified so

[16] See Norman Fairclough, *Media Discourse* (London; New York: E. Arnold, 1995); Tony McEnery and Andrew Hardie, *Corpus Linguistics: Method, Theory and Practice* (Cambridge; New York: Cambridge University Press, 2012).

far. This would allow a further comparison with the Marcel Mayer notebook held at the Fondation Jérôme Seydoux-Pathé already studied in section 3.3.1.

Of course, it would also be necessary to investigate other Kodak archives in the United States of America. In particular, it would be fundamental to ascertain whether the equivalent Rochester research reports survived at the George Eastman Museum or at the University of Rochester, to complement the study about the transfer of knowledge between the three Kodak Research Laboratories carried out in chapter 3.[17] The analysis of the Rochester research reports might also unveil the many activities of the first Kodak Research Laboratory and help to open this initial “black box” to define the nature of innovation used at Rochester from 1912. More specifically, it would be worth identifying and analysing the American researcher Lot Wilder's familial archive, if one exists, to better clarify his research work at the Kodak Research Laboratory in Rochester and his contribution to Kodak Research.

Lastly, this thesis has highlighted the activities of a community of Kodak researchers and independent photochemists and a part of their destiny. It would be worth undertaking an iconographic analysis of the two Kodak archives to complement our knowledge about the research laboratories, the manufacturing plants and about these women and men who invented, for the most part anonymously, twentieth-century photography. The visual material itself contained in the Harrow research reports would greatly benefit from further academic research.

[17] For example, the Kodak Historical Collection #003 held by the Rush Rhees Library at the University of Rochester contains in particular a part of Kenneth Mees’s archive.

Glossary

acetylation process. A chemical reaction producing cellulose acetate material and as well as acetic acid.

backing. A photographic or cine film is usually backed, incorporating an additional anti-halation layer to prevent any rays of incident light from being reflected again through the emulsion. The anti-halation backing is also used to improve the anti-static behaviour of the film.

collodion. A dissolution of cellulose nitrate (nitrocellulose) gelled in a mixture of alcohol and ether.

colloidal chemistry. A branch of chemistry involving the study of colloids and their physico-chemical behaviour. A colloid is the suspension of at least two substances, the first being made of minute particles and dispersed into the second. In photography, the photographic emulsion can be described as a colloidal suspension made of a solid light-sensitive material (silver halide crystals) dispersed in gelatin, which is coated on a film support.

coupler. A coupler is a chemical component necessary for colour development. It is either present in the layers of a tripack film, or in the specific developer for each layer. During the film development, after the exposure, the developer first reacts with the silver halide grains present in the emulsion to form silver and oxidised developing agent. Then the coupler reacts with this oxidised developing agent to produce an insoluble dye. This chemical reaction is called a coupling reaction. The coupler's action forms a dye, the expression yellow-forming coupler, magenta-forming coupler and cyan-forming coupler being frequently used.

diazotype. A reproduction process by contact printing using the diazo chemical process. Diazo paper can be produced by combining a diazonium salt with an azo dye. Diazotype processes create blue-line reproductions on a white background without continuous tones.

diffraction spectroscope. An instrument used to identify chemical materials by spectroscopic analysis, from a light source diffracted by the spectroscope.

dye-transfer process. A color photographic printing process involving the successive transfer of cyan, magenta, and yellow dyes onto a sheet of gelatin-coated paper. It was also used by Technicolor Corporation in the imbibition dye transfer process from the three black and white printing matrix films to produce the final colour film. See ***imbibition***.

fogged. An emulsion is fogged when unwanted density, made of silver crystals, can be found locally on the developed film. In the case of emulsion research, this issue mostly comes from chemical fogging.

gamma. In a photographic film, the slope of its characteristic curve is called gamma. It is used in sensitometry to characterise its contrast, to study the influence of parasite light and to manage the behaviour of the film in low or high lights.

graininess. A perceptual concept referring to the visual appearance of the granular structure in a photographic image. It is different from the physical property of the photographic structures that produce graininess, which is called granularity.

horizontal integration. A business practice used to increase the production capability of the company via acquisition or merger. The use of horizontal integration particularly allows the reduction of commercial impact from the competition and the increase in market share.

hypersensitisation. When an emulsion is exposed to light, it enters a temporary phase that is called latent image. This phase is not chemically stable and can degrade if the exposed emulsion is not developed. The use of hypersensitisation techniques before the exposition provides an increase of the latent image lifetime, up to the development of the photographic material. It is often used in astrophotography for long exposures.

imbibition. A particular type of diffusion involving the absorption of water by solids-colloids and an increase in volume. Imbibition was particularly used by Technicolor Corporation for the dye-transfer technique necessary to produce final colour film. See ***dye-transfer process***.

Latent image. An invisible image produced when a photosensitive material is exposed to light. This image becomes visible when the photographic film is developed.

lenticular. A film made to reproduce natural colours is said to be lenticular if one side of its base is embossed with minute lenticulated elements. These optical elements are similar to minute lenses, directing rays of coloured light to the relevant area of the black and white emulsion at the back of the film base. The first Kodacolor lenticular process used 22 lenticulated elements per millimeter.

maturation. The maturation or ripening is the action of letting the recently mixed emulsion stand for a specific time and at a specific temperature, before it is coating on a photographic support. During the process of maturation the emulsion speed increases because the size of the silver grains also progressively increases.

monopack. A synonym of the term integral tripack. Monopack derives from the product of Technicolor Corp., Monopack, a single-strip colour reversal film introduced in 1941. See ***tripack***.

orthochromatic emulsion. An early black and white photographic emulsion that is sensitive only to the blue and green spectrum. Most photographic emulsions manufactured by the industry between the 1880s and the 1910s were orthochromatic.

panchromatic emulsion. A black and white photographic emulsion that is sensitive to the full visible light, from the blue to the red spectrum. The first panchromatic photographic plates were introduced in 1906 by the British company Wratten & Wainwright, following Mees' research work to expand the sensitivity of the emulsion to all wavelengths of the visible light.

photometer. An instrument used to measure the densities of exposed areas of processed photographic materials, in the context of a sensitometric survey.

Radiographic film. A photographic film, used for general radiography and medical purposes, able to record X-rays, an electromagnetic radiation with wavelengths shorter than visible light.

reverse engineering. In the industry, a technique used to analyse the components of a product to understand their nature and ascertain how the final product was made. The final goal of the process is the ability to manufacture a similar product from this analysis.

sensitising dyes. In a photographic emulsion, chemical dyes used to increase the sensitivity of silver halide crystals to other areas of the visible light. Their discovery led to the production of panchromatic emulsions.

sensitometer. An instrument used to conduct sensitometric tests, in which the photographic material is exposed to a specific amount of light using a standard artificial light source.

sensitometry. The measurement of the sensitivity of photographic materials. Sensitometry is conducted practically by exposing, processing and analysing photographic films. The analysis involves the use of densitometry, the measurement of the density of processed photographic materials.

solarisation. An exposure to light of a photographic element creating the partial or entire reversal of the image tones, by physical overexposure.

tripack. A tripack, or integral tripack, is a photographic color film coated with at least three layers one on top of the other. Each layer is made of an emulsion sensitive to a specific area of the visible spectrum. The complete design of such a multilayered film including the film base and possible additional layers is known as an integral tripack. Tripack films use the subtractive method of colour reproduction, that involves the selective analysis and absorption by the three layers of the red, green and blue components of the photographed subject. See also ***monopack***.

wedge spectrograph. An instrument providing the relative photosensitivity of a photographic material. It produces its spectrogram, i.e. its spectral response to an exposition to a light source.

Index of managers, researchers and other players of the photographic field mentioned in this thesis

Bibliography

Archival sources

Association CECIL, Fragnes, Chalon-sur-Saône, France
33001-33693. Research notebooks (Pathé Cinéma and Kodak-Pathé).

British Library, London
Kodak Collection Archive.
Boxes : 8, 13, 14, 72, 89, 96, 109, 113, 116, 121, 126, 136, 152, 153, 154, 291, 333.
A2897. Harrow Research Reports, 8 volumes (H.1 to H.350, 1929-1935).

De Montfort University, Kimberlin Library, Special Collections, Leicester
770/MEE. Kodak Collection.

École nationale supérieure Louis Lumière, Centre de ressources documentaires, Fonds ancien, Saint-Denis, France
Kodak Collection.

Fondation Jérôme Seydoux-Pathé, Centre de recherche et de documentation, Paris, France
Marcel Mayer notebook.
Pathé Archive.

Primary sources

Periodicals

Publications from the Kodak Research Laboratories

. Publications from the American Kodak Research Laboratory at Rochester

Abridged Scientific Publications from the Kodak Research Laboratories, vol. 10 (1926) – vol. 41 (1964)
Abridged Scientific Publications from the Research Laboratory of the Eastman Kodak Company, vol. 1 (1913-1914) – vol. 9 (1925)
Monographs on the Theory of Photography, no. 1 to no. 6, 1921-1927
Monthly Abstract Bulletin, Vol. 1, no. 1 (1915) - vol. 47, no. 12 (1961)

. Publications from the French Kodak Research Laboratory at Vincennes

Bulletin Bibliographique Mensuel Kodak-Pathé, 07/1927-03/1930 (possibly later)
Résumés des Publications des Laboratoires de Recherches Kodak, 1968 (possibly more)
Résumés des Travaux des Laboratoires Kodak, 01/1942-01/1969 (possibly later)

. Publications from the British Kodak Research Laboratory at Harrow

Abridged Scientific Publications from the Kodak Research Laboratories, vol. 10 (1926) - vol. 41 (1964)

Publications from Eastman Kodak

Bulletin Radiographique, no. 1 to no. 11, 01/1927-11/1928
Kodak Chemicals and Formulae
Kodak Reference Handbook
Kodakery

Publications from the Agfa Research Laboratories

Veröffentlichungen des wissenschaftlichen zentral-laboratoriums der photographischen abteilung Agfa, vol. 1 (1930) – vol. 6 (1939)

Publications from the Lumière Laboratories

Revue des travaux de recherches effectués dans les laboratoires photographiques dirigés par Auguste et Louis Lumière, no. 1 (1904) – no. 16 (1912)

Proceedings of the International Congresses of Photography

Eggert, John and Arpad von Biehler*. Bericht über Den VIII. Internationalen Kongress für Wissenschaftliche Und Angewandte Photographie, Dresden, 1931.* Dresden: Johann Ambrosius Barth, 1932.

Other periodicals

Barron's
Bureau of Standards Journal of Research
Il Progresso Fotografico

Image. Journal of Photography of the George Eastman House
Journal of the Society of Motion Pictures Engineers
Journal of the Society of Motion Picture and Television Engineers
Life
Nature
Photographische Korrespondenz
Science
Science et Industries Photographiques
Science News-Letter
Scientific American Supplement
Scientific Papers of the Bureau of Standards
Sigma Xi Quarterly
The British Journal of Photography
The Journal of Photographic Science
The Photographic Journal
The Scientific Monthly
Vital Speeches

Other

"A New Laboratory for Research in Optics and Photography." *Scientific American Supplement* 76, no. 1960 (July 26, 1913): 56-57.

Abney, William de W. *Photography with Emulsions. A Treatise on the Theory and Practical Working of the Collodion and Gelatine Emulsion Processes*. London: Piper & Carter, 1885.

Bocquin, Raymond. «Les Supports Photographiques Transparents : Le Nitrate De Cellulose, l'Acétate De Cellulose, Le Polyester.» Unpublished report, Chalon-sur-Saône.

Cassinis, Paolo. «I Prodotti Fotografici e l'Autarchia.» *Il Progresso Fotografico* no. 6 (1939): 230-233.

———. «I Progressi Dell'Industria Fotografica Italiana.» *Il Progresso Fotografico* 40, no. 7 (1933): 207-211.

Clark, Walter. "Photography's Research Genius." *New Scientist* 84, no. 1186-1187 (1979): 953-956.

Clarke, Hans T. "Charles Edward Kenneth Mees 1882-1960. A Biographical Memoir by Hans T. Clarke." *Biographical Memoirs of the National Academy of Sciences* (1971): 175-199.

———. "Impressions of an Organic Chemist in Biochemistry." *Annual Review of Biochemistry* 27, no. 3 (1958): 1-14.

Davies, E. Roy. "Reports of Meetings. Scientific and Technical Group's Second After-Dinner Lecture - 15 February 1962." *The Journal of Photographic Science* 10, no. 4 (1962): 252-257.

Demers, Pierre. *Ionographie. Les émulsions nucléaires, Principes Et Applications*. Montréal: Presses Universitaires, 1958.

Didiée, Louis. *Le Film Vierge Pathé : Manuel De développement Et De Tirage*. Paris: Les Établissements Pathé-Cinéma, 1926.

Eggert, John and Arpad von Biehler. »Bericht über Den VIII. Internationalen Kongress für Wissenschaftliche Und Angewandte Photographie, Dresden, 1931.« Dresden: Johann Ambrosius Barth, 1932.

Friedman, Joseph Solomon. *History of Color Photography*. Boston: American Photographic Publishing Company, 1944.

Gallafent, Victor. "The Direction of Photographic Research." *The Photographic Journal* 94, (April, 1954): 104-118.

Gauntlett, Margaret D. "A History of Kodak Limited to 1977." Unpublished report, 1978, Harrow Research Division, Kodak Limited, Harrow.

Hale, George E. "Industrial Research and National Welfare." *Science* 48, no. 1247 (1918): 505-507.

Hamor, William Allen. "The Research Couplet: Research in Pure Science and Industrial Research." *The Scientific Monthly* 6, no. 4 (1918): 319-330.

Harrison, G. B. "The Laboratories of Ilford Limited." *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 220, no. 1143 (December 22, 1953): 9-20.

Hurter, Ferdinand and Vero Charles Driffield. "Photochemical Investigations and a New Method of Determination of the Sensitiveness of Photographic Plates." *Journal of the Society of Chemical Industry* 9, no. 5 (1890): 455-469.

———. *The Photographic Researches of Ferdinand Hurter and Vero C. Driffield*, edited by Ferguson, William Bates. London: Royal Photographic Society of Great Britain, 1920.

James, Thomas H. *A Biography-Autobiography of Charles Edward Kenneth Mees, Pioneer of Industrial Research*. Rochester, N.Y.: Photographic Research Laboratories, Eastman Kodak Co., 1990.

Krohn, F. W. Thomas. "Early Kodak Days". Unpublished report, 1932, Kodak Limited, Harrow.

Little, Arthur D. "Industrial Research in America." *Science* 38, no. 984 (1913): 643-656.

Löbel, Léopold. *La Technique cinématographique : Projection, Fabrication Des Films*. Paris: H. Dunod et E. Pinat, 1912.

Mees, C. E. Kenneth. "Amateur Cinematography and the Kodacolor Process." *Journal of the Franklin Institute* 207, no. 1 (1929): 1-17.

———. *Dr. C.E. Kenneth Mees: An Address to the Senior Staff of the Kodak Research Laboratories, November 9, 1955*. Rochester N.Y.: Kodak Research Laboratories, 1956.

———. "Fifty Years of Photographic Research." *Image, the Bulletin of the George Eastman House of Photography* 3, no. 8 (1954): 49-54.

———. *From Dry Plates to Ektachrome Film; a Story of Photographic Research.* New York: Ziff-Davis Pub. Co., 1961.

———. *The Fundamentals of Photography*. Rochester N.Y.: Eastman Kodak Company, 1920.

———. “The Kodak Research Laboratories.” *Proceedings of the Royal Society of London.Series A, Mathematical and Physical Sciences* 192, no. 1031 (1948): 465-479.
———. “On the Resolving Power of Photographic Plates.” *Proceedings of the Royal Society of London. Series A* 83, no. 559 (1909): 10-18.
———. “The Organization of Industrial Scientific Research.” *Science* 43, no. 1118 (1916): 763-773.
———. *The Organization of Industrial Scientific Research*. New York: McGraw-Hill Book Company, Inc, 1920.
———. “A Photographic Research Laboratory.” *The Scientific Monthly* 5, no. 6 (1917): 481-496.
———. *Photography*. New York: The Macmillan Company, 1937.
———. *The Photography of Colored Objects*. Rochester N.Y.: Eastman Kodak Company, 1919.
———. *The Photography of Coloured Objects*. London: Wratten & Wainwright Ltd., 1909.
———. “Planning a Research Laboratory for an Industry.” *The Scientific Monthly* 7, no. 1 (1918): 54-67.
———. “The Production of Scientific Knowledge.” *Science* 46, no. 1196 (1917): 519-528.
———. “The Publication of Papers from Research Institutions.” *Science* 70, no. 1821 (1929): 502-502.
———. “The Publication of Scientific Research.” *Science* 46, no. 1184 (1917): 237-238.
———. “Recent Advances in our Knowledge of the Photographic Process.” *The Scientific Monthly* 55, no. 4 (1942): 293-300.
———. “Research and Business with some Observations on Color Photography.” *Vital Speeches of the Day* 2, no. 4 (1935): 117-117.
———. “The Science of Photography.” *Sigma XI Quarterly* 19, no. 1 (1931): 1-19.
———. “Secrecy and Industrial Research.” *Nature* 170, no. 4336 (1952): 972.
———. “The Supply of Organic Reagents.” *Science* 48, no. 1230 (1918): 91-92.
———. *The Theory of the Photographic Process*. New York: The MacMillan Company, 1942.
Mees, C. E. Kenneth and John A. Leermakers. *The Organization of Industrial Scientific Research*. 2nd ed. New York: McGraw-Hill, 1950.
Mees, C. E. Kenneth and John Randal Baker. *The Path of Science*. New York: J. Wiley & sons, Inc., 1946.
Mees, C. E. Kenneth and Samuel Sheppard. *Investigations on the Theory of the Photographic Process*. London, New York, Bombay, Calcutta: Longmans, Green and Co, 1907.
Nietz, A. H. *Theory of Development*. Rochester: Eastman Kodak Company, 1922.
Wall, E. J. *The History of Three-Color Photography*. Boston: American Photographic Publishing Co, 1925.
———. *Photographic Emulsions. their Preparation and Coating on Glass, Celluloid and Paper, Experimentally and on the Large Scale*. Boston: American Photographic Publishing Co, 1929.

———. *Photographic Facts and Formulas*. Boston: American Photographic Publishing Co, 1924.
Wentzel, Fritz. *Memoirs of a Photochemist*. Philadelphia: American Museum of Photography, 1960.

Secondary sources

"Dr. C. E. Kenneth Mees." *Image* 10, no. 1 (1961): 1-2.
"Eastman Kodak's Research." *Barron's,* January 4, 1932.
"Grains in Photographic Image Look like Masses of Seaweed." *The Science News-Letter* 38, no. 23 (1940): 355-355.
"The Harrow Research Laboratory. Origins and Growth 1928-1976. A Retrospective Album." Unpublished report, 1977, Harrow Research Laboratory, Harrow.
"In the Picture. Kodak's New European Research Centre on Cambridge Science Park." *Catalyst. Cambridge Science Park Newsletter* (Spring, 2006): 4-5.
Journey: 75 Years of Kodak Research. Rochester, N.Y.: Eastman Kodak, 1989.
"The Rise and Fall of Industrial Research." *Financial World* 160, no. 13 (June 25, 1991): 64-68.
Ackerman, Carl W. *George Eastman*. Boston; New York: Houghton Mifflin Co., 1930.
Ackermann, Robert John. *Data, Instruments, and Theory: A Dialectical Approach to Understanding Science*. Princeton, N.J.: Princeton University Press, 1985.
Allen, Thomas J. and Günter Henn. *The Organization and Architecture of Innovation: Managing the Flow of Technology*. Amsterdam; Boston: Elsevier; Butterworth-Heinemann, 2007.
Allio, Robert J. "Interview with Henry Chesbrough: Innovating Innovation." *Strategy and Leadership* 33, no. 1 (2005): 19-24.
Altman, J. H. "Microphotography and the Kodak Research Laboratories." *Applied Optics* 11, no. 1 (January, 1972): 22-25.
Andrew, Dudley. "The Postwar Struggle for Color." *Cinema Journal* 18, no. 2 (1979): 41-52.
Arundel, Anthony, Keith Smith, Pari Patel, and Giorgio Sirilli. *The Future of Innovation Measurement in Europe: Concepts, Problems and Practical Directions*. Maastricht: STEP Group, 1998.
Ayerbe, Cécile and Valérie Chanal. «Droits De Propriété Intellectuelle et Innovation Ouverte : Les Apports De Henry Chesbrough.» *International Management* 14, no. 3 (2010): 99-104.
Balmer, Brian. "A Secret Formula, a Rogue Patent and Public Knowledge about Nerve Gas: Secrecy as a Spatial-Epistemic Tool." *Social Studies of Science* 36, no. 5 (2006): 691-722.
———. *Secrecy and science: a historical sociology of biological and chemical warfare*. Farnham: Ashgate, 2012.
Becker, Peter and William Clark. *Little Tools of Knowledge: Historical Essays on Academic and Bureaucratic Practices*. Ann Arbor, Mich.: University of Michigan Press, 2001.

Berg, Bruce L. and Howard Lune. *Qualitative Research Methods for the Social Sciences*. 8th ed. Boston: Pearson, 2012.
Berger, Roland, Soumitra Dutta, Tobias Raffel, and Geoffrey Samuels. *Innovating at the Top: How Global CEOs Drive Innovation for Growth and Profit*. Basingstoke; New York, NY: Palgrave Macmillan, 2009.
Berger, Arthur Asa. *Media and Communication Research Methods: An Introduction to Qualitative and Quantitative Approaches*. Thousand Oaks, Calif.: Sage Publications, 2000.
Bijker, Wiebe E., Thomas P. Hughes, and Trevor Pinch. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology.* Anniversary ed. ed. Cambridge, Mass.: MIT Press, 2012.
Bijker, Wiebe E., Thomas Parke Hughes, and Trevor Pinch, eds. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge, Mass.: MIT Press, 1987.
Boersma, F. Kees and Marc de Vries. "Transitions in Industrial Research: The Case of the Philips Natuurkundig Laboratorium (1914-1994)." *Business History* 50, no. 4 (2008): 509-529.
Boulouch, Nathalie. *Le ciel est bleu : une histoire de la photographie couleur*. Paris: Textuel, 2011.
Brayer, Elizabeth. *George Eastman: A Biography*. Baltimore: Johns Hopkins University Press, 1996.
Brown, Laurie M., Max Dresden, and Lillian Hoddeson. "Pions to Quarks: Particle Physics in the 1950s: Based on a Fermilab Symposium." International Symposium on the History of Particle Physics, Cambridge University Press, 1989.
Brown, Elspeth H. *The Corporate Eye: Photography and the Rationalization of American Commercial Culture, 1884-1929*. Baltimore: Johns Hopkins University Press, 2005.
Buchwald, Jed Z., ed. *Scientific Practice: Theories and Stories of Doing Physics*. Chicago: University of Chicago Press, 1995.
Buckland, Michael Keeble. *Emanuel Goldberg and His Knowledge Machine Information, Invention, and Political Forces*. Westport, Conn.: Libraries Unlimited, 2006.
Bustamante, Carlos. "AGFA, Kullmann, Singer & Co. and Early Cine-Film Stock." *Film History* 20, no. 1 (2008): 59-76.
Butterfield, Roger. "The Prodigious Life of George Eastman; the Kodak Brought Him a Fortune and Photography to Millions." *Life* (April 26, 1954): 154-168.
Callender, Ronald M. "Driffield's Predicament: The Year of 1896." *History of Photography* 36, no. 2 (2012): 199-210.
———. "Hurter, Ferdinand (1844–1898) and Driffield, Vero Charles (1848–1915)." In *Encyclopedia of Nineteenth-Century Photography,* edited by Hannavy, John. Vol. 1, 732-734. New York: Routledge, 2008.
Carroll, B. H., D. Hubbard, and C. M. Kretchman. *The Photographic Emulsion*. London: Focal Press, 1968.
Cerveaux, Augustin. « "*From an Art to a Science*" : Chimie Colloïdale, Pigments et Recherche « Fondamentale » Chez Du Pont De Nemours, 1900-1945. » PhD dissertation, Université de Strasbourg, 2010.

———. “Taming the Microworld: Dupont and the Interwar Rise of Fundamental Industrial Research.” *Technology and Culture* 54, no. 2 (2013): 262-288.
Chandler, Alfred D. and Takashi Hikino. *Scale and Scope: The Dynamics of Industrial Capitalism*. Cambridge, Mass.: Belknap Press, 1990.
Chandler, Alfred D. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge, Mass.: Belknap Press, 1977.
Chesbrough, Henry William and Sabine Brunswicker. “A Fad or a Phenomenon? The Adoption of Open Innovation Practices in Large Firms.” *Research Technology Management* 57, no. 2 (2014): 16-25.
Chesbrough, Henry William, Wim Vanhaverbeke, and Joel West. *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University, 2006.
Chesbrough, Henry William. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, Mass.: Harvard Business School Press, 2003.
Christensen, Clayton M. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston, Mass.: Harvard Business School Press, 1997.
Clarke, Sabine. “Pure Science with a Practical Aim: The Meanings of Fundamental Research in Britain, Circa 1916-1950.” *Isis* 101, no. 2 (2010): 285-311.
Cochrane, Rexmond C. *Measures for Progress; a History of the National Bureau of Standards*. Washington: National Bureau of Standards, U.S. Dept. of Commerce, 1966.
Coe, Brian. *Colour Photography: The First Hundred Years, 1840-1940*. London: Ash & Grant, 1978.
Collins, Douglas. *The Story of Kodak*. New York: H.N. Abrams, 1990.
Collins, H. M. and Robert Evans. *Rethinking Expertise*. Chicago: University of Chicago Press, 2007.
———. “The Third Wave of Science Studies: Studies of Expertise and Experience.” *Social Studies of Science* 32, no. 2 (2002): 235-296.
Collins, Harry M. *Tacit and Explicit Knowledge*. Chicago; London: The University of Chicago Press, 2010.
Collins, H. M. *Changing Order: Replication and Induction in Scientific Practice*. London; Beverly Hills: Sage Publications, 1985.
Cooke, Philip. “Regional Innovation Systems, Clusters, and the Knowledge Economy.” *Industrial and Corporate Change* 10, no. 4 (2001): 945-974.
Coote, Jack Howard. *The Illustrated History of Colour Photography*. Surbiton: Fountain, 1993.
Corcy, Marie-Sophie. *Inventaire des brevets du relief optique : dépôts français 1852-1998*. Paris: Prodiex, 2001.
Creswell, John W. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, California: SAGE Publications, 2014.
Dahlquist, Marina. “Global Versus Local: The Case of Pathé.” *Film History* 17, no. 1 (2005): 29-38.
Dang, Rani J., Letizia Mortara, Ruth Thomson, and Tim Minshall. “Developing a Technology Intelligence Strategy to Access Knowledge of Innovation Clusters.” In *Strategies and Communications for Innovations. An Integrative Management*

View for Companies and Networks, edited by Hülsmann, Michael and Nicole Pfeffermann, 51-71. Berlin; Heidelberg; New York: Springer, 2011.
Danto, Elizabeth Ann. *Historical Research*. New York: Oxford University Press, 2008.
Darrigol, Olivier. "Critical Review. Image and Logic: A Material Culture of Microphysics by Peter Galison." *Revue d'Histoire Des Sciences* 54, no. 2 (2001): 255-260.
Daston, Lorraine. *Biographies of Scientific Objects*. Chicago: University of Chicago Press, 2000.
David, Edward E. "Industrial Research in America: Challenge of a New Synthesis." *Science* 209, no. 4452 (1980): 133-139.
De Laet, Marianne, ed. *Research in Science and Technology Studies: Knowledge and Technology Transfer*. Amsterdam; Boston: JAI, 2002.
de Vries, Marc J. *80 Years of Research at the Philips Natuurkundig Laboratorium: (1914-1994): The Role of the Nat.Lab. at Philips*. Amsterdam: Pallas Publications, 2005.
Deacon, David and Michael Pickering, eds. *Researching Communications: A Practical Guide to Methods in Media and Cultural Analysis*. London; New York: Arnold; Oxford University Press, 1999.
Deacon, David, Michael Pickering, Peter Golding, and Graham Murdock, eds. *Researching Communications: A Practical Guide to Methods in Media and Cultural Analysis*. 2nd ed. London: Hodder Arnold, 2007.
Dear, Peter. "Fifty Years of *Structure*." *Social Studies of Science* 42, no. 3 (2012): 424-428.
Dennis, Michael Aaron. "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science." *Social Studies of Science* 17, no. 3 (1987): 479-518.
Duffin, George Frank. *Photographic Emulsion Chemistry*. London: Focal Press, 1966.
Ede, François. «Un Épisode De l'Histoire De La Couleur Au Cinéma : Le Procédé Keller-Dorian et Les Films Lenticulaires.» *1895 Revue d'Histoire du Cinéma* no. 71 (2013): 187-202.
Ede, Andrew. *The Rise and Decline of Colloid Science in North America, 1900-1935: The Neglected Dimension*. Aldershot, Hampshire, England; Burlington, VT: Ashgate, 2007.
Edgerton, D. E. H. and Sally M. Horrocks. "British Industrial Research and Development before 1945." *The Economic History Review (London)* 47, no. 02 (1994): 213-238.
Edgerton, D. E. H. "Industrial Research in the British Photographic Industry, 1879-1939." In *The Challenge of New Technology: Innovation in British Business since 1850*, edited by Liebenau, Jonathan, 106-134. Aldershot: Gower, 1988.
Evans, James. "Industry Collaboration, Scientific Sharing, and the Dissemination of Knowledge." *Social Studies of Science* 40, no. 5 (2010): 757-791.
Fairclough, Norman. *Media Discourse*. London; New York: E. Arnold, 1995.
Fischer, Frank and Carmen Sirianni. *Critical studies in organization and bureaucracy*. Philadelphia: Temple University Press, 1984.
Fisk, Catherine L. *Working Knowledge Employee Innovation and the Rise of Corporate Intellectual Property, 1800-1930*. Chapel Hill: University of North Carolina Press, 2009.

Flick, Uwe. *An Introduction to Qualitative Research*. 4th ed. Los Angeles: SAGE, 2009.
Frangos, Stephen J. and Steven J. Bennett. *Team Zebra: How 1500 Partners Revitalized Eastman Kodak's Black & White Film-Making Flow*. Essex Junction, Vt.: Omneo, 1993.
Friedman, Joseph Solomon. *History of Color Photography.* 2nd ed. London: Focal Press, 1972.
Frizot, Michel. "A Natural Strangeness: The Hypothesis of Color." In *A New History of Photography*, edited by Frizot, Michel and et al., 410-429. Köln: Könemann, 1998.
Fuller, Steve. *The Philosophy of Science and Technology Studies*. New York: Routledge, 2006.
Fuller, Steve and James H. Collier. *Philosophy, Rhetoric, and the End of Knowledge: A New Beginning for Science and Technology Studies.* Mahwah, N.J: Lawrence Erlbaum Associates, 2004.
Funderburk, Kit. *A Guide to the Surface Characteristics: KODAK Fiber Base Black-and-White Papers*, edited by Funderburk, Kit 2009.
Galison, Peter. "Context and Constraints." Chap. 2, In *Scientific Practice: Theories and Stories of Doing Physics*, edited by Buchwald, Jed Z., 13-41. Chicago: University of Chicago Press, 1995.
———. *How Experiments End*. Chicago: University of Chicago Press, 1987.
———. *Image and Logic: A Material Culture of Microphysics*. Chicago: University of Chicago Press, 1997.
———. "On the Partial Existence of Existing and Nonexisting Objects." Chap. 10, In *Biographies of Scientific Objects*, edited by Daston, Lorraine, 247-269. Chicago: University of Chicago Press, 2000.
———. "Secrecy in Three Acts." *Social Research* 77, no. 3 (2010): 941-74.
———. "Three Laboratories." *Social Research* 64, no. 3 (1997): 1127-1155.
Galison, Peter and Bruce William Hevly. *Big Science: The Growth of Large-Scale Research*. Stanford, Calif.: Stanford University Press, 1992.
Ganguli, Prabuddha, Ben Prickril, and Rita Khanna, eds. *Technology Transfer in Biotechnology: A Global Perspective*. Weinheim; Chichester: Wiley-VCH; John Wiley, 2008.
Gavetti, Giovanni, Rebecca Henderson, and Simona Giorgi. "Kodak and the Digital Revolution (A)." *Harvard Business School Case 705-448* (2005, 2004): 1-18.
Giudice, Gian Francesco. "Big Science and the Large Hadron Collider." *Physics in Perspective* 14, no. 1 (2012): 95-112.
Glaser, Barney G. and Anselm L. Strauss. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago: Aldine Pub. Co., 1967.
Godin, Benoît. "In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation." *Minerva* 46, no. 3 (2008): 343-360.
———. "The Linear Model of Innovation: The Historical Construction of an Analytical Framework." *Science, Technology, & Human Values* 31, no. 6 (2006): 639-667.
———. "The Linear Model of Innovation: Maurice Holland and the Research Cycle." *Social Science Information* 50, no. 3-4 (2011): 569-581.
Gorman, Michael E. *Scientific and Technological Thinking*. Mahwah, N.J.: L. Erlbaum, 2005.

———. *Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration*. Cambridge, Mass.: MIT Press, 2010.

Gorman, Michael E. "Levels of Expertise and Trading Zones: A Framework for Multidisciplinary Collaboration." *Social Studies of Science* 32, no. 5/6 (2002): 933-938.

Gove, H., P. Kubik, P. Sharma, S. Datar, U. Fehn, T. Hossain, J. Koffer, J. Lavine, S. Lee, and D. Elmore. "Applications of AMS to Electronic and Silver Halide Imaging Research." *Nuclear Instruments and Methods in Physics Research* 52, no. 3-4 (1990): 502-506.

Graham, Margaret B. W. and Alec T. Shuldiner. *Corning and the Craft of Innovation*. Oxford [England]; New York: Oxford University Press, 2001.

Graham, Margaret B. W. "Technology and Innovation." In *The Oxford Handbook of Business History*, edited by Jones, Geoffrey and Jonathan Zeitlin, 347-373. Oxford [England]; New York: Oxford University Press, 2008.

Grimm, Christine. *Inside a Secret Software Laboratory. An Ethnographic Study of a Global Software Package Producer*. Wiesbaden: Springer Gabler, 2012.

Guilhon, Bernard. *Technology and Markets for Knowledge: Knowledge Creation, Diffusion, and Exchange within a Growing Economy*. Boston; Norwell, Mass.: Kluwer Academic Publishers; Distributors for North, Central and South America: Kluwer Academic Publishers, 2001.

Guillemette, François. «L'approche De La Grounded Theory; Pour Innover ?» *Recherches Qualitatives* 26, no. 1 (2006): 32-50.

Hackett, Edward J., Olga Amsterdamska, Michael Lynch, and Judy Wajcman. *The Handbook of Science and Technology Studies*. 3rd ed. Massachusetts: Massachusetts Institute of Technology, 2008.

Hamberg, D. "Invention in the Industrial Research Laboratory." *Journal of Political Economy* 71, no. 2 (1963): 95-115.

Hardie, D. W. F. "The Emergence of the German Dye Industry." *Business History* 5, no. 2 (1963): 118-122.

Hartley, James. *Academic Writing and Publishing a Practical Handbook*. New York: Routledge, 2008.

Headrick, Daniel R. *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940*. New York: Oxford University Press, 1988.

Hedtmann, Sophie, Philippe Poncet, and Marie-Laure Cazin. *William Henry Fox Talbot*. Paris: Les Editions de l'Amateur, 2003.

Henney, Keith and Beverly Dudley. *Handbook of Photography*. New York: Whittlesey House, 1939.

Herzog, Philipp. *Open and Closed Innovation: Different Cultures for Different Strategies*. Wiesbaden: Gabler, 2011.

Higgins, G. C. "Kodak Research Laboratories." *Applied Optics* 11, no. 1 (January, 1972): 1-3.

Hintz, Eric S. "The Post-Heroic Generation: American Independent Inventors, 1900-1950." *Enterprise & Society* 12, no. 4 (2011): 732-748.

Ho, Jonathan C. and Chung-Shing Lee. “A Typology of Technological Change. Technological Paradigm Theory with Validation and Generalization from Case Studies.” *Technological Forecasting & Social Change* 97, (2015): 128-139.

Hoddeson, Lillian and Gordon Baym. *Critical Assembly: A Technical History of Los Alamos during the Oppenheimer Years, 1943-1945*. Cambridge [England]; New York: Cambridge University Press, 1993.

Holland, Maurice and Henry F. Pringle. *Industrial Explorers*. New York & London: Harper, 1928.

Horrocks, Sally M. “Enthusiasm Constrained? British Industrial R&D and the Transition from War to Peace, 1942–51.” *Business History* 41, no. 3 (1999): 42-63.

———. “Industrial Chemistry and its Changing Patrons at the University of Liverpool, 1926-1951.” *Technology and Culture* 48, no. 1 (2007): 43-66.

———. “The Internationalization of Science in a Commercial Context: Research and Development by Overseas Multinationals in Britain before the Mid-1970s.” *British Journal for the History of Science* 40, no. 145 (2007): 227-250.

Hounshell, David A. and John K. Smith. *Science and Corporate Strategy: Du Pont R&D, 1902-1980*. Cambridge; New York: Cambridge University Press, 1988.

Hounshell, David A. “Du Pont and the Management of Large-Scale Research and Development.” Chap. 9, In *Big Science: The Growth of Large-Scale Research*, edited by Galison, Peter and Bruce William Hevly, 236-261. Stanford, Calif.: Stanford University Press, 1992.

Hughes, Thomas P. *The Evolution of Large Technological Systems*. Berlin: Wissenschaftszentrum, 1986.

Hunt, Robert W. G. *The Reproduction of Colour*. London: Fountain Press, 1957.

Imbs, Constantin. « Répercussions esthétiques attendues des différents procédés d’enregistrement photochimiques et de restitution de l’information photographique au XIXe siècle ». MA dissertation, Sorbonne (Paris-IV), 2004.

Jacobson, Gary. “KODAK: Research is in the Driver's Seat.” *Management Review* 77, no. 10 (1988): 32-32.

Jenkins, Reese. *Images and Enterprise: Technology and the American Photographic Industry, 1839 to 1925*. Baltimore: Johns Hopkins University Press, 1975.

Johnston Sean F. *Holograms: a cultural history*. Oxford: Oxford University Press, 2015.

———. *Holographic visions: a history of new science*. Oxford: Oxford University Press, 2006.

Jones, Geoffrey. “Foreign Multinationals and British Industry before 1945.” *The Economic History Review* 41, no. 03 (1988): 429-453.

Kadiyali, Vrinda. “Entry, its Deterrence, and its Accomodation: A Study of the U.S. Photographic Film Industry.” *The Rand Journal of Economics (Washington)* 27, no. 03 (1996): 452-478.

Kaiserfeld, Thomas and Tom O'Dell. *Legitimizing ESS: Big Science as a Collaboration across Boundaries*. Lund: Nordic Academic Press, 2013.

Kanter, Rosabeth Moss, Lisa Richardson, Jeffrey North, and Erika Morgan. “Engines of Progress: Designing and Running Entrepreneurial Vehicles in Established Companies; the New Venture Process at Eastman Kodak, 1983–1989.” *Journal of Business Venturing* 6, no. 1 (1991): 63-82.

Kapecki, Jon A. “Color Photography.” In *The Focal Encyclopedia of Photography (Fourth Edition)*, edited by Peres, Michael R., 692-700. Boston: Focal Press, 2007.
Knorr-Cetina, Karin. *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science*. Oxford; New York: Pergamon Press, 1981.
Kragl, Udo, ed. *Technology Transfer in Biotechnology from Lab to Industry to Production*. Berlin; New York: Springer, 2005.
Kuhn, Thomas S. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press, 1962.
Latour, Bruno. *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford; New York: Oxford University Press, 2005.
———. *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge, Mass.: Harvard University Press, 1987.
Latour, Bruno and Steve Woolgar. *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills: Sage Publications, 1979.
Lavédrine, Bertrand and Jean-Paul Gandolfo. *The Lumière Autochrome: History, Technology, and Preservation*. Los Angeles: Getty Conservation Institute, 2013.
Le Guern, Nicolas. “Founding of a Research Laboratory at Eastman Kodak in 1912.” Paper presented at the Workers and Consumers: The photographic industry 1860-1950 Conference, De Montfort University, Leicester 24-25 June, 2013.
———. “Industrialists, their Scientists and the Endless Invention of Twentieth Century Photography.” *Photoresearcher* no. 25 (2016): 36-44.
———. «Des Recherches De Rodolphe Berthon chez Pathé En 1913-1914 Au Procédé Lenticulaire Kodacolor.» In *Les Cahiers De Recherche Pathé (1904-1930)*, edited by Salmon, Stéphanie. Paris: Fondation Jérôme Seydoux-Pathé, Forthcoming.
Lesch, John E., ed. *The German Chemical Industry in the Twentieth Century*. Dordrecht; Boston: Kluwer Academic Publishers, 2000.
Lichtenthaler, Ulrich and Eckhard Lichtenthaler. “Technology Transfer across Organizational Boundaries: Absorptive Capacity and Desorptive Capacity.” *California Management Review* 53, no. 1 (2010): 154-170.
Liu, Sifeng, Zhigeng Fang, Hongxing Shi, and Benhai Guo, eds. *Theory of Science and Technology Transfer and Applications*. Boca Raton: CRC Press, 2010.
Locke, Terry James. *Critical Discourse Analysis*. London; New York: Continuum, 2004.
Löhnert, Peter and Manfred Gill. “The Relationship of I.G. Farben's Agfa Filmfabrik Wolfen to its Jewish Scientists and Scientists Married to Jews, 1933-1939.” In *The German Chemical Industry in the Twentieth Century*, edited by Lesch, John E., 123-145. Dordrecht; Boston: Kluwer Academic Publishers, 2000.
Loveland, Roger. *A History of Chemistry in the Eastman Kodak Company*. Unpublished report, 1981, Kodak Research Laboratories, Rochester.
Lucas, H. C. and J. M. Goh. “Disruptive Technology: How Kodak Missed the Digital Photography Revolution.” *Journal of Strategic Information Systems* 18, no. 1 (2009): 46-55.
Lynch, Michael. *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory*. London; Boston: Routledge & Kegan Paul, 1985.
Lynch, Michael, Eric Livingston, and Harod Garfinkel. “Temporal Order in Laboratory Work.” In *Science Observed: Perspectives on the Social Study of Science*, edited by

Knorr-Cetina, K. and M. J. Mulkay, 205-238. London; Beverly Hills: Sage Publications, 1983.
Mangolte, Pierre-André. «Brevets Et Émergence De l'Industrie Cinématographique, Une Étude Comparative Etats-Unis - Europe (1895-1908).» *Annales, Histoire, Sciences Sociales* 61, no. 5 (2006): 1123-1145.
———. «Patents Wars: Brevet d'Invention et Patent, une Comparaison.» Working paper, 42, 2010, https://hal.archives-ouvertes.fr/hal-00624454.
Marchand, E. W. "Optics in the Kodak Research Laboratories." *Applied Optics* 11, no. 1 (January, 1972): 60-63.
Marignier, Jean-Louis. *Nicéphore Niépce (1765-1833). L'invention de la photographie*. Paris: Belin, 1999.
Martin, Louis Claude and William Gamble. *Colour and Methods of Colour Reproduction*. London: Blackie and Son Limited, 1923.
McCarthy, Jane Baum. "The Two-Color Kodachrome Collection at the George Eastman House." *Image* 30, no. 1 (1987): 1-12.
McCauley, Elizabeth Anne. *Industrial Madness: Commercial Photography in Paris, 1848-1871*. New Haven: Yale University Press, 1994.
McEnery, Tony and Andrew Hardie. *Corpus Linguistics: Method, Theory and Practice*. Cambridge; New York: Cambridge University Press, 2012.
Michel, Jean-Marie. «Contribution à l'Histoire Industrielle Des Polymères en France.» Société Chimique de France. Accessed June 15, 2013. www.societechimiquedefrance.fr/1/premiere-partie-les-polymeres-avant-staudinger.html.
Mitchell, Daniel John. "Reflecting Nature: Chemistry and Comprehensibility in Gabriel Lippmann's 'Physical' Method of Photographing Colours." *Notes and Records of the Royal Society* 64, no. 4 (10, 2010): 319-337.
Morgan, Mary S. and Peter Howlett. *How Well do Facts Travel?: The Dissemination of Reliable Knowledge*. Cambridge; New York: Cambridge University Press, 2010.
Mortara, Letizia, Ruth Thomson, Chris Moore, Kallopi Armara, Clive Kerr, Robert Phaal, and David Probert. "Developing a Technology Intelligence Strategy at Kodak European Research: Scan & Target." *Research Technology Management* 53, no. 4 (2010): 27-38.
Moser, Petra. "Patents and Innovation: Evidence from Economic History." *The Journal of Economic Perspectives* 27, no. 1 (2012): 23-44.
Mowery, David C. "Plus Ca Change: Industrial R&D in the "Third Industrial Revolution"." *Industrial and Corporate Change* 18, no. 1 (2009): 1-50.
Mowery, David C. "Industrial Research and Firm Size, Survival, and Growth in American Manufacturing, 1921-1946: An Assessment." *The Journal of Economic History* 43, no. 4 (1983): 953-980.
———. "Industrial Research in Britain, 1900-1950." In *The Decline of the British Economy*, edited by Elbaum, Bernard and William Lazonick, 189-222. Oxford: Clarendon Press, 1986.
Munir, Kamal A. and Nelson Phillips. "The Concept of Industry and the Case of Radical Technological Change." *Journal of High Technology Management Research* 13, no. 2 (2002): 279-297.

Munir, Kamal and Nelson Phillips. “The Birth of the ‘Kodak Moment’: Institutional Entrepreneurship and the Adoption of New Technologies.” *Organization Studies* 26, no. 11 (2005): 1665-1687.

Myers, Greg. “From Discovery to Invention: The Writing and Rewriting of Two Patents.” *Social Studies of Science* 25, no. 1 (1995): 57-105.

National Academy of Engineering. *The Impact of Academic Research on Industrial Performance*. Washington, D.C.: National Academies Press, 2003.

N'Diaye, Pap. «Peter Galison et Bruce Hevly (Dir.), Big Science. The Growth of Large-Scale Research.» *Annales. Économies, Sociétés, Civilisations* 48, no. 2 (1993): 414-417.

Ndiaye, Pap. *Du Nylon et Des Bombes : Du Pont De Nemours, Le Marché Et l'Etat américain, 1900-1970*. Paris: Belin, 2001.

Nersessian, Nancy J. “Interpreting Scientific and Engineering Practices: Integrating the Cognitive, Social, and Cultural Dimensions.” Chap. 2, In *Scientific and Technological Thinking*, edited by Gorman, Michael E., Ryan D. Tweney, David C. Gooding and Alexandra P. Kincannon, 17-56. Mahwah, N.J.; London: Lawrence Erlbaum Associates, Publishers, 2005.

Neuman, William Lawrence. *Social Research Methods: Qualitative and Quantitative Approaches*. Boston [etc.]: Pearson, 2011.

Nicholas, Tom. “Cheaper Patents.” *Research Policy* 40, no. 2 (2011b): 325-339.

———. “Independent Invention during the Rise of the Corporate Economy in Britain and Japan.” *The Economic History Review* 64, no. 3 (2011a): 995-1023.

———. “The Role of Independent Invention in U.S. Technological Development, 1880–1930.” *The Journal of Economic History* 70, no. 01 (2010): 57-82.

Packer, Martin J. *The Science of Qualitative Research*. New York: Cambridge University Press, 2011.

Park, Doing. “Give Me a Laboratory and I Will Raise a Discipline: The Past, Present, and Future Politics of Laboratory Studies in STS.” Chap. 12, In *The Handbook of Science and Technology Studies*, edited by Hackett, Edward J., Olga Amsterdama, Michael Lynch and Judy Wajcman. 3rd ed., 279-295. Cambridge, MA; London: The MIT Press, 2008.

Pénichon, Sylvie. *Twentieth-century color photographs: Identification and care*. Los Angeles, California: Getty Conservation Institute, 2013.

Pickering, Andrew. *Constructing Quarks: A Sociological History of Particle Physics*. Chicago: University of Chicago Press, 1984.

———. “Knowledge, Practice and Mere Construction.” *Social Studies of Science Social Studies of Science* 20, no. 4 (1990): 682-729.

———. *The Mangle of Practice: Time, Agency, and Science*. Chicago: University of Chicago Press, 1995.

———. *Science as Practice and Culture*. Chicago: University of Chicago Press, 1992.

Pinch, Trevor. *Confronting Nature: The Sociology of Solar-Neutrino Detection*. Dordrecht, Holland; Boston; Higham, MA, U.S.A.: D. Reidel Pub. Co, 1986.

Price, Derek John de Solla. *Little Science, Big Science... and Beyond*. New York: Columbia University Press, 1986.

Price, Derek J. de Solla. *Little Science, Big Science*. New York: Columbia Univ. Press, 1963.

Pritchard, Michael. “The Development and Growth of British Photographic Manufacturing and Retailing 1839-1914.” PhD dissertation, De Montfort University, 2010.

Ratcliff, J. D. “Eastman Kodak's Research Odyssey: Profitable Sidelines Add to Company's Earnings from Photographic Products.” *Barron's,* June 23, 1941.

Ravetz, Jerome R. *Scientific Knowledge and its Social Problems*. Oxford: Clarendon Press, 1971.

Reich, Leonard S. *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926*. Cambridge; New York: Cambridge University Press, 1985.

Reppy, Judith, ed. *Secrecy and Knowledge Production*. Ithaca, N.Y.: Cornell University Peace Studies Program, 1999.

Roberts, Pamela Glasson. *The Genius of Color Photography: from the Autochrome to the Digital Age*. London: Goodman, 2010.

Rogers, David. *The Chemistry of Photography: From Classical to Digital Technologies*. Cambridge: Royal Society of Chemistry, 2007.

Rooij, Arjan van. *The Company that Changed itself: R&D and the Transformations of DSM*. Amsterdam: Amsterdam University Press, 2007.

Roulier, Annette. *A Short History and Concepts of Color Photography*. Swiss Virtual Campus: Imaging and Media Lab, 2008.

Ruedel, Ulrich. “The Technicolor Notebooks at the George Eastman House.” *Film History* 21, no. 1 (2009): 47-60.

Ruivo, Céline. «Le Technicolor Trichrome : Histoire d'un Procédé et Enjeux de sa Restauration.» PhD dissertation, Paris 3, Institut de recherches en études théâtrales, 2016.

Ryan, Roderick T. *A History of Motion Picture Color Technology.* London: Focal Press, 1977.

Rzasa, Philip V., Terrence W. Faulkner, and Nancy L. Sousa. “Analyzing R & D Portfolios at Eastman Kodak.” *Research Technology Management* 33, no. 1 (1990): 27-32.

Salmon, Stéphanie, ed. *Les Cahiers De Recherche Pathé (1904-1930)*. Paris: Fondation Jérôme Seydoux-Pathé, forthcoming.

Salmon, Stéphanie. *Pathé : À La conquête Du cinéma (1896-1929)*. Paris: Tallandier, 2014.

———. “Tinting and Toning at Pathé: The Jacques Mayer Notebook.” *Film History* 21, no. 2 (2009): 177-179.

Salt, Barry. “Film Style and Technology in the Thirties.” *Film Quarterly* 30, no. 1 (1976): 19-32.

Sanderson, Michael. “Research and the Firm in British Industry, 1919-39.” *Social Studies of Science* 2, no. 2 (1972): 107-151.

Sandström, Christian G. “A Revised Perspective on Disruptive Innovation: Exporing Value, Networks and Business Models.” PhD, Chalmers University of Technology, 2010.

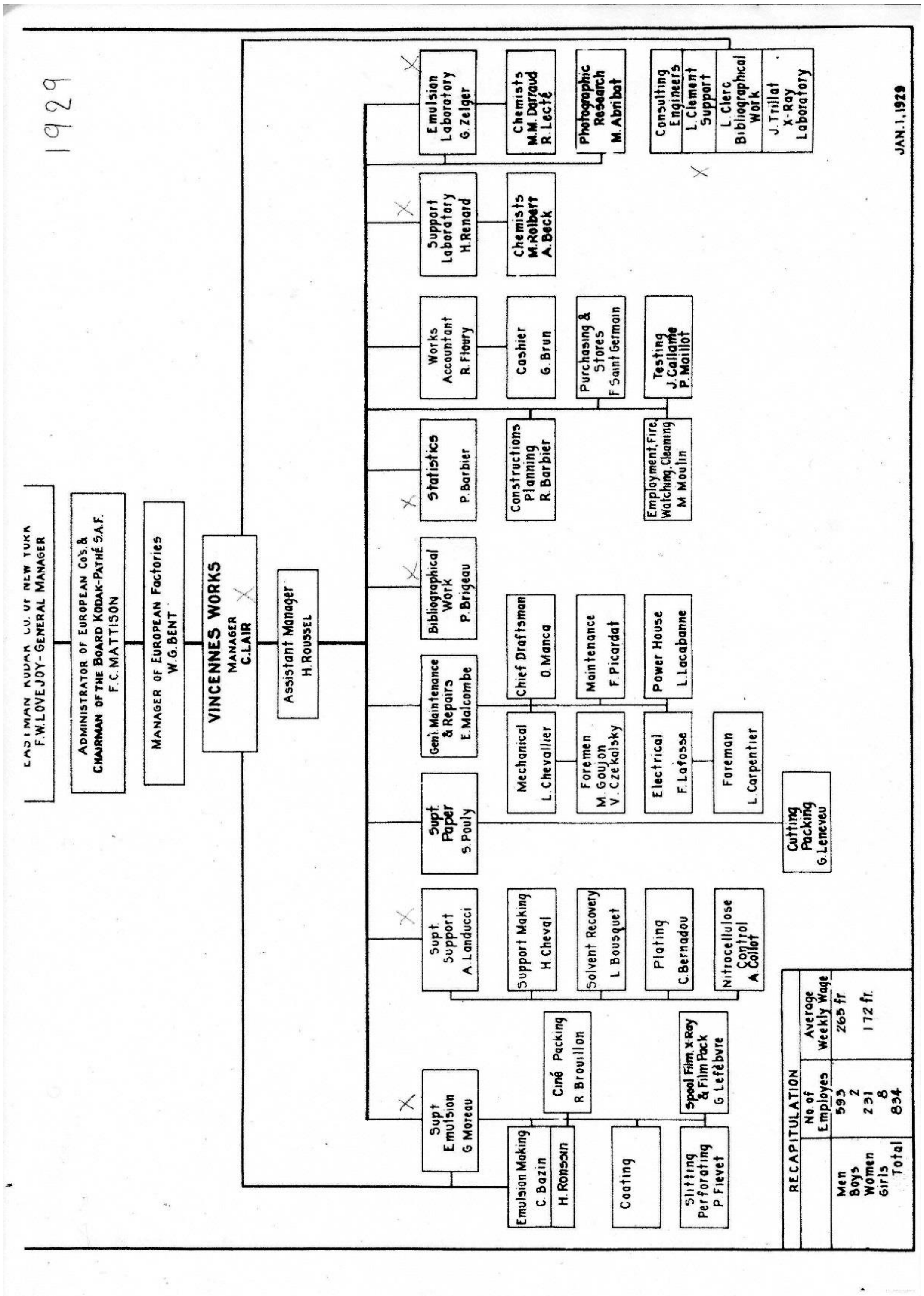
Sarvas, Risto and David M. Frohlich. “Domestic Photography and Technological Paths.” Chap. 2, In *From Snapshots to Social Media - the Changing Picture of Domestic*

Photography, edited by Sarvas, Risto and David M. Frohlich, 5-22. London: Springer, 2011.
———. *From Snapshots to Social Media: The Changing Picture of Domestic Photography*. New York: Springer, 2011.
Sauteron, François. *La Chute De l'Empire Kodak*. Paris: Harmattan, 2009.
———. *Une Si Jolie Usine: Kodak-Pathé Vincennes*. Paris: Harmattan, 2008.
Schaaf Larry J. and William Henry Fox Talbot. *Records of the dawn of photography: Talbot's notebooks P & Q*. Cambridge [England]: Cambridge University Press in cooperation with the National Museum of Photography, Film & Television, 1996.
Schimmelman Janice G. *American Photographic Patents 1840-1880: The Daguerreotype and Wet Plate Era*. Nevada city: Carl Mautz-Publishing, 2002.
Schlesinger, Frank. "Presentation of the Henry Draper Medal to C.E. Kenneth Mees." *Science* 85, no. 2210 (1937): 434-435.
Schmitt, Franz. *Dictionnaire des brevets cinématographiques français : des origines à 1929*. Paris: Prodiex, 1996.
Schrader, Robert J. "Eastman Kodak & the Manhattan Project." Accessed June 15, 2014. www.mphpa.org/classic/COLLECTIONS/OR-RSCH/STORY/Pages/RSCH_Gallery_01.htm.
Schrader, Robert J. *Eastman Kodak and the Manhattan Project at Oak Ridge, Tennessee: The Atomic Bomb*. Longview, TX: Robert J. Schrader, 2004.
Schumpeter, Joseph A. *Theorie Der Wirtschaftlichen Entwicklung*, edited by Duncker & Humblot. Leipzig: Verlag von Duncker und Humblot, 1911.
Schumpeter, Joseph A. and Redvers Opie. *The Theory of Economic Development. An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge, Mass.: Harvard University Press, 1934.
Shanebrook, Robert L. *Making KODAK Film. The Illustrated Story of State-of-the-Art Photographic Film Manufacturing*. Rochester, NY: Robert Shanebrook Photography, 2010.
Shapin, Steven, Simon Schaffer, and Thomas Hobbes. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life: Including a Translation of Thomas Hobbes, Dialogus Physicus De Natura Aeris by Simon Schaffer*. Princeton, N.J.: Princeton University Press, 1985.
Shapin, Steven. *The Scientific Life: A Moral History of a Late Modern Vocation*. Chicago: University of Chicago Press, 2008.
Shaughnessy, Haydn. "Recognizing the Ecosystem Phase-Change: A Guide to Four Types." *Strategy & Leadership* 42, no. 1 (2014): 17-23.
Shenhav, Yehouda A. *Manufacturing rationality: the engineering foundations of the managerial revolution*. Oxford: Oxford University Press, 1999.
Sherwood, Martin. "Photographic Research in Focus." *New Scientist* (February 8, 1973): 301-303.
Shrum, Wesley, Joel Genuth, and Ivan Chompalov, eds. *Structures of Scientific Collaboration*. Cambridge, Mass.: MIT Press, 2007.
Sipley, Louis Walter. *A Half Century of Color*. New York: Macmillan, 1951.
Sismondo, Sergio. *An Introduction to Science and Technology Studies*. Chichester, U.K.: Wiley-Blackwell, 2010.

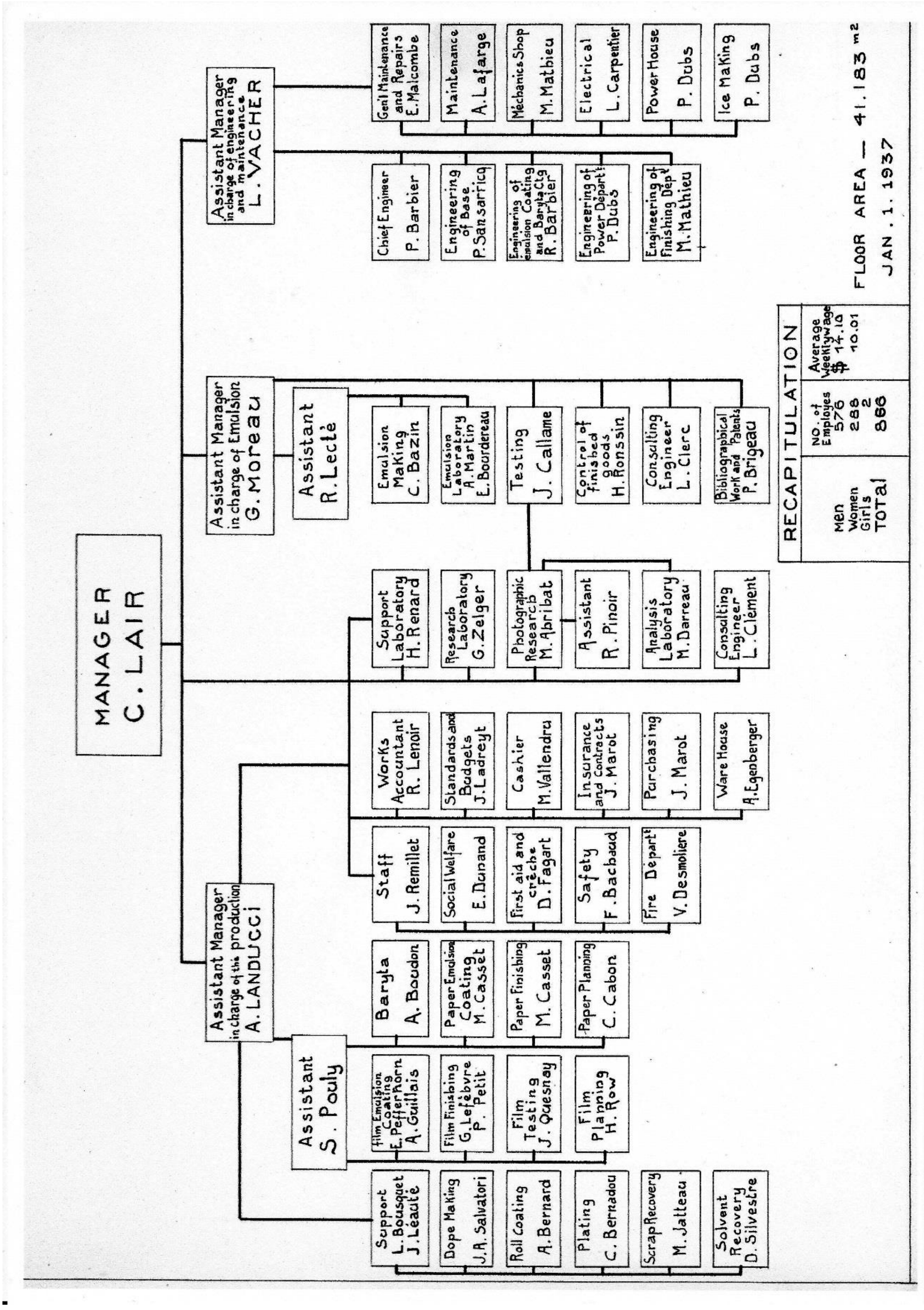
Smith, John K. and David A. Hounshell. “Wallace H. Carothers and Fundamental Research at Du Pont.” *Science* 229, no. 4712 (1985): 436-442.
Sokal, Alan D. and J. Bricmont. *Intellectual Impostures*. London: Profile, 2003.
Souza, Paulo Antonio de. *Innovation in Industrial Research*. Collingwood, Vic.: CSIRO Publishing, 2010.
Speser, Phyllis L. *The Art & Science of Technology Transfer*. Hoboken, N.J.: John Wiley Sons, Inc, 2006.
Strong, Frank P. “Kodak: Beyond 1990.” *Journal of Consumer Marketing* 5, no. 3 (1988): 53-60.
Sturchio, Jeffrey L. “Artifact and Experiment.” *Isis* 79, no. 3 (1988): 368-372.
———. “Experimenting with Research: Kenneth Mees, Eastman Kodak, and the Challenges of Diversification.” Paper presented at the R&D pioneers Conference, Wilmington, Delaware, Hagley Museum and Library, October 7, 1985.
Styhre, Alexander. *The innovative bureaucracy: bureaucracy in an age of fluidity*. London: Routledge, 2007.
Sullivan, Neil F. *Technology Transfer: Making the most of Your Intellectual Property*. Cambridge; New York: Cambridge University Press, 1995.
Taylor, John. “Kodak and the "English" Market between the Wars.” *Journal of Design History* 7, no. 1 (1994): 29-42.
Taylor, Roger and Larry J. Schaaf. *Impressed by light: British photographs from paper negatives, 1840-1860*. New York: Metropolitan Museum of Art, 2007.
Thackray, Arnold, Jeffrey L. Sturchio, Thomas Carroll P., and Robert Bud, eds. *Chemistry in America, 1876-1976: Historical Indicators*. Dordrecht; Boston; Lancaster: D. Reidel, 1985.
Timby, Kim. *3D and Animated Lenticular Photography. Between Utopia and Entertainment.* Berlin: Walter de Gruyter & Co., 2015.
———. “Colour Photography and Stereoscopy: Parallel Histories.” *History of Photography* 29, no. 2 (2005): 183-196.
Travis, Anthony S. *Determinants in the Evolution of the European Chemical Industry: 1900-1939: New Technologies, Political Frameworks, Markets and Companies*. Dordrecht: Kluwer Acad. Publ., 1998.
Trott, Paul and Dap Hartmann. “Why 'Open Innovation' is Old Wine in New Bottles.” *International Journal of Innovation Management* 13, no. 4 (2009): 715-736.
Uthman, Alan P. “Laboratory Information Management Systems at Kodak: Foundation for the Future.” *Chemometrics and Intelligent Laboratory Systems* 17, no. 3 (1992): 289-294.
Utterback, James M. “Developing Technologies: The Eastman Kodak Story.” *The McKinsey Quarterly* 1, (1995): 130-144.
Varma, Roli. “Changing Research Cultures in U.S. Industry.” *Science, Technology, & Human Values* 25, no. 4 (2000): 395-416.
Vaughan, Diane. “The Role of the Organization in the Production of Techno-Scientific Knowledge.” *Social Studies of Science* 29, no. 6 (1999): 913-943.
Vinck, Dominique. *Sociology of Scientific Work: The Fundamental Relationship between Science and Society*. Cheltenham: Edward Elgar Publishing Limited, 2010.

Weinberg, Alvin M. “Impact of Large-Scale Science on the United States.” *Science* 134, no. 3473 (1961): 161-164.
Weissberger, Arnold. “A Chemist's View of Color Photography: How does Color Photography Work? What is required of the Light-Sensitive Material? What is the Origin of the Image Dyes?” *American Scientist* 58, no. 6 (1970): 648-660.
Wilder, Kelley E. “Kodak and Photographic Research.” In *American Photography: Local and Global Contexts*, edited by Gockel, Bettina, 259-270. Berlin: Akademie Verlag, 2012.
———. *Photography and Science*. London: Reaktion, 2009.
Wilson, Jonathan. *Essentials of Business Research: A Guide to Doing Your Research Project*. Los Angeles: Sage Publications, 2010.
Wise, George. *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research*. New York: Columbia University Press, 1985.
Wünsch, Ludek. “Karel Schinzel, an Inventor Crossed by Fate.” *The Heart of Europe* no. 4 (2006): 16-19.
Ziman, John. “An Evolutionary History of High Energy Particle Physics, with Metascientific Goals.” *Minerva* 36, no. 3 (1998): 289-293.

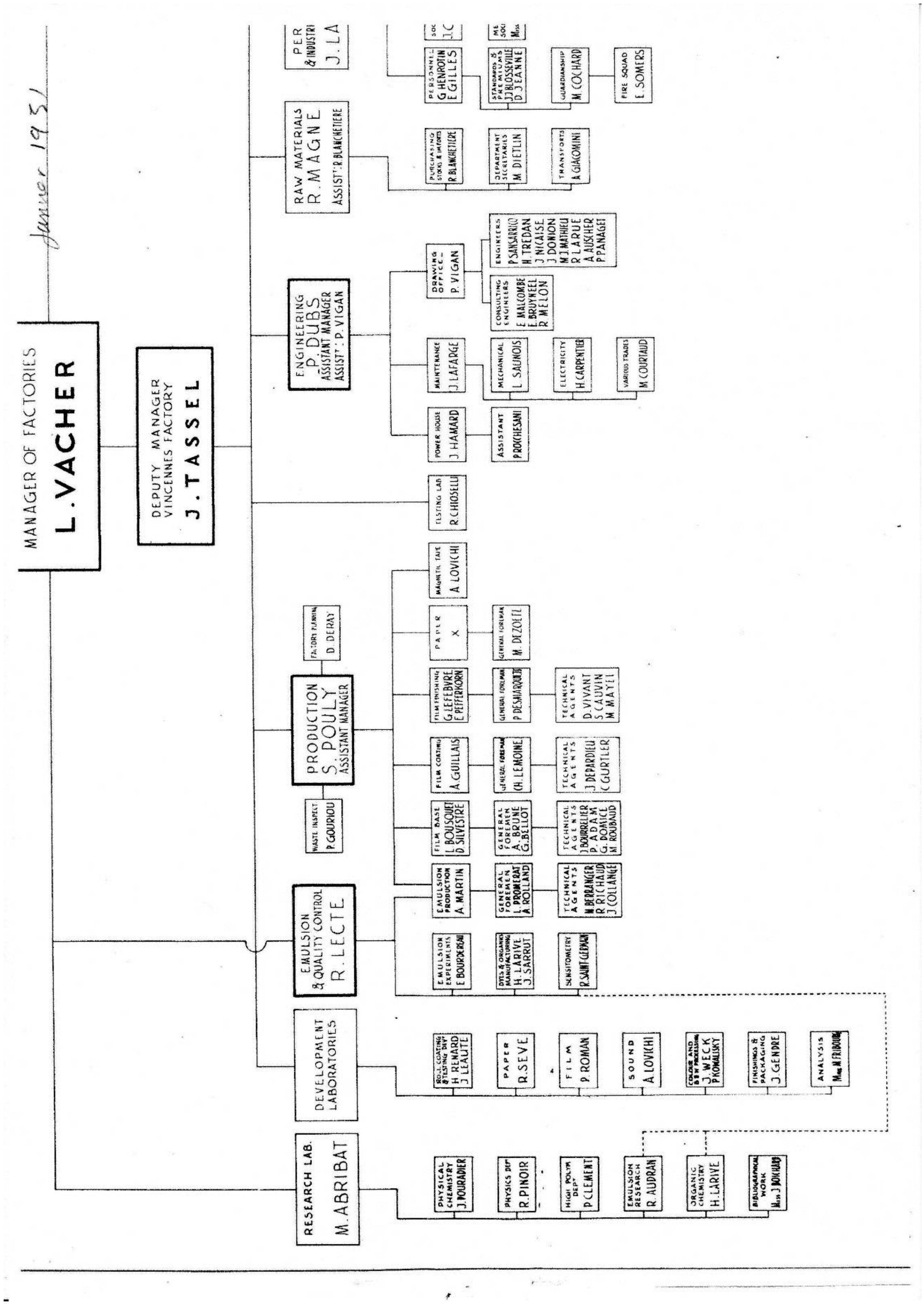
Appendices



Organisation chart of the Kodak-Pathé company, 1929 (CECIL document).



Organisation chart of the Kodak-Pathé company, 1937 (CECIL document).



Organisation chart of the Kodak-Pathé company, 1951 (CECIL document).

	NUMBER	TITLE	TYPE
1	H.2	**Investigation of removal of dye from red-backed and green-backed Cine Kodak film**	Patent issue with competitors
2	H.30c	**Interim report on crystallisation test for quinoline yellow**	Testing of new dyes
3	H.65	**Photographic activity of thoriated tungsten filaments**	New material testing following a collaboration with a third party
4	H.68	**Contrast of cine positive film developed on continuous machines at some British film**	Testing of film processing
5	H.71c	**Dr. Binder's developing outfit and daylight developer**	New material testing following a collaboration with a third party
6	H.79g	**Visit to Keller-Dorian Works, Paris**	Visit abroad to meet partners and to look for new technologies
7	h.79g(ii)	**Second visit to Keller-Dorian, August, 1929**	Visit abroad to meet partners and to look for new technologies
8	H.81g	**Visit to Germany and Belgium**	Visit abroad to meet partners and to look for new technologies
9	H.82g	**Investigation of white spots at Vincennes**	Investigation due to production issue
10	H.83g	**Steam heating coils in silver nitrate plant**	Investigation due to production issue
11	H.84g	**Colour Snapshots, Ltd**	Investigation into a new technology developed by another company
12	H.84g(ii)	**Colorsnap process of colour photography (confidential)**	Investigation into a new technology developed by another company
13	H.98p	**Tests of Three Kodak lenses**	Testing of finished products
14	H.100p	**Some Kodascope projector lamps**	New material testing following a collaboration with a third party
15	H.110d	**Report on visit to Mr. August, March 4th, 1930**	Investigation into a new technology developed by another company
16	H.110d(ii)	**Visit to Mr. August, April 17th, 1930**	Investigation into a new technology developed by another company
17	H.110d(iii)	**Visit to Mr. August, 19th May, 1931**	Investigation into a new technology developed by another company
18	H.116c	**The effect of ammonium bromide on the pH of gelatin. I.**	Investigation into the behaviour of a photochemical compound
19	H.117d	**A system of sound reproduction**	Investigation into a new technology developed by another company
20	H.118p	**Burning rates of film, paper and textile fabrics**	Testing and comparison between proprietary and competitive products
21	H.118p(ii)	**Burning tests on film according to the German method.**	Testing and comparison between proprietary and competitive products
22	H.120g(ii)	**Some references to the literature of Diazotype processes**	Complete memorandum about a specific topic
23	H.120g(iii)	**Note on the scope and validity of patent claims by Kalle and Co. concerning the manufacture of light-sensitive layers containing diazo compounds.**	Patent issue with competitors
24	H.120g(iv)	**Investigations on Diazotype papers. Summary of position at March, 1931**	Patent issue with competitors
25	H.123p	**Defect on a print made on copenick nitrate support 4-829**	Investigation due to production issue
26	H.124p	**Nature of dye in Sel duplicating negative film**	Investigation into a competitive product by reverse engineering
27	H.128p	**Henderson-treated film**	Investigation into a competitive product by reverse engineering
28	H.139d	**A safety film (Robins).**	Investigation into a new technology developed by another company
29	H.144p	**Sensitometry of Harrow Cine Positive film and experimental emulsions 341, 570 and 582**	Development of new products
30	H.144p(ii)	**Sensitometry of Agfa sound film, T. F. 3. and Harrow positive**	Testing and comparison between proprietary and competitive products
31	H.144p(iii)	**Sensitometry of films**	Testing and comparison between proprietary and competitive products
32	H.144p(iv)	**Sensitometry of plates**	Testing and comparison between proprietary and competitive products
33	H.148p	**Sensitometric procedure for films and plates**	Summary of testing procedures at the Laboratory
34	H.150P	**Raycol process of cinematography in colours**	Investigation into a new technology developed by another company
35	H.152p	**Identification of dye backing of photographic plate**	Investigation into a competitive product by reverse engineering

List of the 62 Harrow research reports (1929-1935) used in section 3.2.1 for the analysis of the Harrow Research Laboratory activities (1/2).

36	H.155g	**Visit to Vincennes, November, 1930**	Meeting with the staff of the Kodak-Pathé Research Laboratory
37	H.156d	**Cine-radiographic process of Mr. B.E. Luboshez**	Visit abroad to meet partners and to look for new technologies
38	H.174c	**Granularity in developed cine positive emulsion caused by bacterial infection**	Investigation due to production issue
39	H.179c	**Hardening of gelatin by ultra-violet light**	Investigation into the behaviour of a photochemical compound
40	H.185o	**Investigation of the dyes from Isochrome film**	Investigation into a competitive product by reverse engineering
41	H.203	**Adaptation of a Capstaff-Purdy densitometer for the measurement of reflection densities**	Development of the instrumentation for the laboratory's activities
42	H.207	**Interim report on a photometer for the measurement of transmission and reflection densities**	Development of the instrumentation for the laboratory's activities
43	H.209	**Hypersensitisation with silver-tungstate patented process of the Deutsche Versuchsanstalt für Luftfahrt**	Investigation into a new technology developed by another company
44	H.212	**Anti-halation devices, with especial reference to the use of dyes**	Complete memorandum about a specific topic
45	H.226	**The periodic occurrence of white spots on Copenick X-ray film**	Investigation due to production issue
46	H.236	**Report on sensitometric tests on roll films**	Testing and comparison between proprietary and competitive products
47	H.237	**The absorption spectra of some typical symmetrical cyanine dyes.**	Complete memorandum about a specific topic
48	H.249	**Conference on graininess in cine-film at the Harrow Research Laboratory. May 13th, 1933**	Meeting with the staff of the Kodak-Pathé Research Laboratory
49	H.255	**Examination of Gevaert velours paper**	Investigation into a competitive product by reverse engineering
50	H.256	**Selection of cut films for the process of colour photography controlled by Colour Photographs Limited**	Investigation into a new technology developed by another company
51	H.258	**A meeting for the standardisation of procedure in Harrow and continental factories for routine colorimetric pH measurements.**	Investigation due to production issue
52	H.283	**Investigation of sensitising dye used in Schleussner "Tempo-Lux" plates.**	Investigation into a competitive product by reverse engineering
53	H.298	**Resolving power tests on Kodak and Ilford stripping paper, Toronto process film, and Ilford ordinary plate.**	Testing of film processing
54	H.301	**Testing of dyes for sensitizing power. Period March - July, 1934**	Testing of new dyes
55	H.305	**Spectrophotometric measurements and calculations on glass filters**	Development of new products
56	H.307	**A method of extracting dyes from silver halide emulsions**	Investigation into a competitive product by reverse engineering
57	H.317	**The properties of Agfa Direkt Duplikat Film**	Investigation into a competitive product by reverse engineering
58	H.323	**Uniformity of processing 35 mm. Kodacolor film on the Research Laboratory developing machine**	Development of the instrumentation for the laboratory's activities
59	H.331	**Wear and tear testing**	Testing of film processing
60	H.333	**The properties of Agfa Direkt Duplikat Film. II. Preparation of a similar solarising emulsion**	Investigation into a competitive product by reverse engineering
61	H.334	**Routine physical testing of 16 mm. film at Harrow**	Testing of film processing
62	H.340	**A possible scheme for the restoration of defective Kodachrome film**	Investigation due to production issue

List of the 62 Harrow research reports (1929-1935) used in section 3.2.1 for the analysis of the Harrow Research Laboratory activities (2/2).