The University of Aston in Birmingham

Product Innovation in a New Technology Based Firm

by

Andrew David Pickard

Submitted for the Degree of Doctor of Philosophy

September 1986

The University of Aston in Birmingham

PRODUCT INNOVATION IN A NEW TECHNOLOGY BASED FIRM

Andrew David Pickard

Submitted for the Degree of Doctor of Philosophy

1986

Summary

This thesis examines the "state of the art" of product innovation in new technology in the UK. The roles in innovation attributed to small and large firms are examined. Growing attention is being focused upon the small firm sector as a seedbed for innovation and government policy has been changing to encourage the entrepreneurial new technology based firm (NTBF).

The novel perspective of this research results from working in such a firm. It provides a longitudinal study of the management of innovation in conjunction with the corporate strategy of the firm. Given that the researcher was a participant and observer in the firm studied, the research is akin to action research in methodology but is better described as grounded theory.

Theoretical concepts are drawn from the prescriptive literature describing corporate strategy, and from the empirical literature which has evaluated new product success and failure. Models of the innovation process are discussed and appropriate strategies and reasons for product innovation failure in NTBFs are described.

The strategy, structure and new product development progress of the company are examined, using both the researcher's observations and company documents. This provides information on the methods and practices adopted for product innovation in a NTBF. The thesis analyses the performance of the firm in terms of product innovation. The models and strategies derived from the literature are then tested in the light of the experience of the company.

Conclusions are drawn regarding strategies for innovation in NTBFs and about the innovation process in general. The importance of a NTBF adopting a synergistic strategy is shown. Links are established between the existence of synergy in the strategy and coupling in the management of innovation. Innovation is shown to be a laterally interdisciplinary exercise and therefore the "pipeline model" is criticised. Finally a set of guidelines is produced for the managers of NTBFs.

KEY WORDS: Product innovation, New technology, Strategy, Entrepreneurial

To my parents

and

The memory of my grandfather

Mr Harry Walton (Febuary 1895 - August 1986)

He saw more innovations than most and would have liked to have read this

Acknowledgements

I would like to thank those people who have made this thesis possible.

In particular my thanks go to Dr Clark, who has continued to supervise and support both me and the work through times of uncertainty and change, to Dr Cochran, my IHD tutor, who provided valuble advice in the management of the work and to Dr Briscoe for agreeing to take on the role of supervision at a late but important stage.

My thanks are due to the Directors and the Receiver's Managers of Dutom Meditech plc who allowed me access to many company documents.

I would like to thank Dr Jackson for his painstaking reading of the proofs.

Finally my thanks to all my friends and colleagues who have provided me with discussion and comment on the work and have encouraged, persuaded, distracted, coersed and cajoled me through it. Without them it would have been a longer and lonelier road.

List of Contents

List of Figures

List of Tables

List of Programs

CHAPTER 1

THE RESEARCH ENVIRONMENT

1.1.0 Introductions
1.1.1 Introduction to IHD
1.1.2 Introduction to Dutom Meditech

1.2.0 The project in context
1.2.1 New product development - Formaldehyde monitor
1.2.2 New product evaluation - Adsorba monitor
1.2.3 The company innovation strategy

1.3.0 The nature of the research

1.4.0 The thesis outline

"Our higher education establishments need
- to be concerned with attitudes to the world outside higher education and in particular to industry and commerce.
- to go out to develop their links with industry and commerce.
- strong connections with their local communities. The development of close links with local industry and commerce is of prime importance." Section 1.6

"Employer involvement is even more important for postgraduates than elsewhere in higher education." Section 5.17

Government Green Paper on Higher Education, May 1985

OUTLINE

This chapter provides an introduction to the ethos, aims and objectives of the IHD Scheme. The position of the IHD Scheme in the university structure, the nature of the sponsoring organization and the role of the supervisory team are described.

The work carried out during the time spent with the firm is described together with the reasons for changes in emphasis and direction which occurred. Through this work, experience was gained in several aspects of the innovation process namely the invention, testing, production and marketing of new products. In the context of the commercial failure of the company this experience provided a basis from which to research the strategy and management of innovation in a new technology based firm.

The nature of the research is discussed with regard to the appropriateness of the research methodology employed. Finally a thesis outline is presented.

1.1.0 Introductions

The topic of this thesis is currently of interest to industrialists, academics, political economists and protaganists of technology transfer alike. The importance of product innovations has long been recognised as an important feature of business. The emergence of small firms committed to new technologies has only recently been both recognised and encouraged for the contribution it may make to technological progress and the national economy through product innovation.

This thesis examines issues related to product innovation in these New Technology Based Firms (NTBF). The subject is addressed in the thesis because I believe it to be the most relevant and important research derived from being both a participant in and observer of invention, testing, production, marketing and innovation management within a firm committed to the application of new technology commercially. The ability to research the management of innovation by such a firm and relate it to the existing innovation studies offered a unique opportunity to contribute to the debate on the subjects of innovation and new technology based firms, from a position of experience. As such, the thesis is a diversion from some of the practical work undertaken at the company and from the original concept of the project initially proposed by the firm. The research environment is described, briefly, so that some of the reasons for the changes which the project underwent may be understood.

1.1.1 Introduction to IHD

In the mid 1960's the orientation of the British University research programme was criticised as being too academic and diverted able students away from industry.*(1)* Despite the centres of excellence established in the universities, British industry was not benefiting from technological advance in the same way as some overseas countries. The Swann Report called for greater technological orientation of our universities and for:

"Bold new advances with the PhD."*(2)*

In response Aston University Interdisciplinary Higher Degrees Scheme (IHD) was launched in 1968, and found support from the newly funded Joint Committee of SRC/SSRC. The Scheme acts to bridge the division between academic and 'industrial' research projects and provide interdisciplinary training for its students in the environment of the real world. The orientation of the IHD Scheme is unusual at present in British universities. It is an entirely postgraduate scheme and looks for its research projects outside the university setting, i.e. it attracts and co-ordinates a diversity of research projects from outside organizations. Projects are welcomed not just from industry but from a gamut of organizations including, manufacturing industry, central government, charities, and pressure groups.

The history, methods, success and failures of the scheme are well summarised by Cochran 1981.*(3)* It is sufficient here just to reiterate the aims that the Scheme has in co-ordinating research to the standard of the PhD.

> "To equip postgraduate students for positions of responsibility in industry and publicly financed organizations, by providing training in practical, real world problem solving: more specifically in,
> *application of existing knowledge
> *generation of new knowledge needed
> *appreciation of academic disciplines different from those of student's first degree
> *appreciation of practical constraints in real world problems
> *implementation of solutions."

The position of IHD in the university structure is anomalous. It has not been incorporated into one of the Faculties of the University instead it has the status of an "Academic Unit" and reports directly to a committee of Senate, the IHD Research Senate Committee.

Despite running a number of research projects, the Scheme has very limited facilities. It has no scientific or engineering equipment or workspace, instead it limits itself to some student office space, offices for the IHD academic tutors and small scale secretarial support. Students are encouraged to find the research equipment, space and expertise they require within the university, from the departments most appropriate to their projects. This enables IHD students to draw on differing areas of expertise, as necessary, and maintain an interdisciplinary approach.

In keeping with a collaborative project, student time is split between the sponsor and the university, although the proportion of time spent in each place is determined by the nature of the project. Time at the university is required for library research, consultation with supervisors and lectures. IHD arranges a core of coursework, especially for Total Technology students, which is designed to introduce students to other disciplines and factors within their collaborating organizations. This course is best described as diverse rather than intensive but students are also encouraged to study specific subject areas by attending courses in other departments.

The interdisciplinary approach is also applied to supervision of the projects. IHD staff are not generally responsible for the academic supervision. Instead they act as co-ordinators of the project and aid in its management. The main supervisor is normally located in a department with an interest akin to the project. In addition members from other departments are invited to participate as the associate supervisors, and finally a representative of the sponsor completes the supervisory team as industrial supervisor.

The supervisory team acts to review project progress and agree the direction of the project. The regular meetings of the team facilitate planning of the project and maintain the interdisciplinary approach to the work. It is the role of the student to co-ordinate and minute the meetings of the team and liaise with team members between meetings. The supervisory team formally recommends the student for registration of thesis title and degree.

So IHD by concept, history and organizational practice allows the student to undertake research at the interface of different academic disciplines, and at that of industry and academia.

1.1.2 Introduction to Dutom

The sponsoring organization for this project was Dutom Meditech. The company had been founded in August 1980 by Mr J Dutton and Dr J Thompson to exploit Dr Thompson's expertise in the fields of analytical chemistry and bio-chemistry. Initially known as Dutom Laboratories Ltd the certificate of incorporation was issued on 7 November 1980 and the company registered as a private limited company no. 1502766. The name was changed to Dutom Meditech Ltd on 29 December 1980. The Board of Directors comprised the two founder members with Professor R Belcher as Chairman until his death in June 1982. The company began recruiting staff and trading during 1981.

At the time I joined the company in October 1982 the company registered office was premises in Luton. The business of the company, however, was carried out from small integrated office and laboratory facilities in Digbeth, Birmingham. The premises had been opened by the Under Secretary of State for Industry on 22 October 1981, and were intended as the company headquarters. A company directly controlled by one of the directors, but engaged in an unrelated business, operated from the same premises.

The company had been set up as an innovative, new technology based firm (NTBF) with interests in analytical chemistry, bio-technology and microprocessors. It had been partly financed by a government start-up loan under the Business Start-Up Scheme, and was the subject of a Department of Industry study of entrepreneurial activity. It was later to become one of the first independent entrepreneurial companies to raise capital under the auspices of the new Business Expansion Scheme. In October 1982 the company had a staff of the two directors, nine full-time employees, mainly of a technical background, recruited from Birmingham University, and two contracted employees. Several projects were underway and at various stages of development.

Two students, myself and David John, were recruited under the IHD Scheme as honorary employees. Both were allocated to the occupational hygiene side of the company, where the activities revolved around the collection and analysis of toxic pollutants. The company offered a product range for occupational hygiene monitoring which was based on bought-in, franchised products plus two "in-house" products. The orientation of the company was towards thermal desorption of collected pollutants prior to analysis. Besides this product range the company offered two services which were marketed as Envirochem - a collection service for air pollution, and Analchem - the analytical function.

The Adsorba personal monitor was a collection tube for pollutants through which pollution was drawn. This steel monitor was then heated in the Desorba thermal desorption oven in a gas stream, to flush the collected pollutant into the analytical instrument. Adsorba and Desorba were the "in-house" products, the concept of which had originated during a PhD thesis supervised by Dr Thompson at Birmingham University and carried out by the Dutom Research Manager, Dr Sithamparanadarajah. Neither product was fully developed at the time I joined the company.

Thus Dutom - A Child of the 80's (see Appendix A) was a new technology based firm with hopes for a bright and successful future.

1.2.0 The project in context

No-one who has been involved in higher education over the last four years can be unaware of the scrutiny and financial pressure to which the university world has been subjected. British industry has over the same period suffered what is referred to as "the recession", with record numbers of small businesses going into receivership.

Meanwhile the British Government has been offering inducement schemes to aid business start-up of technological entrepreneurial activity. These were the environments of this project.

Because few IHD projects arise from an established research base, the principle of project reassessment, redefinition and the exploration of potential blind alleys is a recognised feature of the IHD project.*(4)* In the model IHD structure, nine months is considered typical for this process, to establish the field of research and build the research base. Not all IHD theses naturally conform to this pattern, indeed Callaghan*(5)* casts doubt upon the validity of the whole pattern, and several IHD theses*(5),(6),(7)* may be cited where the research has undergone many redefinitions and transformations, although the reasons for these are diverse. In concept then, the collaborative nature of IHD projects is such that IHD students are engaged in what Rapoport has defined as "action research".

> "Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework."*(8)*

The aim of this section is to set the research in the context of its environment to show the factors which have affected the project and the research methodology applied. This is best done by providing a brief account of how the project developed. It is not done to present any excuses for this thesis but to assist the reader understand the transformations the project and the research methodology have undergone.

1.2.1 New Product development - Formaldehyde monitor

The two projects which Dutom presented to IHD were based on monitoring formaldehyde. One was the development of a new formaldehyde monitor in keeping with Dutom's product range, the other was the comparison of existing formaldehyde monitors. Given these two projects, supervisory expertise was established for the projects in the Departments of Chemistry, Occupational Health, Environmental Health and IHD.

Initially based at Dutom, experience was gained of Dutom's "in-house" techniques, and a project run which included generating and collecting samples of formaldehyde vapour. Meanwhile an information base of the techniques available for capturing and detecting formaldehyde was established, and this formed the basis of a later publication (see Appendix B).

The company constraints on the new product were that it was to be in line with Dutom's existing product range. i.e. a thermally desorbable, re-useable monitor. This required product development from an inventive step and I moved to the Chemistry Department and then to the Environmental Health Department, at the university, in order to acquire some research facilities.

In the interim the company had come under severe financial pressure. This was relieved when the company received large stocking orders for its "in-house" products from distributors. However, the company had no manufacturing facilities or experience of bulk manufacture. Both IHD students were, therefore, diverted to provide both the techniques and labour to establish a team to manufacture and quality control the products.

Despite the stocking orders, Dutom's financial position continued to decline and the company were only rescued from closure by a share issue on the public market, during Summer 1983. Following the share issue the company began a major internal reorganization, restructured itself into four divisions, carried out alterations to the building and laboratories, and recruited additional staff.

Meanwhile the formaldehyde monitor had been shown to be technically unfeasible along the lines suggested. Interest in formaldehyde monitoring declined; a government spokesman*(9)* acted to quell fears of its effects in houses, and no connection with human cancer was established. Formaldehyde monitoring and analysis had proved to be a small part of Dutom's business, during the period since I had joined the company. So once the distraction of reorganization was complete the Dutom management redirected both IHD projects to studies of the Dutom Adsorba monitor.

1.2.2 New Product Evaluation - Adsorba monitor

The project I was then allocated, was to evaluate the performance of the Adsorba monitor in order to demonstrate its suitability and limitations for particular uses. For this work I was allowed to define the method of investigation to be used. A literature search provided an outline of a technique which would provide technical data for the monitor in a manner which mimicked its field use. While this search was in progress an oven was designed and built to solve a production problem with bulk Adsorba manufacture.

Because the nature of the work was product evaluation, it needed a commercial interface, and was better located at the company. Hence university equipment was moved to Dutom, to develop the method to be used for evaluation.

Despite the recapitalisation and reorganization of the company, a negative cash flow persisted. The company again was approaching a crisis, and from March - September 1984 an average of two people per month were dismissed or resigned. The Adsorba work, although located in the commercial division of the company, was funded through the R&D budget, which was now under severe scrutiny. Furthermore, as a product evaluation exercise it was neither earning money nor inventing a new product, and was therefore seen as a low financial priority. Several proposals for equipment for the project were placed before the company but were rejected. Equipment was therfore sought at the university and market research was carried out in the interim.

The university was similarly in the process of reorganization. This included the Department of Occupational and Environmental Health, created by the merger of the two former deparments, being closed. The associate supervisor therfore endure several changes of Department. In IHD the academic tutor and research fellow, who had left, were not replaced, and for some time it was questionable whether the secretarial staff were to be replaced. Supervisors and tutors were, therefore, under considerable pressure of work. The demands made on the departments for financial constraint, planning, staff reduction etc had the effect of causing departments to be very protective of their resources. The result of this for IHD was particularly catastrophic because of the policy of using equipment and expertise in the departments where it is located.

In this environment it proved difficult to borrow equipment, and especially to take it outside the university. The university equipment was therefore returned to the university and additional equipment was borrowed during the long vacation to continue the work. The effects of this "beg, steal and borrow" approach to equipment acquisition was written up for a second year IHD assessment.

After demonstrating the feasibility of the Adsorba evaluation method the borrowed equipment had to be returned for term time which halted development work until IHD funded the computer equipment requested from Dutom eight months earlier. Software for the new computer system was written and trials on the Adsorba ran through until mid March 1985.

Dutom was taken into receivership in April 1985, and financial support for the project ceased. There remained no commercial interest in the work as it stood nor in evaluating a product which had ceased to exist.

1.2.3 The Company Innovation Strategy

Of much greater interest was the knowledge and experience gained by being part of the company. The company epitomised the high hopes of new technological revolution from small businesses. Furthermore the company had maintained strong links with the academic world and was in many ways an ideal company according to the criteria expressed by the government. They had received government support at start-up and had been one of the very first companies launched under the Business Expansion Scheme. Yet they were a failure. The how and why of this result has greater significance to government, the public and the universities. This is what is presented in the thesis as "the research".

1.3.0 The Nature of the Research

Had the present state of affairs been forseen when launching the venture in 1982, an IHD project would never have been conceived. Nor would the student have applied for it. The nature of this research has been dictated by factors beyond the academic world, namely the research environment e.g. market trends, financial constraints, company policy, structural organization, company collapse. Nevertheless these factors have provided the researcher with the novel opportunity to study new technology based firms from the perspective of longitudinal involvement.

The resultant changes in the project have had important consequences with regard to the work being undertaken and with regard to the research methodology employed. Through the changes the work has exhibited certain action research characteristic. Thus, when contrasting and comparing research types, Clark*(10)* describes action research as:

1 Tentative, non-committal and adaptive
2 Focused on the next stage
3 Evolves the future out of emerging opportunities
4 Has to interpret the present as a basis for asking questions
5 Attempts to comprehend a wide range of factors in a dynamic relationship.

Checkland*(11)* writes of action research:

> "The researcher becomes a participant in the action and the process of change itself becomes the subject material."
> "The problem with action research is that it cannot be wholly planned and directed down particular paths."*(11)*

Cherns*(12)* has made some important distinctions when classifying the relationship of a client with a researcher. This is reproduced in Figure 1.1. By this classification, it is apparent that during the formaldehyde work the researcher's role was that of a technician, and during the Adsorba work that of an engineer. These roles and research methodologies are at odds with the IHD concept of research. Only upon the closure of the company did the actual problem which Dutom possessed become available for research, namely; Product innovation in a new technology based firm. The formaldehyde project and Adsorba project were merely two aspects of this more general problem.

Although the company closure opened up the nature of the problem in a way appropriate to an IHD study, it also robbed the research of its collaborative nature, and hence of being action research. However, in an award winning paper on research into planned change, Dunn and Swierczek described research akin to action research, in theory construction and application, as "grounded theory", which they defined as:

> "Grounded theory means continuous efforts to relate existing concepts, methods and practices such that 'experience' in its widest sense becomes available for public discussion."*(13)*

The research method required for this is retrospective case analysis linked to theoretical expectation. Their research was on planned organizational change, and given that innovation is also concerned with the management of change, a similar research methodology has been

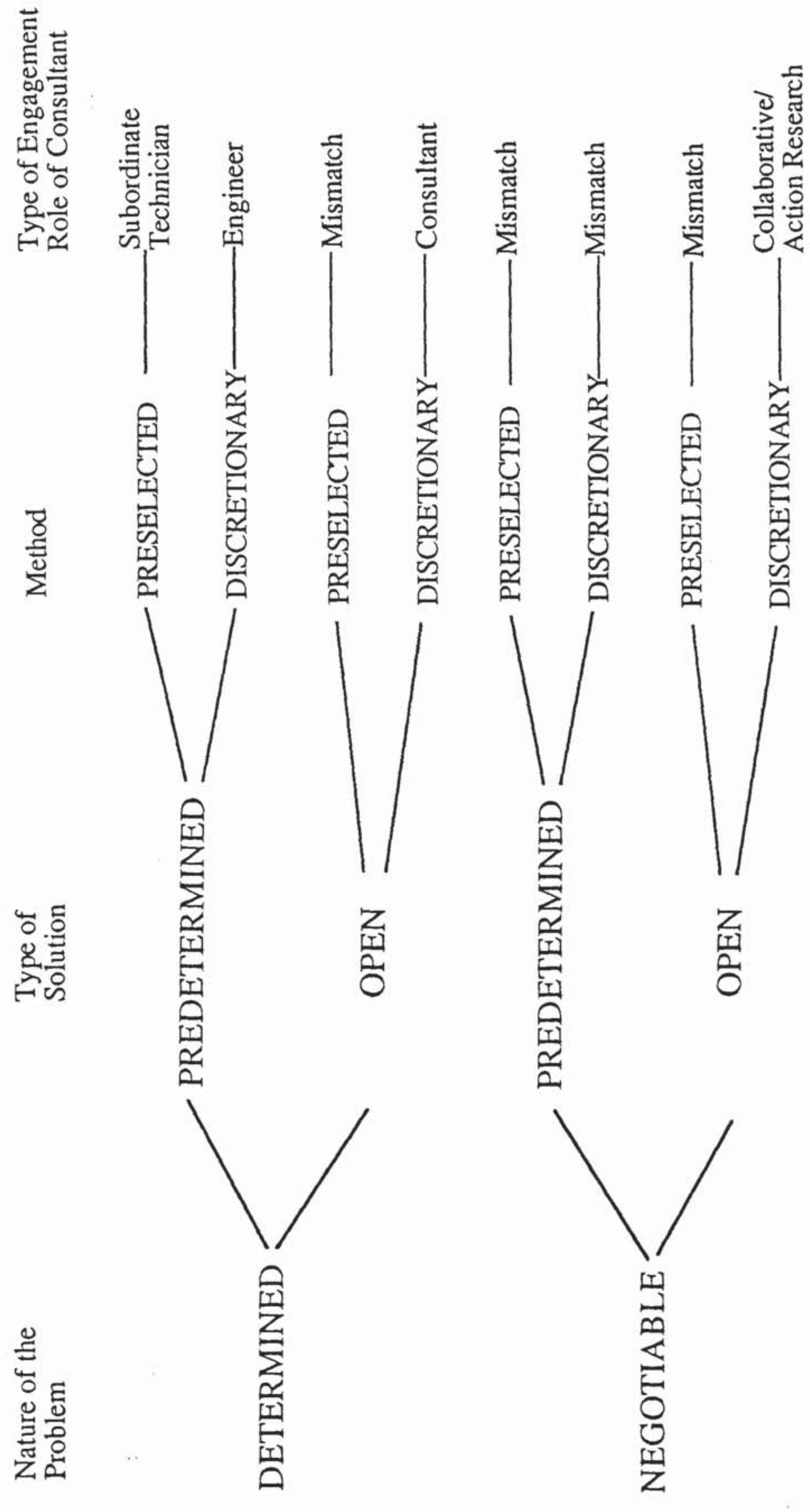


Figure 1.1 Classification of the researcher-client relationship
Adapted from Cherns *(12)*

applied here. To pretend that the material of this research was planned rather than discovered would be fallacious, it has indeed "evolved the future out of emerging opportunities".

The thesis aims to be a "thesis for its day", to provide a contribution of experience, at the interaction of industry and research, on the potential results of new technological entrepreneurial activity.

1.4.0 The Thesis Outline

Finally the reader is introduced to the structure of the thesis. This chapter has been used to introduce the subject of the thesis and describe the Research Environment within which the Research has been carried out.

Chapters 2 to 4 examine the literature pertinent to a study of product innovation in NTBFs. Thus Chapter 2 examines Why, Where and How innovation occurs in the economy. Chapter 3 describes the management of innovation from a corporate viewpoint, by discussing factors involved in determining corporate strategy and examining structural features associated with innovation. The chapter then seeks to derive appropriate strategic options for a NTBF. Chapter 4 completes the literature review by examining the empirical research which has looked at innovation from the viewpoint of the product and derived features associated with product innovation successes and failures.

Chapters 5 to 7 relate the contribution of experience provided by Dutom Meditech. Chapter 5 examines the phases of structure and strategy the company adopted throughout its history, thereby describing Dutom corporately. Chapters 6 and 7 examine the product innovations which were attempted in the analytical and occupational hygiene side of Dutom's business. The history of these innovations from invention to market response is described and some analysis made of important features in the management of these product innovations. The biotechnology aspects of Dutom are deliberately not examined because I was never a part of the innovations being made in this field.

The discussion of Chapter 8 draws together the experience of the strategies and practices adopted for innovation at Dutom Meditech with those described in the prescriptive and empirical literature on innovation. It argues that the strategic and practical management of innovation at the company was a major contributor to the failure of the company and illustrates the important features for the benefit of other NTBFs.

Finally some conclusions are drawn on the process of innovation and its management for both innovators and researchers in Chapter 9.

Please note that throughout the thesis references are presented by chapter to assist the reader.

CHAPTER 2

INNOVATION AND NEW TECHNOLOGY BASED FIRMS

"Change is inevitable in a progressive country. Change is constant."

Benjamin Disraeli

OUTLINE

New technology based firms (NTBFs) by definition conduct the majority of their business with new products and in emerging industry sectors. They are by nature, therefore, small and innovative firms. This chapter examines the importance of innovation and the small firm in the economy. It examines the role and types of small firms associated with innovation, and finally looks at some theoretical models of how innovation occurs.

2.1.0 Why Innovation?

The process of innovation is recognised as inherent to all the theories of the economic system. Marx has been attributed as the first economist to realise fully the significance of technological change on society and its economics.

> "What (individuals) are, therefore, coincides with their production, both with what they produce and how they produce it."*(1)*

This is not simply to argue that economic activity alone causes the pattern of social life, as Engels has commented.*(2)* Rather it is to recognise a dynamic interaction between the forces in society, not a mechanical abstraction.

Schumpeter*(3)* proposing a theory of innovation, suggests innovation is a function of the capitalist system, and that technical development is a consequence of capitalism.

> "Capitalism, then is by nature a form or method of economic change and not only never is, but never can be stationary. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumer goods, the new methods of production or transportaton, the new forms of industrial organization that capitalist enterprise creates."*(3)*

Innovation is thereby placed at the heart of the economic system, for both our society and industry. The need to innovate or allow economic decline is inherently understood today both at a government level:

> "It is the widespread application of the new technologies, supported by a competitive UK supplier industry, leading to a strong competitive position in the world and to the generation of that national wealth which is ultimately the basis of a better tomorrow for us all."*(4)*
>
> Geoffrey Pattle, Minister of State for Industry, 1985

and at an individual company level:

> "Without question technological innovation is the keystone of

economic productivity."*(5)*

Vice President, Bell Telephone Laboratories

If innovation gives a competitive advantage then some degree of innovation must exist in all societies and companies if they are to survive in a competitive world system. White*(6)* therefore sees a product innovation function is a prerequisite to company survival and growth. Studies have shown that innovative companies have a competitive advantage*(7)* and an increased profit performance. Mueller writes:

> "An organization that does not confront change and believes that it need not innovate stagnates, decays and dies."*(8)*

The importance of the innovative process is highlighted by two features in the current climate. A number of people have suggested that the introduction of microprocessor-based technology has begun a new technological revolution with similar implications to those of the Industrial Revolution. e.g. Heininger recently observes:

> "The world is in the grips of a roller coaster upheaval the likes of which it hasn't seen for 200 years."*(9)*

In this climate the introduction of new technology and products will have a profound effect upon our economic system, our structures of society and the competitiveness of individual companies.

The second feature concerns the rate of innovation, since not only is change important but also the rate of change. Schon*(10)* proposes that the rate of change is on the increase leading to shorter product and process life cycles. This accelerating rate of innovative activity is identified by those acting in a consultative capacity to industry by management consultants, Booz-Allen and Hamilton*(11)* and the shortened product life cycle seen in comments on business strategy by McKinsey and Company:*(12)*

> "Faced with this challenge management must regard the

(microprocessor-applied) industry as almost a fashion industry."*(12)*

The importance of innovation in the economy and the accelerated rate of change currently focus much attention and pressure on the necessity to ensure innovative activity is maximised.

2.2.0 Role of the Small Firm in Innovation

New technology based firms (NTBFs) by definition are dependent on emerging industries for the majority of their turnover, and hence tend to be small. Therefore, the literature on both small firms and innovative firms is examined to determine the importance of the NTBF in the economy.

2.2.1 A Matter of Definitions

When one begins to research the topic of the small firm in the economy, one is immediately made aware of the paucity of information and lack of clear research initiatives in the area. So one encounters statements:

- "The state of knowledge pertinent to the strategic management of small and growing firms is woefully inadequate."*(13)*

- "It is surprising that there has been very little research on the most appropriate strategies for small firms."*(14)*

- "We know very little about the dynamics of the small business sector in the UK."*(15)*

- "Aspects of business as are unique to the small high technology firms have received, however, little attention in the literature."*(16)*

- "I am conscious of the need for reliable statistics."*(17)*
  David Trippier - Minister for Small Businesses. 1985

The position is then complicated by the diversity of definitions encountered as to what actually constitutes a small business. Examples from the academic literature include:

up to 20 employees *(18)*

up to 200 employees *(19)*

up to 500 employees *(20),(21)*

up to 1000 employees *(22)*

less than $150 000 annual sales *(23)*

less than $3 million annual sales *(24)*

Even the Bolton Report*(25)* for the government, chose to define a small business in a variety of ways depending upon the sphere of activity i.e. wholesaler, retailer, motor trader, manufacturing haulage etc.

This confusion can best be avoided in the UK literature in future, by following the definition prescribed for company accounting procedure under 1981 Companies Act. This act makes the distinction clear between small and medium sized companies with regard to filing of accounts, and is in keeping with the need to identify the genuine small firm sector.

Under the Act the small company is below the limits of at least two of the following criteria.

Total Assets	£700,000
Turnover	£140,000
Average number of employees	50

Finally some literature in the field suffers from the "little big business syndrome", where definitions and methods used within large organisations are proposed for small busineses. These may or may not be appropriate.

The above comments and unhelpful definitions emphasise the size and heterogenous character of the small firm sector within which the study is located.

2.2.2 The Importance of Small Firms in the Economy

Despite the lack of clarity of information and definition, small firms make a substantial contribution to the economies of the developed nations.

In the US it is estimated that there exist over 10 million businesses, 97% of which have annual sales of less than $5 million.*(26)* Figures for the UK for 1971 indicate at least 1.2 million small firms employing 6 million people or 25% of the workforce and producing 20% of the GNP.*(27)* In a cross nation comparison of manufacturing firms with 200 employees or less the percentage of such firms in each country, versus the total number of manufacturing firms is: Britain 30%, USA 40%, Japan 70%.*(28)*

Despite the size of this sector it has received a mixed reception regarding status and political support. In 1971 the Bolton report observes:

> "The contribution of the small firm to national output and employment is declining not only in this country but in all other developed countries."*(29)*

The climate for small firms was considered adverse and the only two factors working to favour small firms were identified as:

a) the transition towards a more fully employed economy,

b) the increase in the standard of living.

However, in a time of recession which has seen larger business rationalise and shed jobs, the small business sector has been looked to, by government, for innovation and job creation. This is directly contrary to the climate which favours the small firm as identified by Bolton.

Nevertheless, the high unemployment levels created by rationalised large industry has led to major political support being expressed in the small firm sector for job creation.*(30),(31)*

> "The government is interested in creating employment and the growth of small businesses is important in this."*(30)*
> Sir Geoffrey Howe, Foreign Secretary, 1985

> "I believe the Business Expansion Scheme to be an important and innovative measure which reflects the government commitment to the encouragement of the small business sector."*(31)*
> David Trippier, Minister for Small Businesses, 1984

Recent UK statistics also suggest that the decline in numbers of small businesses has been arrested under the current economic climate. With government support for the sector there was reportedly a net increase of 34000 business start-ups over closure, in the year 1982, and 138,000 business start-ups during the same period.*(32)* However, a Scottish survey was still reporting a net decline in small firms between 1976 and 1980.*(33)*

With regard to the government hope that the small firm sector can create employment Rothwell states:

> "The widespread belief in the employment generating potential of small manufacturing enterprises rests, as yet

upon a limited empirical foundation."*(34)*

Studies in the US on data from 1969-76 have shown approximately 50% of gross new jobs are created in the small firm sector.*(35)* Canadian data have also demonstrated small businesses created a high percentage of new jobs between 1969 and 1977.*(36)*

A study comparing employment statistics in the UK and US suggests the small firm sector has shown a tendency to increase employment. This is estimated as 15% for new manufacturing jobs, but regional and technological variations are pointed out.*(37)* It is important therefore to distinguish the age, technology and location for such firms in the UK. Oakey,*(38)* however, has been very critical of those who have distorted those statistics to see short term employment growth in the small manufacturing sector. He points out that much of the growth is due to service industries, i.e. not manufacturing, and not innovative, and manufacturing employment growth can only be viewed in the long term for this sector. So of new technology based firms in the US it has been written:

> "High technology industries however broadly defined will account for only a small proportion of new jobs through 1995."*(39)*

The small firms sector is notoriously volatile and particularly at risk is the small new venture. In the US, Dun and Bradstreet report that only 1 in 3 new, and hence often small, firms survive the first four years.*(40)* Bayliss quotes approximately 100,000 small firms starting up and terminating in the UK per annum.*(41)* government statistics over recent years reveal that between 30% and 40% of new businesses registered for VAT, close within four years, and of those closing two thirds do so within the first 30 months.*(42)*

Cooper and Scott have both argued that closure rates do not represent failure of small firms accurately. Cooper shows that failure rates for high technology companies in the US is much lower than non technical firms,*(43)* and argues for a brighter future for these firms. Scott reinterprets the statistics and by following up companies still trading concludes that "failure rates are low".*(44)* A study of the UK small business sector, published alongside the Scott article, and investigating the employment contribution and numbers of small businesses concludes, however, that:

> "There would seem little reason to believe, that we are observing a dynamic small firm sector and we may be observing the reverse."*(45)* i.e. the sector may be in decline.

2.2.3 Business Size and Innovation

The relation of the size of a company to its ability to innovate has been supported by two contrary arguments. The first that large size and monopoly power are prerequisites for progress via technical change. The second that small size enables more rapid response to be made to scientific discovery and market change.

J K Galbraith is renowned as the champion of the former proposition.

> "Technical development has long since become the preserve of the scientist and engineer. Most of the cheap and simple inventions have, to put it bluntly, been made. .... Because development is costly it follows that it can only be carried on by a firm that has the resources associated with considerable size."*(46)*

A belief in the large and monopolistic enterprise appears to have predominated in the economic systems of the post war period. It may be illustrated by the tendency for nationalisation and merger to form monopolies in industry. e.g. formation of British Steel, British Rail, British Shipbuilding and British Leyland.

The argument that innovation is the domain of the large company can be backed with a number of post war statistics. If R&D expenditure is considered, then statistics compiled by the Organization for Economic Cooperation and Development (OECD) show 90% of all R&D expenditure in the US is attributable to the large (greater than 5000 employees) firms, and the figures for UK and W. Germany are 75%.*(47)* A study of the sources of innovations in the UK, for the Bolton Committee, showed the contribution from large companies over the period 1945-70 was on the increase.*(48)*

The prevailing advice to the British government in the late 1960's is illustrated by the writing of Shanks, who was Chief Industrial Adviser to the Department of Economic Affairs at the time.

> "The trouble is, however, that a large proportion of British industry consists of small firms; and while there is no necessary relationship between size and efficiency, many of the trends of modern technology do appear to favour large units. ..... There is therefore, a growing danger of the emergence of a 'dual economy' in British industry just as exists in Japan; on the one hand a highly advanced sector of mainly large firms employing all types of modern technology (both of hardware and software); on the other a wide fringe of mainly small firms, operating at a lower level of sophistication, unable to profit from the discoveries of technology, depressing the level of the whole economy."*(49)*

We owe to Schumpeter the two fundamental premises, that invention must be distinguished from innovation, and that technological advance is more important than price advantage, during the early stages of a product lifecycle. The latter advocates that the small entrepreneurial company, with the ability to make a more rapid response to technological advance, has an advantage over the large company in the early stages of product innovation. Entrepreneurs, therefore, play a significant part in the establishment of new branches of industry. In the later stages of the product lifecycle, and in mature markets, cost becomes the predominating factor, process innovation replaces product innovation and large companies begin to predominate. Rothwell has been able to map this process occurring in the patent literature.*(50)*

The Schumpeterian analysis of economic development argues in favour of the entrepreneurial, small firms as a seedbed of industrial innovation. Freeman*(51)* has described a similar model of 'entrepreneurial' innovation in small firms (NTBFs) fostering the growth of new products in emerging industries.

> "It may be reasonable to postulate that small firms may have some competitive advantage in the earlier stages of inventive work and the less expensive but more radical innovations, while large firms have an advantage in the later stages and in improvements and scaling up of early breakthroughs."*(51)*

The late 60's and early 70's saw a disenchantment with large scale organisation and policy, and a search for smaller scale systems or economics; a mood perhaps best captured by Schumacher in "Small is Beautiful":

> "To go for giantism is to go for self destruction."*(52)*

The coupling of Schumpeter's entrepreneurial theory with Schumacher's "Small is Beautiful" philosophy - led to an increased interest in the small firm sector for innovation, and the onset of a number of studies in this field.

Studies of the sources of invention were carried out by scrutinising patent statistics. From these studies Jewkes et al. conclude that universities, private inventors and small firms have made a disproportionately large contribution to radical innovations.*(53)* There has been a tendency to believe small firms have a lower propensity to patent than large firms, thus further exaggerating these statistics. Schmookler*(54)* in the US and Pavitt*(55)* in the UK have however, shown the reverse to be true.

Studies of the sources of innovation in the UK, since the war, reveal that small firms have accounted for approximately 12% of all industrial innovations compared with their share of employment at 22% and production at 19% (1963 figures).*(56)* This study has recently been confirmed and updated*(57)* to 1980, and demonstrates that the innovative activity of small firms has remained static or slightly increased despite a fall in output and employment. The balance of product versus process innovation over the period of the studies has also remained constant. Important innovations attributable to small companies include the printed circuit board, foam-laminated carpet backings, the mini TV. The US semi-conductor industry is exceptional but frequently quoted, as it spawned a large number of new small innovative companies creating the industries now referred to in Silicon Valley.

Size, by itself however, is not the dominating factor in innovation. Freeman*(58)* argues from results of a study of paired new product successes and failures, that size is relevant to the type of innovation but not to its success. Myers and Marquis*(59)* find no consistent relationship between company size and the rate of innovation. Mansfield*(60)* argues that once a certain minimum size is reached then firm size has no effect on the rate of innovation.

When industry is categorised into sectors, small firms show little innovative activity in areas such as aerospace, pharmaceuticals and steel. These areas have low small firm penetration, and are highly capital intensive or have very heavy development costs. They are monopolised by large firms. In industries with lower capital costs, smaller firms have made significant innovative contributions, at times above and beyond their share of the output for the industry.

On this basis, Freeman proposes that there exists a threshold level of R&D expenditure below which innovative activity will not lead to new products.*(61)* The areas where small firms prosper are where this threshold level is low, and the flexibility of small firms then gives them a competitive advantage.

So Freeman concludes that:

> "Although post war innovation has been dominated by large firms the results confirm the view of those economists who suggested that the innovative efficiency of small firms may be greater than that of large firms (for those small firms who perform R&D)."*(61)*

Similarly the Bolton report observed:

> "Small firms in spite of relatively low expenditure on R&D by sector as a whole, are an important source of innovation in products, techniques and services."*(62)*

Rothwell*(63)* and Scherer*(64)* therefore, argue for dynamic complementarity of small and large firms for successful industrial innovation, with large firms monopolising process innovation and small firms being product innovators.

> "No single firm size is uniquely conducive to technological progress. There is room for firms of all sizes. What we want, therefore may be a diversity of sizes, each with its own special advantages and disadvantages."*(64)*

Because the economy is in a state of flux both Rothwell*(63)* and Penrose*(65)* identify that there is a place for small firms in the interstices neglected by large organisations, especially in a growing economy.

2.2.4 Types of Small Businesses

Just as it has been important to be able to categorize whole branches of industry within which small firms may operate. So it is important to categorize small firms themselves, since only some 5% of small firms perform any R&D. It is amongst this 5% that the NTBFs are to be found.

Small firms may be broken down by function as: retail, service and manufacturing.

Adams*(66)* identifies three groups amongst engineering firms as:

Specialists	-Those firms which manufacture a specialist product for a large firm.
Jobbers	-Those firms which work on products to the specification of customers but offer a broad service range.
Marketeers	-Those firms which produce products of their own and sell to all comers.

Vesper*(67)* identifies companies by aspiration as:

Mom and Pop firms.	-The family business, frequently in the retail trade, with few employees.
Stable high payoff firms.	-Firms with an established and stable product range and customer base.
Growth orientated firms.	-Firms seeking new products, markets and profitability.

The firms which are the technical innovators amongst the small firms tend to be drawn from the third area of each of these definitions. i.e. manufacturing companies which are marketeers and aspire to rapid growth; although the service sector has increasingly been contributing to new technology e.g. computer software.

It is from amongst companies which comply with the above criteria that innovation might be expected to occur, especially if they are looking to exploit new technology, and these companies have been labelled as new technology based firms (NTBFs) by Rothwell*(68)* and Little.*(69)* Interest in the economic effects of NTBFs was aroused by the impact of the electronics-semiconductor industry in the US. Similar high growth phenomena have not been observed in Western Europe, and Little reports less than 200 genuine NTBFs in existence in the UK in 1977.*(69)*

The advantages and disadvantages of the innovative small NTBF firm when compared to a "big brother" are essentially due to short chains of communication and decision making. Shimshoni*(70)* proposes:

> "Small firms had advantages in motivation, low cost, lead time in development work and flexibility. New firms had advantage in technological expertise bought in from elsewhere in the R&D system."*(70)*

The advantages may be summarised as good internal communications, high flexibility, rapid response to technology shift and market demand. Disadvantages may arise due to the lack of technical manpower, lack of managerial expertise, lack of financial resources; this may also lead to a cash flow shortage during growth. They have few established outlets to the market. The small firm can therefore be said to enjoy certain "human" advantages in innovation and the large firm certain "resource" advantages.*(71)*

2.3.0 Models of the Process of Innovation

Some authors have modelled the innovative process in order to identify important characteristics and enable generalisation and analysis to be made.

Utterback and Abernathy*(72)* proposed a very helpful dynamic model which draws upon the Schumpeterian hypotheses, and allows the nature of the innovative process and hence the characteristics of the firm involved in innovation to be followed, versus the product life cycle or stage of development. The model shows a systematic variation of the types and stimuli of innovation with the environment for innovation and stage of product development. This is summarised in Figure 2.1.

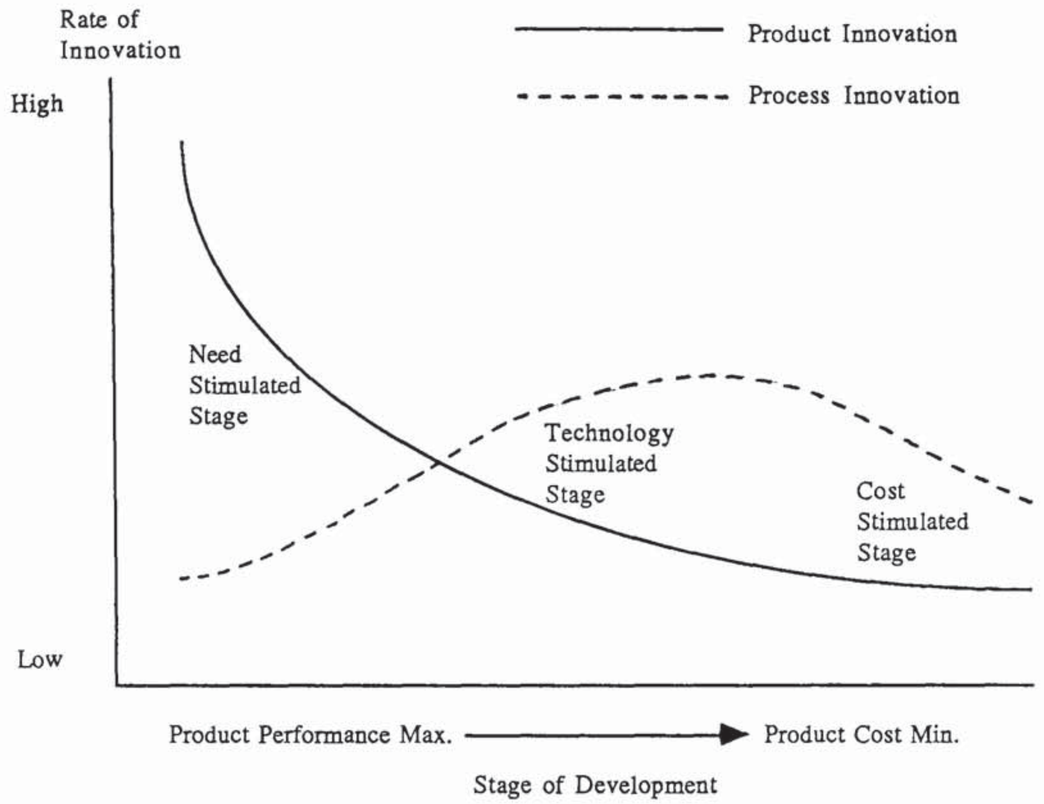


Figure 2.1 Model of the rate and type of innovation
Adapted from Utterback and Abernathy (72)

They have characterised the phases of product innovation and successful responsive strategy as:

1. Performance maximising

This is early in the product life cycle or development when the rate of change is rapid. Characteristics of successful firms are typically:

i) Small new firms or firms entering new markets

ii) They are market stimulated and rely heavily on external sources of information.

iii) Products are non standard, production is flexible and markets are uncertain.

iv) If new technology is critical it is applied to products rather than the process.

2. Sales maximising

Experience of the product has been gained and market uncertainty reduced. Product differentiation is important and some designs tend to predominate. Characteristics of the phase are:

i) Product innovation is directed toward improvements.

ii) Users develop loyalties and standardisation of information is required.

iii) Technology is important for product differentiation and providing new components etc.

3. Cost minimising

In the evolved product lifecycle, variety is reduced, the product becomes standardised.

i) The industry becomes oligopolistic.

ii) Innovation is dominated by the process and economy of scale.

iii) Product features are well articulated and analysed.

iv) Prospects for rapid company growth are poor.

Other authors have neglected the external environment and examined in more detail the process of innovation as viewed within a company. This has given rise to five types of model. Comparison of the models with observations of the longitudinal progress of innovation within a firm assists in the elucidation of the real life innovation and enables the models themselves to be examined.

Traditionally the approach has been to follow the product idea chronologically through from birth. This has caused writers to identify three specific phases [1],[2],[3] of the process of innovation which have been referred to as:

Ref.*(73)*	Ref.*(74)*	Ref.*(75)*
1 The generation of an idea	1 Invention	1 Ideas generation/screening
2 Development	2 Innovation	2 Development
3 Diffusion	3 Diffusion	3 Commercialisation

2.3.1 The Pipeline Model

Following the chronological approach the factors involved in the process were developed in a pipeline model. In its most complete form this is set out by the management consultants Booz-Allen and Hamilton*(76)* and is reproduced in Figure 2.2. This model which incorporates the need to recognise the undercurrent of the overall business plan is a modification of an earlier version employed by them.

The pipeline model in various forms from very simple to complex is popular and prevelant e.g. in Merrifield.*(77)* An identical concept is proposed by McCrory*(78)* but he identifies two factors as stimulating the idea generation stage "recognition of need" - market push or "state of the art" - technology push. A number of papers offering these models are reviewed by Bessant.*(79)* They all feature the transfer of the product from one stage or department of innovation to the next. Myers and Marquis*(80)* propose a similar model but also indicate the states of technical knowledge and of the market as running parallel to the process and being searched at points in the process.

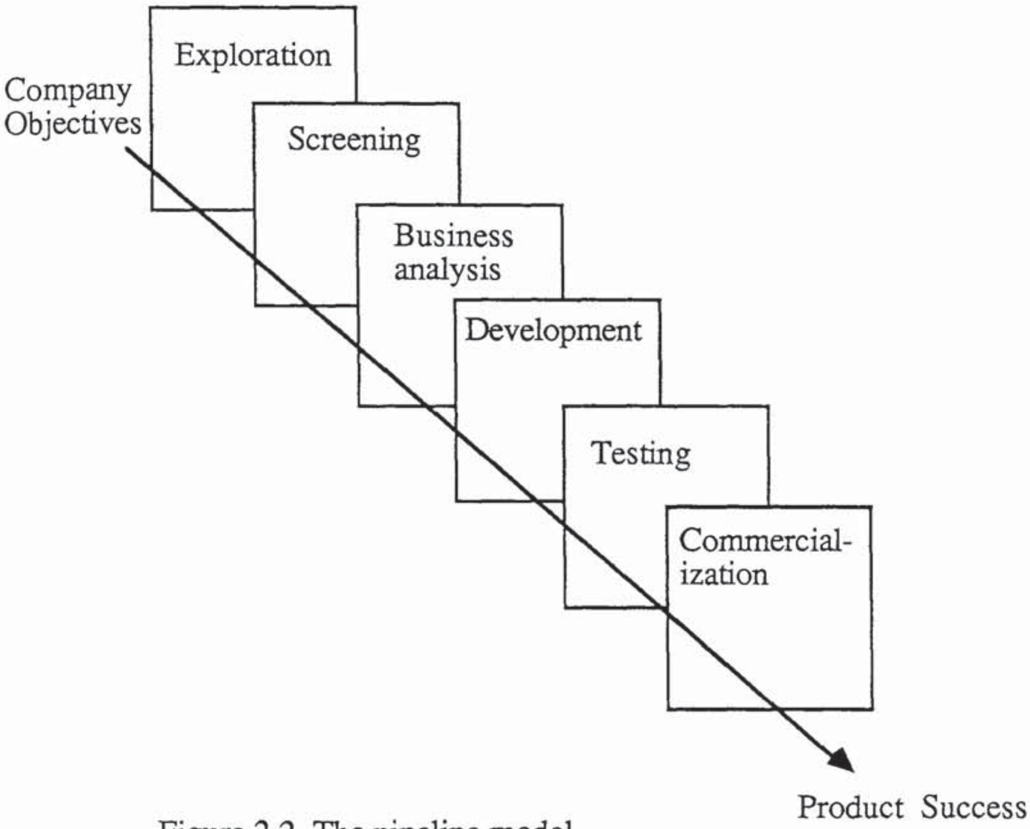


Figure 2.2 The pipeline model
Adapted from Booz-Allen and Hamilton(76)

2.3.2 The Systemic Model

This model attempts to treat the innovation as a cybernetic system of interacting sub-systems or departments.*(81)* It relates the need for different functions in the process to be in communication with one another but makes no comment on the time scale. (see Figure 2.3)

2.3.3 The Combined Pipeline - Systems Model.

This model, expoused by Morton,*(82)* describes the need for a systems method within the pipeline model, i.e. a systems approach is applied at each stage of the pipeline development.

2.3.4 The Concomitance Model

Schmidt-Tiedman's title for his own model,*(81)* which identifies three functions Research, Technical and Commercial and recognises that all these must accompany one another throughout the innovation process with a quasi-continuous interaction. This recognises that innovation is not simply handed on from one function to another but that all functions must be involved throughout. The model is able to locate milestones in the process and relate these to demands upon each of the functions.

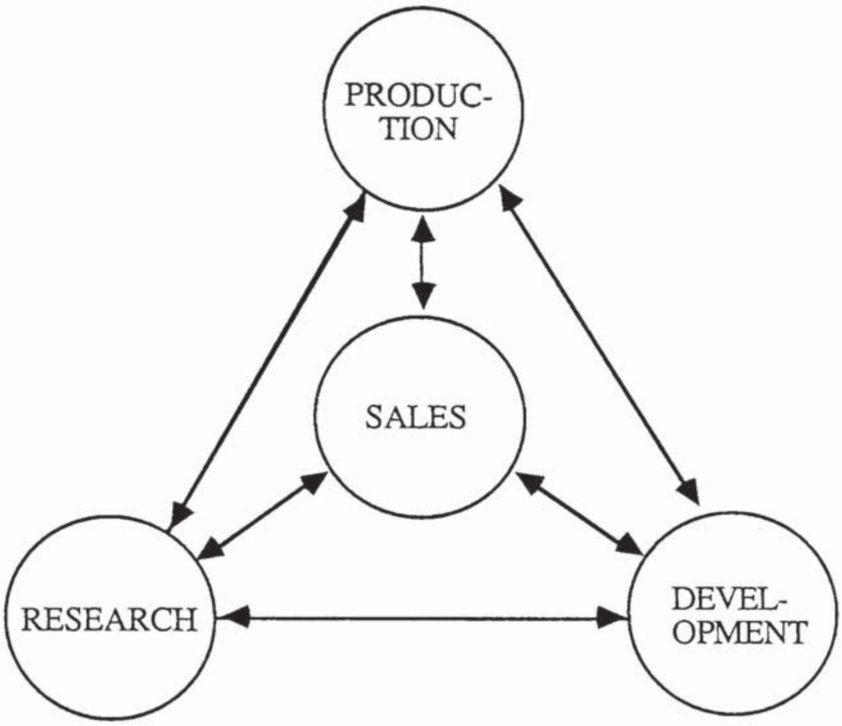


Figure 2.3 The systemic model
Adapted from Morton (82)

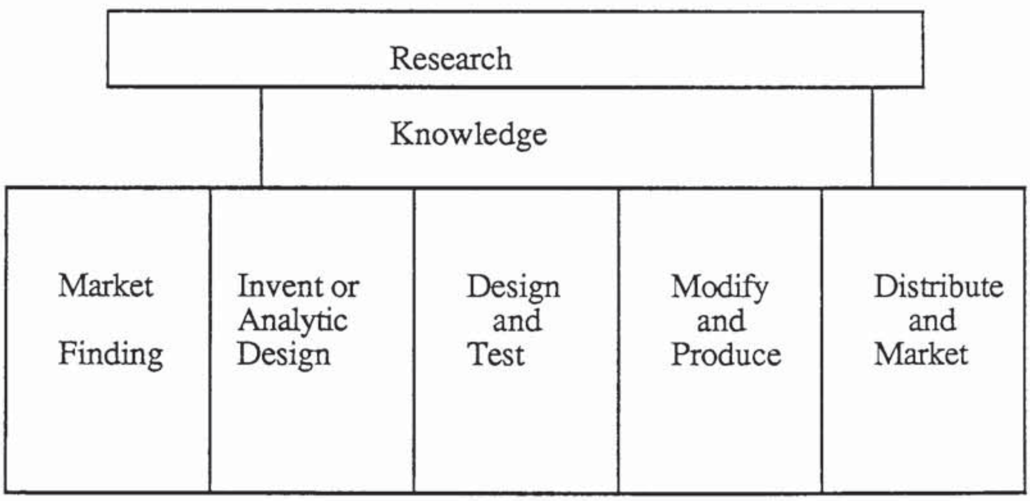


Figure 2.4 The chain-linked model
Adapted from Kline (83)

2.3.5 The Chain-linked Model

Kline's recent contribution is to argue that the pipeline model is false particularly in setting the research function at the begining and marketing at the end. Instead he hangs all the activities of the process from the bars of research and knowledge*(83)* (see Figure 2.5). Although his central chain of innovative activities resembles the pipeline model with feedback loops, because all activities hang from the fields of research and knowledge, he is able to dismiss the technology push versus market pull debate. Science he argues can stimulate new products, but perceived need can stimulate important research. In some measure this model, therefore, resembles that of Myers and Marquis.

The paper's contribution is to outline the role of science and types of research in the innovative process, particularly so that policy decisions at the level of government and education may be soundly based.

2.3.6 The Venetian Blind Model

Personally, I understand Kline's model has much to commend it as a more accurate description of the links of innovation with science. For the individual company or manager, however, it remains abstract. When coupled with the insights of the concomitance model I propose it offers a graphic picture of the process as the venetial blind model. Goldhar*(84)* has similarly commented on the need to refer both to the technology and the market at each stage.

In the "venetian blind model" innovation is viewed as attached to the 'ceiling' of research by the 'housing' of knowledge, the vertical strings represent the areas of invention, development, marketing etc. of the pipeline mode and Kline's model. The horizontal blinds themselves are the feature of the exercise, the product.

Lowering the blind represents the passage of time. Anyone who has lowered a venetian blind appreciates both the difficulty but necessity of lowering both sides equally, but this is the illustration of this model that all functions must be integrated into the process throughout. To try to close the blind with one side unextended is both ridiculous and impossible, as is to neglect entirely any discipline in the innovative process.

Finally the cord is pulled by the customer, and the gap in the market is closed by the new product.

CHAPTER 3

STRATEGIES FOR INNOVATION IN A NEW TECHNOLOGY BASED FIRM

> "Forward he cried from the rear and the front rank died. Generals sat and the lines on the map moved from side to side."
>
> Pink Floyd

OUTLINE

The success of a new technology based firm (NTBF) is intimately associated with its ability to innovate. The strategic decisions of the company and its organizational structure provide the framework within which the innovations are brought about. This chapter examines the prescriptive literature on strategy and some of the organizational features which have been associated with innovation. It identifies the constraints upon strategy formulation and the nature of the elements which together make up the corporate strategy.

Since the NTBF is to be found in emerging industries and is by nature small and innovative, the characteristics of emerging industries and innovative organizations are discussed. Having identified the elements of strategy and the strengths and weaknesses of the NTBF's position the chapter then derives strategies which are appropriate to support innovation by the firm.

3.1.0 Linking Strategy to Innovation

The success of a new technology based firm (NTBF) is intimately tied up with the ability of the company to bring about successful innovation i.e. to develop new products and sell them. The strategic decisions which the company makes, determine the objectives of the company and set the limits within which the company will compete with its products. The organizational structure of the company and the methods employed determine the ability of the company to carry out innovation, the success of which is finally determined by the reception of the company's products in the market place.

Initially the two disciplines of organizational strategy and innovation methodology developed separately. Buijs*(1)* was one of the earliest authors to try to relate the two. The disciplines may have evolved separately because of the prescriptive nature of the literature regarding strategy as contrasted with the empirical approach of much of the literature on innovation. Secondly the importance of new technology based firms in the economy, and in the process of innovation particularly, has only recently been recognised. For these firms success is intimately associated with their product innovation record, and hence the relationship between the corporate strategy, organizational structure and innovation methodology is of vital importance. Sage*(2)* investigated the link between strategic management and the success of product innovation, from research into some of the large and medium sized firms of the UK electronics industry. And Robinson and Pearce*(3)* have stressed the importance of research which helps to improve strategies for innovation within small entrepreneurial firms.

> "The revitalisation of 'revolution' of the economy and its technological base will require a major extension of the innovation initiatives traditionally characteristic of small entrepreneurial firms. Success in these roles will depend upon the quality of strategic decisions made by the principals in such businesses. Clearly, research that helps to improve the quality of decisions in small firms could make major practical as well as theoretical contributions."*(3)*

This chapter, therefore, examines the prescriptive literature on strategy and structures, to establish the constraints and nature of the corporate strategic choices a company must make. From these constraints and choices, appropriate strategy elements for a new technology based firm are derived. Some organizational features have been related to innovation and its success. Reviewing these could form a separate section, however, to avoid repetition and to begin drawing the studies of strategy and innovation methodology together this rather more empirical literature has been incorporated into the discussion of the characteristics of the organizational structure of a NTBF.

3.2.0 What is Corporate Strategy?

Littler has outlined corporate strategy as concerned with the what, why, how, and when of business. Namely; What is the business of the company? Why is the company in business? How does it mean to achieve its objectives?, When does it aim to achieve its goals?*(4)* Chandler's more frequently quoted definition is:

> "The determinaton of the basic long term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals."*(5)*

Chandler's approach which typifies much of the management theory literature, identifies corporate strategy as a deliberate conscious set of planning guidelines determining future actions. It suggests that the corporate strategy is always explicit, planned in advance and consciously developed.

Unfortunately, the real world is rarely so self-conscious or ordered in its actions and in trying to identify some of the principles of corporate strategy applicable to small new technology based firms, two criticisms are immediately apparent.

First small firms do not tend to plan. Robinson's review of studies of planning in small firms concludes:

> "The consensus findings from these studies was that comprehensive planning was conspicuously absent in small firms. Planning was described as unstructured, irregular and incomprehensive."*(6)*

Secondly the environment (i.e. factors outside the control of the firm) may have a major influence on a company leading to changes in corporate plans.

> "The environment in which the organization operates is widely recognised as a major determinant of its functioning. (This) may influence any aspect of the organization e.g. goals, structure, plans ...."*(7)*

Nevertheless, no company goes about its business in an entirely random fashion, not even a non planning small business. Mintzberg*(8)* adopting a definition of corporate planning as "patterns of strategy formation", has then been able to identify three types of strategy as:

deliberate strategies - intended strategies that get realised;

unrealised strategies - intended strategies that fail to get realised;

emergent strategies - realised strategies that were not intended.

Using these criteria all organizations may be said to have followed a strategy, and for this study the task is then to identify appropriate strategies for the small new technology based firm.

The terminology used to differentiate particular features of the strategy varies. Terms such as mission, domain, common thread, target have been used for Littler's "What is the business of the company?" while objectives, criteria, and goals have been used as terms for "why the company is in business".

The effect of clearly identifying the nature of the business the firm is engaged in provides a statement of what the business stands for. It may act to focus attention on that area of business, to prevent any business venture being pursued, alternatively it may help to indentify new business areas for the company. e.g. when Hallmark defined their business as "The social expression business" it enabled them to diversify from cards into gifts and jewellery.*(9)*

The objectives of the business or answers to why the company is in business may be multiple. These are the ends that the company hopes to achieve not the means by which they achieve them.

Glueck and Jauch*(10)* identify four reasons for the importance of a firm having objectives:

1. They help define the enterprise.
2. They become constraints on decisions.
3. They provide standards by which to evaluate success.
4. They offer tangible targets.

Typically the objectives are concerned with, items such as the return on investment, commitment to company growth, contribution to social welfare, risk involved, level of technology etc. Some authors include here items such as market leadership, low cost products etc., but most would consider these as the components of the strategy i.e. the means rather than the ends.

Given the mission and objectives of the business, the corporate strategy is completed by the choice made as to "how" and "when" the objectives may be realised i.e. a series of strategic decisions have been referred to as the "components of strategy",*(11)* the "programme of strategy"*(12)* and the "differentiation" and "thrusts"*(13)* of the corporate strategy. Here I describe them as a series of strategic elements each of which is to be given a value, from within the range available. Such elements embrace decisions regarding the relationship to competitors, market types, costs etc.

3.3.0 Constraints on the Corporate Strategy

For the development of a corporate strategy, be it consciously or unconsciously, three key areas are important in the determination of objectives. They are, the values of key managerial staff, the skills of the organization as a whole and the demands of the environment. These three areas each act to constrain the potential strategy that a company may adopt successfully.

The weight each constraint is allowed, and the net balance between the three areas, acts to define the actual objectives the company are prepared to set. So Thompson and McEwen*(14)* have described the process of objective setting as a power balance between the firm and its environment, while Mintzberg*(15)* has discussed the process as a power play between personalities and groups, internal and external to the firm.

3.3.1 Values of the Key Personnel

Every individual holds a series of personal values, or conceptions of what is desirable, which may be viewed as culturally derived. These values are the guiding principles for decision making in everyday life. Because these values are integral and active parts of the personality structure, the values also act as principles in decisions made on organizational and strategic issues, so the personal values of top managers act as a constraint or guide to strategic decisions and hence may affect the success or failure of the venture.

So an executive with dominant economic values may tend to emphasise opportunities which promise to increase profitability, while one with dominant aesthetic values may tend to eschew profitability that would detract from the quality of the product and image of the firm. The net results of the two value approaches may well be strategies of the "Woolworths" as opposed to "Rolls Royce" type.

Guth and Taguiri*(16)* have identified six major kinds of value orientations, and the balance or dominance of any of these kinds may significantly affect a manager's strategic decision.

1. Theoretical - A dominant intellectual interest.
2. Economic - Orientation towards practical affairs and the use of wealth.
3. Aesthetic - Dominant interest in the artistic.
4. Social - Dominant value is the love of people.
5. Political - Dominant interest in power and influence.

6. Religious - Primary orientation towards ethics and relationship to God and creation.

They have examined the interplay of some of these values with that of corporate formulation. England*(17)* has been able to establish that different sets of personal values are held by managers in companies of different national origins. No manager, however, works in isolation, and the values of the manager are, therefore, interrelated with those of others in the management team. Mintzberg*(18)* proposes that the result of this interaction is that the strategy making process of management falls into one of three modes, which he characterizes as:

1. The Entrepreneurial Mode
2. The Adaptive Mode
3. The Planning Mode

Hence the personal values, and nature of interrelation in the management team have a major impact upon the strategic decisions the company make. In particular this is true of a small new technology based firm where the company may be derived from the ideas of one individual and where the management team may easily be dominated. Miles and Snow,*(19)* summarising a number of studies conclude that the philosophy and values of the management need to match the strategy and structure of the organization for it to be effective.

3.3.2 Environmental Factors

This is where most of the prescriptive literature designed to aid managers formulate strategy, begins. Managers are encouraged to make an appraisal of the factors which are external to the immediate management control of the firm. The future of the firm is determined by how successfully it can trade with a dynamic environment, so an assessment of the significant factors at work in the environment enables the company to identify potential trade opportunities or threats to its business. For new technology based firms change represents both great opportunity and vulnerability. They are too small to counter change and are situated in a highly dynamic environment because of the new technology they seek to apply.

There are many different ways to categorise sectors of the environment which may be of significance; Glueck,*(20)* Shirley *et al.*,*(21)* Ansoff,*(22)* and Steiner*(23)* have all proposed categories. The following is simply a summary.

a) Social factors

Values, attitudes and patterns of lifestyle of the people in society change. The trends of change may have important effects for the strategies of companies with regard to products, production and selling. e.g. Increased interest in healthier eating may render some high fat foods unacceptable. Increased awareness of the environment may impose greater pollution control upon a firm's production techniques. The trend towards more women working may make door to door selling techniques less effective.

> "Economic development is associated with social changes which pervade the relationship of people to their environment and their fellows."*(24)*

b) Economic factors

Whatever side of the Keynesian-Friedman debate one cares to adopt, it is clear that the current and future state of the economy can have significant effects upon the appropriateness of a company strategy.

Particular items which may be of importance include:

* the general state of the economy be it in recession, growth, prosperity etc.
* the level of inflation which will have significant effects upon prices and the cost of services.
* monetary policy e.g. interest rates and currency exchange rates can have significant effects on the costs of investment in new plant, and the viability of products in foreign markets.
* tax rates, grants etc.

c) Geographic factors

> "Harnessing the location of leading firms would ensure that the benefits of high productivity enterprise were registered in less developed regions."*(25)*

Enterprise zones and grant aided regions of the country, shifts of population and available skills may combine to make a location for the firm or outlet for its products advantageous. Such factors are compounded in importance when international markets are considered. Values, market characteristics, market size and profitability may all be very different from that of the home country as may the distribution problems of trading there.

Climatic and or seasonal effects on supplies and markets might result in an important similar effect.

d) Political factors *(26)*

Government is both a large purchaser of goods and a powerful influence on purchasing decisions in some industries. Government legislation on for example pollution control, and standards approval of product designs can affect the market needs and purchasing patterns. Furthermore the government may subsidise or encourage particular sectors of industry through grants etc., thereby making resources available to the firm or its competitors. The level of taxation and interest was discussed above but import restrictions, tariff barriers and trade treaties made by the government may all have radical effects on a business.

e) Industry factors

Each industry has its particular dynamic features which affect anything from costs to markets. Features include:

* the criteria for success in an industry, be it new products, low costs, extensive distributorship, vertical integration etc.
* the barriers to entry to the industry. Ansoff and Stewart*(27)* have referred to the "critical mass" a company must attain for viability.
* similarly there exist barriers to exit from an industry, relating to the ease of divestment.
* the type of market for the industry, be it seasonal, regional, monopolistic, fragmented, declining, growing etc.
* the rate of technological change. Freeman*(28)* has proposed thresholds of R&D activity exist below which it is not possible to sustain technological parity with competitors. The length of the "learning curve" in the industry must also be assessed relative to the rate of technological change.
* legal requirements. Some industries are subject to particular legislation.
* the economy of the industry, be it stable, growing or in decline.

f) Technological factors

New discoveries are constantly being made outside the firm, which may alter the competitive nature of the industry. Hence the level of technology, number of technological advances, the timescale of technological development, rate of technological obsolescence and nature of innovation (e.g. process versus product) in the industry, are all important.

This is dramatically illustrated by the transformation in the watch industry, brought about by the technological change from mechanical to electronic watches,*(29)* which resulted in mass unemployment in former highly skilled areas such as La Chaux de Fonds in Switzerland.

g) Competitor factors *(30)*

Every firm should have a thorough knowledge of its competitors and of their operating characteristics. The strengths, weaknesses, strategy, reputation and market share of competitors are factors against which the company's own strategy is pitted. The strategy should therefore be chosen which enables the firm to compete most favourably.

3.3.3 Organizational Strengths and Weakness

No two firms are identical. Each has particular characteristics and strengths and weaknesses, which is why management theory has moved more towards contingency theory as opposed to "rule of thumb" prescriptions. Nevertheless, the small and innovative nature of NTBFs will focus the strengths and weaknesses of these firms in certain directions. The "name of the game" for a successful business is to match the strengths of the organization to the environmental opportunities, and ensure that the weaknesses of the company are not exposed in any role of importance. However, the small and innovative features of NTBFs will focus the strengths and weaknesses of these firms in certain areas.

The word "synergy" is used in the literature, the notion is that of the whole is greater than the sum of the parts. With regard to innovation and new business opportunity, it has been used to relate the new opportunity to both the existing organizational structure and to the existing business.

"Success comes from matching opportunity with capability."*(31)*

Ansoff particularly uses the concept of synergy with regard to matching diversification opportunities to operating strengths of the firm. e.g. start-up synergy, production synergy, R&D synergy, etc. Relating the opportunity to the existing organizational structure occurs because firms typically do not have the flexibility of structure to allow for organizational change, in order to meet an opportunity synergistically. Ansoff*(32)* recognises the decision of choosing to match opportunity to structure or new structure to opportunity, is an important early top management decision.

Synergy is also used of the business areas a firm may engage in. So a company able to offer complementary products or services may reduce overheads and attract a greater market share because of the "one shop" or "hypermarket" factor. The internal strengths and weaknesses of an organization act as the third constraint on a successful strategy, and every area of the company's business should be examined to establish where the strengths and weaknesses lie. Any breakdown may be appropriate but frequently the five headings of Marketing, Technology, Operations, Finance and Management are chosen. Potentially a NTBF may be strong in some of these areas but characteristically weak in others.

FUNCTION	POTENTIAL STRENGTHS AND WEAKNESSES
MARKETING	-Distribution system, service system, customers, sales staff, marketing staff, promotional techniques, company and product image, price, brand loyalty, market share, market research.
TECHNOLOGY	-Level of company technology, age of the technology, expertise of R&D, budget for R&D, phase of the product lifecycle, type of the company's R&D, patent protection.
OPERATIONS	-Supply system, size and location of production plant, sophistication of production scheduling, production policy.
FINANCE	-Type and amount of funding available, debtors/creditors ratio, credit rating, cash flow, budgeting methods.
MANAGEMENT	-Location of plant and management, experience of the management, type of communication structure, level of external influence.

The above three areas of management values, environmental factors and organizational strengths and weaknesses, act together to constrain the appropriate strategy available to a firm. The matching of values, and internal strengths to opportunities whilst avoiding company weaknesses and threats, can be viewed as identifying niches in the product/market mix where the company holds the competitive advantage. The size and nature of the niche may be determined in a number of ways.

3.4.0 The Strategic Elements

Turning from the constraints on the strategy to the nature of the strategic choice itself, there are potentially a myriad of strategic combinations. From amongst these only a limited number will be appropriate for a NTBF. In order to derive such strategies a simplification is to divide the whole strategy into six elements, each of which describes an area where a company must make a strategic choice. The element represents the spectrum of choice from within which the company must choose. These six elements and their range are described below. The actual choice likely to be made is constrained by the three key areas identified above. Furthermore the elements are not completely independent of each other, which tends to reduce the potential number of combinations to a smaller number of strategic options. Various authors have proposed generic strategy options which have been based on the element which they have considered to be of greatest importance. These generic options are discussed below with the element from which they are derived. These strategic options are described in order that the appropriate options of a NTBF may be seen in relation to those of industry as a whole.

The arena where the appropriateness of the company strategy is ultimately realised and tested, is that of the market, so the discussion of the elements commences with those which relate most closely to the product/market mix. Some authors discuss this to the exclusion of the other areas.

1 *The Differential Advantage Element*

The differential advantage of a company and its products is concerned with those features in the product/market mix which set apart the products from those of the company's competitors. The particular advantage may be one derived from the products themselves or the markets served. Porter's definition of only three generic strategies is based upon this element as the overriding prerequisite.*(33)*

The product may be differentiated from rivals in a number of different ways.

a) Uniqueness

The level of individuality of the product range may be used to differentiate the product. An artist may choose to issue a limited print edition as opposed to a volume print run, of one of his works. Similarly a manufacturing company may customize products at the request of a particular customer, or produce for the mass market.

b) Technology

The level of technology and proximity to the frontier of technology are significant here. The level of sophistication is important in the choice between a food processor and a hand whisk. Similarly the choice of established or latest technology must be decided in choosing between a daisywheel or laser printer.

c) Performance

The quality or performance characteristics of products may be very different, and this may be used to differentiate a high performance product from a utility product. Perhaps the comparison of a Porsche 944 with a Mini Metro City illustrates how this feature has been used.

d) Product range

The breadth or diversity of the product range can be significant. e.g. the hypermarket versus the specialist climbing shop. Other strategic choices of this type are discussed under the integration element below.

The market to which the products are sold may be differentiated by a number of marketing features.

a) Market segment

Products may be marketed to narrow or broad market segments. Once the breadth of the required market segment has been decided segmentation may be achieved in a number of ways. e.g. geographically, demographically, industrially.

b) Price

The differential advantage may be perceived via price. A high price may be the key to customers perceiving a quality product. Alternatively where there is little product differentiation a low price may offer an identifiable differential advantage. Price competition becomes more significant in maturing industries.

c) Service

This may achieve a differential advantage through the distribution system or level of after-sales service.

d) Promotion

Establishing a brand loyalty by advertising, possibly in combination with one of the above features can be the differential advantage. e.g. Benson & Hedges have achieved product differentiation recently, through the quality of their advertisements, while Persil advertising maintains brand loyalty by coupling its advertising with a quality image.

Based on the factors in the product/market mix Porter proposed that only three successful strategic options exist.*(33)* Namely those of:

i) Overall cost leadership

Price is the major differential advantage sought. This strategy requires efficient operations activity, possibly through process innovation, and cost minimizing in areas such as R&D and service. The low cost strategy is defensible against competitors, but typically requires a large market share and substantial investment for volume production.

ii) Differentiation

Uniqueness is sought through one of the other differential advantage means e.g. technology, and this provides insulation to price sensitivity. The perception of exclusivity or quality is incompatible with high market share and the strategy is maintained by innovative R&D, or advertising.

iii) Focus

This strategy is simply the concentration of the company on a limited market or product line, and it achieves success by better responding to the needs of its particular market segment.

Porter sees these three strategic options as mutually exclusive, and considers a firm which is "stuck in the middle" to be extremely vulnerable to competitors and have poor profitability. He couples the poor performance with a poor image of the firm, poor organizational system and its difficulty in regaining a successful strategy.

> "The firm stuck in the middle also probably suffers from a blurred corporate structure and conflicting sets of organizational arrangements and motivation system."
> "Once stuck in the middle it usually takes time and sustained effort to extricate the firm from this unenviable position. Yet there seems a tendency for firms in difficulty to flip back and forth between generic strategies. Given the potential inconsistencies involved in pursuing these three strategies, such an approach is almost always doomed to failure."*(34)*

2 *The Innovative Element*

This element is not so much concerned with the level of technology the firm adopts, as the degree and type of innovative activity the company engages in. It defines some vital aspects of the strategy of NTBFs. The element is used by Littler,*(35)* Freeman*(36)* and Rickards*(37)* to outline some strategic options. It embraces the range of products from innovative products in new markets to traditional products in traditional markets and has often been described by reference to a product market matrix. Littler categorizes generic strategies according to the innovative activity of the firm as follows.

Pioneeer or *leader* strategy is adopted by firms at the forefront of technological advances who choose to be first to the market with the new product. This strategy demands an intensive R&D and marketing effort. The *follower* strategy is to introduce products to the market after the pioneer, learning from the market reaction to the pioneer. The products are frequently superior to and different from those of the pioneer, although of similar technological sophistication. The strategy is lower in risk than that of the pioneer because it has more opportunity to gauge the market response. However, it requires efficient R&D to minimize the lead time of the pioneer. The product must also be differentiated from that of the pioneer by design or marketing features.

An *imitative* strategy seeks to imitate the products of others. The advantage sought is that of cost, by bulk manufacture or process innovation. This strategy is lower in risk because it carries lower development costs because the products and markets are known. It is more suitable in stable mature markets, where the product design is established and price competition is the differential advantage.

A *dependent* strategy is one in which innovation is carried out in response to a specific customer request. Companies employing this strategy are often dependent on one customer for their markets e.g. component manufacturers to the car industry. Freeman adds a *traditionalist* strategy which involves old technology and no innovative activity, this may be appropriate to a craft industry, and an *opportunist* strategy, i.e. entrepreneurial activity arising from observing a market need.

3 *The Integration Element*

This element identifies where new product opportunities are sought in relation to the company's existing operation. This has important consequences due to the synergy effect on the company.

Defined simply integration may occur in a "horizontal" or "vertical" direction. A strategy of "horizontal" integration is the addition of products or markets which complement the existing business definition. e.g. BL were producing a range of cars for different segments of the car market: the Mini Metro - for the small car, low cost, high utility market, the Montego - for the fleet car market, the Rover 3 litre Vandan Plas - for the executive market, the Jaguar XJS - for the sporty chief executive.

A "vertical" integration strategy expands or contracts the business definition into the suppliers of the existing business (vertically backwards) or towards the customers of the existing business (vertically forwards). David*(38)* has reviewed the strategic options open to a firm by considering the integration and growth elements. He has related the options to the conditions which demand such a strategy.

4 *The Growth Element*

Glueck*(39)* defines three broad strategic options within the spectrum of this element: Growth, Stability, Retrenchment; but he acknowledges that a fourth option, a Combination strategy may be followed when Growth is deliberately followed by Retrenchment.

A firm may commit itself to a strategy of growth be that of products, markets, turnover or businesses. The strategy is higher in risk than the other strategies and most appropriate in new and expanding markets. Retrenchment is a strategy designed to concentrate on the aspects of the business where the company has good profitability or competitive advantage. The retrenchment may involve reduction in products, markets, production or service. The strategy is not uncommon and profitable companies frequently divest themselves of the less profitable or synergistically poor aspects of their business. The ultimate retrenchment strategy is, however, liquidation. The strategy is often reserved for dealing with crises, since it implies failure or previous poor decisions.

A stable strategy may be adopted when the business is performing well in stable markets with products at a mature stage of their lifecycle. The strategy is to continue serving the same markets with existing products, and any changes tend to be incremental in nature.

Glueck *et al.* *(40)* were able to categorize the strategies of large companies according to this element, and demonstrated that a Growth strategy was the most popular and successful strategy, whilst Retrenchment was the least popular and least successful. However, they found companies did not adopt similar patterns of strategy when subjected to similar types of environmental change.

5 *The Assertive Element*

This refers to the strategic alternatives with regard to attitude and timing. An *active* or *offensive* strategy seeks to initiate or anticipate environmental change. This may result in a high profile advertising campaign to stimulate a potential market, or an R&D department which spends time seeking technical opportunities. A *passive* or *defensive* strategy waits and reacts to the environmental demand. Miles and Snow organized their four generic strategy options around this element.*(41)* They describe the four strategy options as the Defender, the Prospector, the Analyser and the Reactor.

Defenders are organizations which serve and protect narrow product/market niches. *Prospectors* are organizations which continually search for new market opportunities, and regularly experiment with potential responses to emerging environmental trends.

Analysers are organizations which operate in two types of product/market niches, one relatively stable, the other changing. In their stable areas they operate routinely and efficiently through the use of formalised structures and processes. In their more turbulent areas, top managers watch the strategies of competitors closely for new ideas, and rapidly adopt those ideas which appear most promising. *Reactors* are organizations in which managers frequently perceive change and uncertainty occurring in their environment, but to which they are unable to respond effectively.

Ansoff earlier used similar titles to define three generic strategies based on this element, as Reactors, Planners and Entrepreneurs.*(42)* The strategic archetypes based on this element correspond closely with Mintzberg's three modes of the decision making proccess.

6 *The Resource Element*

The final strategic element refers to the degree of independence the company adopts in the resources it draws upon. The company may choose to pursue its strategy independently (internal) or in conjunction with outside organizations (external). This element is of importance because it relates both to the sources of ideas and information flowing into the company, the types of operation the company engages in or contracts-out and the relationship of the company to other sectors of the business world.

The resource element is inevitably coupled with the other elements. Thus an external growth strategy may result in the company seeking to acquire products or business e.g. by licensing rather than by development, while a combined internal and external strategy may result in seeking a joint venture agreement.

3.5.0 Appropriate Strategies for a New Technology Based Firm

Having reviewed the nature of the strategic elements and choices available, the purpose of this section is to derive appropriate strategies for the small new technology based firm. By definition a number of characteristics of the firm and its environment follow.

New technology based firms (NTBFs) are located in emerging sectors of industry, which have the potential for growth of both the products and the markets. The firms themselves are, by definition, small and entrepreneurial and derive most of their business in this emerging business sector. The firm must be innovative and relatively close to the state of the art of the technology. Furthermore, the newness of the technology and the markets together with the infancy of the firm commit the company to radical innovation, and the corporate strategy and new product strategy should be closely related.

3.5.1 Environmental Factors

Porter*(43)* has identified the structural and competitor characteristics of an emerging industry as follows:

Technological uncertainty

There is a great deal of technological uncertainty in an emerging industry and an absence of product or technological standardisation. The pace of technological advance is fast and the product lifecycle is short as second and third generation products make others obsolete. The product quality is erratic because of the lack of industry standards, variation in raw material sources and the number of newly established firms.

Strategic uncertainty

Customers are first time buyers, they are confused by the multiplicity of product variations, the new technology and the claims and counter claims of competitors. Distribution channels, service, information and complementary products are initially inadequate. Market segments have greatly different rates of adoption of the new product and it is important to identify the early and late adopters.

The emerging phase of the industry is accompanied by the greatest proportion of newly formed companies, especially as new companies "spin off" existing companies. The industry participants may adopt a variety of strategic approaches, the result is uncertainty in market share in the markets of competitors, in their strategies, and in reliable industry sales figures.

Costs

Initially costs are high, due to small production volumes and newness. An increased demand for the raw material used by the emerging industry may lead to a period of rapid escalation of the raw material costs, while a later increase in volume and the effect of experience result in subsequent cost reduction.

Regulation

Government regulation and standardisation can significantly affect the rate of development of an industry. Government can also affect the industry by making subsidies available to early industry entrants.

3.5.2 Organizing for Innovation

Structures

Chandler's maxim*(44)* is that structure follows strategy, Mintzberg*(45)* however, questions the validity of this. For the sake of convenience and to avoid repetition, organizational features associated with innovation are dealt with here.

A review of the literature on this subject leads to the conclusion that the trend amongst organizational theorists has been away from the notions of perfect models, or structures, to the recognition that there is no one best way to organize. So the literature moves from rule based models to contingency theory.

The trend to contingency theory has been accelerated by the recognition of the complexity of the commercial environment, and the number of elements which affect it. In this climate there is much to be gained from examining each case in its environment rather than trying to impose upon the company a normative model:

> "The case for a more intensive consideration of the individual company is overwhelming."*(46)*
>
> "The value of case work resides not in statistical conclusions but in the significant cases."*(47)*

The theory of radical innovation predominating in the seedbed of small entrepreneurial units has persisted and organizational theorists have sought to emulate the small unit in the search for an innovative organization. Burns and Stalker offered one explanation for the buoyancy of innovation in smaller units, when they differentiated between mechanistic management organizations, which are strong on hierarchy and control, and organic management organizations, where lateral communication and task redefinition enable the management of change to be carried out.*(48)* Pleas for flexibility and diversity in the organizational structure and task have been echoed by Nystrom*(49)* and Shanks*(50)* if creativity and innovation are to occur.

Many methods have been proposed as to how a larger company can emulate the small unit for product innovation. Essentially these involve setting up a new product team, or drawing together interdisciplinary expertise from existing departments. The reader is referred to a review of the success of various methods by Souder*(51)* for more information, but the methods include:

a) The New Venture Division

b) The New Product Department

c) The Product Committee

d) The Product Manager

e) The Line Manager

f) The Joint Leader or Dyad

Contingency theory admits there is no one best way to structure an organization for innovation.

Small companies where all employees may know one another and multiple tasks may be the responsibility of one individual or department, have the opportunity for short and lateral chains of communication, and tend, therefore, to be more organic in management style. Rothwell and Zegveld*(52)* assessed the strengths and weaknesses of small firms versus larger competitors, in the process of innovation. They identified good communication and the ability of the small firm to respond more rapidly to technological change or market demand as the areas where a small firm holds an advantage over a larger competitor.

The Little report links these advantages of short communication chains with the added flexibility these firms have to satisfy the needs of the customer.

> "NTBFs have all the advantages of being small. They are able to provide a higher level of customer sevice, carry out low volume orders, and adopt flexible pricing. Small size enables them to make quick decisions and move new products rapidly from the laboratory onto the market."*(53)*

Small firms, particularly in the start-up phase have very limited financial and human resources. They have no reputation, and few benefits of the economy of scale or of experience. The capabilities of the management team are often unbalanced reflecting the previous experience of the personnel. Against these problems the firm has no ties to the past, it can innovate without worrying about effects on existing product sales. It has short chains of communication and has the talents and drive of the founding group:

> "This ... is undoubtedly one reason why new and small firms are remarkably fertile sources of technical innovation."*(54)*

The strengths and weaknesses of the new technology based firm, therefore, lie to a large part with the management team of the company. They enjoy the advantages of enthusiasm, good communication and the opportunity to react quickly to change or demand. However, they lack experience of many of the facets of business management.

Inevitably every management team is unique but some personality characteristics have been identified in the process of innovation.

Some Personalities in Innovation

The Entrepreneur

In a new, small and technologically orientated business the entrepreneur is normally the founding member and more than likely the chief executive. Given the limited staff available, the skills he or she brings to the company will be fundamental to the company's management posture, and the company strategy will reflect him or her to a certain degree.

Curran and Stanworth,*(55)* from a study of small businessmen, have suggested that the owner manager of a business tends to be a socially marginal person, i.e. there was a discontinuity between the entrepreneur's previous role and attributes. McClelland has suggested that a strong achievement motivation is required in entrepreneurs coupled with a belief that they can control their own fate.*(56)*

These entrepreneurial characteristics are not necessarily characteristic of the outstanding scientist. Indeed peer group pressure of professionalism and culture in the scientific community have been noted as major factors which disuade the professional scientist from becoming an innovator or entrepreneur.*(57)* So a difference in characteristics between the entrepreneur and the researcher is recognised. Similarly Schon identifies a difference in approach is required in managing innovation, i.e. change, from managing other business functions, i.e. control.*(58)*

Some have identified that entrepreneurs are driven to that role by a need to avoid being subordinate to others, be it parents, or previous employers.*(59)* Cooper identified this with frustration in the previous employment*(60)* which finally overcomes the pressures of professionalism and culture, while Bruce seeks to identify a 'determining event', in their backgrounds.*(61)* Entrepreneurs have, therefore, been described as:

"Creative, impatient, disorderly driven zealots."*(62)*

Incubator Environments

The "incubator environment" or environment out of which the new technological entrepreneur emerges, has been assessed and a number of common features identified. The entrepreneur frequently comes from a family or cultural group where he is surrounded by role models of entrepreneurship.*(63)* The technical entrepreneurs are characteristically well educated, and in their 30's when they launch their business, having amassed a degree of experience and capital by this stage.*(64)*,*(65)*

The organization within which the entrepreneur previously worked has been shown to be important in the founding of new technology based firms. The Little report on new technology based firms*(66)*, demonstrates that the majority of entrepreneurs work in the private sector, before beginning their business, as opposed to working in universities or government institutions. This is because in the private sector;

- the research and exploitation stages are chronologically closer than elsewhere,
- attitudes are more favourable towards technologically based firms and

the staff are in closer contact with business practice and more exposed to a commercial environment,

- the inventor may see opportunities being lost through bad management.

A. C. Cooper points out that it is the incubator environment which provides the entrepreneur with his particular management skills and know how.*(67)* He has been able to show that amongst the more successful new technology based firms, the entrepreneur frequently came from a large organization, not a small one.*(68)*

> "It is in the positions that they have just left that they have gained the most up to date knowledge of markets and technologies. The founder who starts a firm in a field where he has little experience faces a higher probability of failure."*(68)*

Similar findings have been pointed out by Rothwell.*(69)* The conclusions drawn from this are that although the American semiconducter industry has led to many spin off companies starting from other new technology based firms, the contribution of management experience in a large firm is significant.

The Product Champion

The concept of the "product champion" was first introduced by Schon.*(70)* He proposed that where radical innovation is concerned, an individual with belief in the innovation, power and prestige to influence others and the willingness to risk failure, (the product champion) must emerge or the idea will die. This champion must be of some standing within the company, be able to use the company's system of informal relationships, and be able to bridge across the specialized fields of R&D, marketing, finance and production.*(70)*

Chakrabati*(71)* identifies five qualities necessary for the successful product champion as:

- technical competance,
- knowledge about the company,
- knowledge of the market,
- drive and aggressiveness,
- political astuteness.

Further contributors have taken up the champion idea and developed a series of names and or functions depending upon the size and age of the firm and the contribution made to the process of innovation. In essence these contributions have been to break down the requirements of the process of innovation, often using the pipeline model, and identified key personnel for each function; e.g. Champions of the technical screening function are called technical gatekeepers or Maxwell's demons and those of market information as market gatekeepers. The key roles and functions of these various champions has been reviewed by Madique.*(72)*

In the start-up phase of a new technology based firm, however, many of these roles will be performed by one and the same individual, frequently the entrepreneur or chief executive, and it would be meaningless to break down the role beyond that of the product champion.

Support for the importance of the role of the product champion comes from recorded studies of the success and failure of new product launches. In a study of products from 45 NASA based innovations Chakrabati*(73)* identifies success and failure with product champions as follows:

	No. of relatively successful cases	No. of less successful cases	Total
A product champion was identified	16	1	17
A product champion could not be identified	1	27	28

Prior to the SAPPHO project, four key positions were postulated:

1 Technical innovator.
2 Business innovator or innovation manager.
3 Product champion.
4 Chief executive.

Analysis of the paired successes and failures of the SAPPHO study led to the conclusions that:

"The presence of someone acting in the product champion role was more common in successes than failures."*(74)*

"The SAPPHO study provides systematic evidence in favour of the champion hypothesis."*(75)*

However, the results do not substantiate the view that the Product Champion can be brought in from outside to ensure new product success. i.e. He has no other formal role within the project management. In only 1 out of 5 cases where this occurred did the product succeed. Instead the product champion was identified with one or more of the other roles, most commonly that of the business innovator. Where product champions existed but were unsuccessful they did not have this business innovator role. Recent conference proceedings, critical of the product champion theory, support this conclusion.*(76)* Top management expressed dissatisfaction with trying to "manage" the product champion, and believed it was not a formal role. They attributed championing more to overcoming the imperfections in the management and organization structure and recognised that the championing process acted at the points of intraorganizational tension.*(76)*

Organizational problems for new technology based firms

Schon(77) proposed the view that organizations are resistant to change and hence innovation is a task which leads to conflict. Cohn and Lindberg(78) draw attention to a number of distinctive personnel problems of the small firm, including the facts that; a small firm may be easily dominated by one individual, that small firms offer less emotional security and that they have special difficulty in developing management skills. A NTBF, therefore, is likely to encounter organizational problems both because of its size and its nature of work.

As identified earlier, the strengths and weaknesses of a NTBF are found within the management team relationship. A key advantage is the potential for good, short and lateral chains of communication but the process of innovation puts particular strain upon this. Kennedy reviewing product innovation writes:

> "Scarcity of resources may inhibit innovation and lead to conflict."(79)

In a NTBF, resources are limited and hence conflict for them may be strong. This explains his finding that contrary to some expectations small organizations have more interpersonal aggression and conflict.

An alternative organizational problem is highlighted by a report on small high technology firms.(80) This US report cites a major difficulty of such companies in recruiting and retaining staff of a high calibre. The report however, notes that the problem is less critical during the initial entrepreneurial stages of the company.

3.5.3 The Resultant Element Positions

1 *Differential advantage* - With the high costs in the emerging industry, and the small size of the firm mitigating against volume production, the NTBF is unlikely to be able to provide a differential advantage based on cost. Instead one potential advantage is that based on the level of technology of the product.

Secondly since the firm does not have a volume product it must seek a niche in the market where it has a competitive advantage.

> "Small firms make a serious mistake venturing into products with a high enough volume demand to permit low unit costs of mass production."*(81)*

Crawford*(82)* refers to seeking market niches away from strong competitors. Mason*(83)* talks of supplying specialized markets through local or specialized distribution. Penrose*(84)* and Rothwell*(85)* have commented on the importance of addressing innovation to narrow market niches even in a growing market sector.

> "Small firms can innovate to fill narrow market niches considered too small by their larger competitors."*(85)*

And the Little report identifies a niche strategy as a major competitive advantage of a NTBF.

> "The main competitive strengths of a NTBF are its ability to concentrate on a specific niche in the market or technology, ..."*(86)*

Hlavacek *et al*. argue that a small firm has many problems with a large distribution system.*(87)*

2 *Innovation* - Clearly a new technology based firm is committed to a high level of innovative activity and maintaining a close proximity to the frontier of technological innovation.

> "They should be at the leading edge of technological and

> industrial change."*(88)*

This commits the firm to a pioneer or fast follower strategy, and both approaches have their supporters. Rothwell*(89)* associates "major new product groups" with NTBFs arguing that the Schumpeterian model of enterpreneurial innovation means new products are pioneered by NTBFs.

> "If this pattern of evolution is valid then while the initial small entrepreneurial firms are concerned primarily with new product innovation and major product improvement, the large established firms become increasingly involved in process innovation and minor product improvements."*(89)*

Mason argues that a small firm will have a limited R&D capacity and restricted customer feedback, which limits them to a follower role.

> "Large organizations are able to innovate in technologically sophisticated markets, the smaller firm can only imitate."*(90)*

Ansoff*(91)* in an investigation of the strategies of technology based firms argues that either is a possible strategy, but the two strategies need to be followed by two different types of firm, the "research intensive" and the "development intensive" firm. Meanwhile, Porter*(92)* relates the validity of the strategy to the characteristics of the industry the firm is in.

3 *Integration* - Mason*(93)* argues that since a small firm has limited human and financial resources then new product development should be on a least cost basis. Synergy should be sought without overstretching limited resources, i.e. through complementary products produced and marketed via similar channels. This is horizontal integration.

4 *Growth* - Since the industry and the companies are both in their infancy, the company must anticipate growing together with the emerging market.

5 *Assertion* - Emerging industries have a poorly developed infrastructure, so the company may be able to manipulate the industry to its advantage. Porter writes:

> "The overriding strategic issue in emerging industries is the ability of the firm to shape industry structure. Through its choices the firm can try to set the rules of the game in areas like product policy, marketing approach and pricing policy. ... The firm should seek to define the rules in the industry in a manner that will yield it the strongest position."*(94)*

Goldman*(95)*, and Ansoff and Stewart,*(96)* have identified that short product lifecycles are characteristic of the products of NTBFs. They, therefore, stress the importance of the firm being in close contact with both the technology and the market demand. Goldman argues for the importance of marketing at an early stage of product development, and both papers stress the importance of good interdisciplinary and interdepartmental communication, "coupling", within a NTBF. The company must therefore, have an "active" strategy.

6 *Resources* - As identified earlier, the resources of a small firm are limited, and hence a NTBF will not be expected to perform all the business functions alone. Robinson*(97)* demonstrated a greater increase in profitability and effectiveness amongst firms using outsiders in strategic planning. Potts*(98)* showed an improved performance with accounting advice, Rothwell*(99)* reports that successful innovators establish good links with outside scientific and technical establishments and Hlavacek *et al. (100)* argue that a small innovative business should enter into a Joint Venture arrangement with a large organization, to provide marketing power. The company must therefore, expect to use resources located outside the firm.

CHAPTER 4

MANAGING NEW PRODUCT INNOVATION

"New products don't squirm out of machines, jump into boxes, and climb on to grocery shelves of their own volition. They don't appear as mutations, hybrids or illegitimate accidents. Someone put them there, someone operating from some motive or intellegence or intuition, or from some type of hypnotic trance is responsible. Bear in mind that no one, unless he is mentally unbalanced, develops a new product because he thinks it will fail. He enters into it because he thinks, or at least hopes, it will succeed. Yet most of these things fail, which, of course, means that wrong or bad decisions have been made."

R. Tortolani

OUTLINE

Chapter 3 argued for the link between strategy and successful innovation. While much of the literature on strategy is prescriptive much useful information has been derived empirically from studies of the successes and failures of product innovation. This chapter examines this empirical literature in order to discover factors in the management of innovation which have proved significant for or detrimental to success. By examining several empirical studies the chapter isolates common problems in the management of innovation and criticises some of the innovation models of Chapter 2.

4.1.0 Types of Innovation

New product introductions have been reported as accounting for 39% of industrial product sales*(1)* and trends have been observed towards the increasing importance of new product development based on technological advances, shorter product lifecycles, changing market requirements and increasing world competition.*(2)*

When considering innovations, a variety of types of product innovation can be identified. These have commonly positioned on the two axes of newness to the company and newness to the market.*(3)* This has given rise to categorising new product innovation on a spectrum of "newness" from evolutionary to radical innovation embracing intermediate types such as product revision, product line additions, new product lines etc. It can be argued that different types of innovation require different management approaches. However, for NTBFs, the technology is new, the firms are typically in their infancy, and trade in an emerging industry. Therefore, all innovation in this case may be considered to be radical by nature.

4.2.0 Studies of New Product Success and Failure

Characteristics which may be associated with new product success or failure have been the subject of a number of studies. Perhaps the most famous of these is Project SAPPHO, which paired successful and unsuccessful products in an attempt to distinguish the important factors for success. The conclusions of a number of contributors are outlined here by author, to illustrate collectively the current state of knowledge of the subject.

Project SAPPHO (4),(5)

As well as the roles e.g. product champion identified from the SAPPHO work and mentioned in Chapter 3, the authors were able to draw out a number of operating characteristics which were associated with new product success. They report five areas where successful products could be differentiated from unsuccessful products, these are reproduced in Table 4.1.

Table 4.1 Features associated with successful innovation.

1. Strength of management
   - the innovation encountered less opposition on commercial and technical grounds.
   - the innovation was made more for marketing than production reasons.
   - the innovation was more deliberately sought.
   - R&D was "in-house", and the R&D chief had a position of seniority.

2. Understanding user needs
   - the innovation needed less adoption by users.
   - the innovation needed fewer modifications after sale.
   - the firms understood user needs better and earlier than competitors.

3. Marketing and sales performance
   - the firms enjoyed greater sales effort.
   - the firms devoted attention to educating users.
   - the firms gave greater publicity to the innovation.

4. Efficiency of development
   - the innovations had fewer problems or adjustments in production or after sales.
   - the innovations were modified less during production.
   - the firms rated technical success lower at the outset.

5. Communications
   - the firms had better contact with the external technical community.
   - the firms benefited from outside technology in production.
   - the firms had better internal and external communications.

Adapted from Achilladelis *et al .(4)*

Rothwell (6)

Rothwell has reviewed nine studies of innovation in progressive firms, including the SAPPHO study. Each of these studies could be considered in its own right, but his comparison enables emerging characteristics to be more readily seen. He reports eight main areas common to most of the studies which are associated with new product success. Briefly these are:

1. Good communication and efficient collaboration.

   This is an area of agreement found in all nine studies. It covers the importance of internal communication with both customers and technical establishments.

2. Innovation is a corporate task.

   He states:

   > "Innovation is not simply a matter of R&D but should involve inputs from the production and marketing departments throughout the course of the project."*(6)*

3. Efficient development work.

   This underlies the importance of eliminating technical problems prior to market launch, or the poor reputation engendered damages sales.

4. Planning and management techniques.

   Essentially the ability and willingness to look and plan ahead, contributes to the success of the product.

5. Quality of the management and management style.

   This reflects the greater ability of the management and the association of success with a more organic, open and horizontal management style.

6. Marketing and user needs.

This feature was also common to all the studies. The majority of successful innovations arise in response to a market need. Failure is associated with the "we know best" attitude. Success is associated with an active marketing and sales policy.

7. Aftersales service and user education.

Preparation of customers prevents damaging after sales problems: the more the innovation the greater the need for education and service.

8. Key individuals.

The importance of individuals and their roles in innovation was recognised.

Nylen (7)

From the position of experience in a US management consulting group Nylen identifies reasons for new product failure. He concludes that the problems may be managerial rather than technical and offers four managerial problems which hinder new product success:

1. Commitment from the top is lacking.
2. Organization for new products is inadequate.
3. The role of the market place in new product development is often misunderstood.
4. Management fails to accept the risk inherent in the new product process.

Millman (8)

Millman also examines barriers to product innovation. He highlights the importance of the personal skills of the management team, the paucity of marketing and the need for better communication, as the three major barriers in innovation.

> "Lack of market orientation and breakdown in communications are the most frequently cited reasons for British industry failing to complete the innovation cycle and achieve full commercial exploitation."*(8)*

Adams

In studies specifically investigating innovation in small firms Adams identifies impediments to innovation as:*(9)*

1. A lack of resources within the firm can lead to difficulties in retaining high calibre staff.

2. Small firms need external information because of their limited resources, but a problem is identified with the efficiency of this flow of information. Similar results are reported in a Capital Planning Information Study.

   > "There is a serious and wide ranging communication gap which is blocking the flow of information between providers of most kinds and small firms users."*(10)*

3. The limited experience of the management.

   > "(This) invariably results in a lack of experience in the marketing and management function."*(9)*

The lack of experience is implicitly known by the managers and the tendency is therefore to over-rate their ability in the technical fields which the entrepreneurs believe they understand, and to underestimate the needs of other fields e.g. strategic planning and marketing.

In a complementary paper on the subject,*(11)* he attributes all the major impediments of the small firm to the inadequacy of the management. He reports that the staff lack experience and training, the firm lacks organization to spread the load, and the entrepreneur who is unable to delegate inhibits development. This management problem leads to problems in five key areas of marketing, product design, finance, technical management and personnel management.

The net effect of these characteristics for the following is:*(11)*

1. Market strategy
   -"The companies have a strong technical/production orientation but a relatively weak marketing field."

2. Product strategy
   -With regard to selecting products for development, the major reason given by managers was "Gut feel".

3. Product design
   -"The firms generally considered that they were better than their competitors in product design and engineering skills."

   But he also reports:
   "Managers seemed unaware of their needs in this area .... and many firms have learnt the hard way."

Twiss

On examining the factors which contribute to successful innovation, Twiss*(12)* lists as most critical:

1. A market orientation.

2. Relevance to the organization's corporate objectives.

3. An effective project selection and evaluation system.

4. Effective project management and control.

5. A source of creative ideas.

6. An organization receptive to innovation.

7. Commitment by one or a few individuals.

Cooper R G

Cooper amplifies Twiss's point regarding the relation of the new product to the corporate strategy. It is Cooper who has examined the new product success and failure empirically is an attempt to identify the factors of a successful new product strategy.

He concludes that a high success rate for new product introduction demands ability in all the three areas of product superiority, market orientation, and technical and production strength. From a study of product success and failures,*(13)* he lists eleven points which he shows to be significantly associated as with new product success. These are outlined in Table 4.2. He concludes that:

> "Our research clearly shows that the most important features for success were comprised mostly of variables over which the firm has control...... The message clearly is, it matters not what situation you face; it matters more what you do about it."*(13)*

Table 4.2 Factors which predict or account for new product success.

1. Source of idea (market derived is positive)
2. Strength of marketing communications and launch effort
3. Newness to the firm (negative)
4. Competitive market with satisfied customers (negative)
5. Marketing and managerial synergy
6. High priced product, no economic advantage (negative)
7. Market need, growth and size
8. Dynamic markets with many new product introductions (negative)
9. Technical and production synergy and proficiency
10. Market knowledge and marketing proficiency
11. Unique superior product

Adapted from Cooper*(13)*

His work on new product strategies,*(14)* initially identified a total of sixty-six strategy elements and from these he categorised firms into one of five new product strategy types. These are outlined briefly below.

1. The technically driven strategy.

This was the largest category by numbers and the firms sought technologically sophisticated, innovative and high risk new products. The firms were grouped in the high technology industries, however, they totally lacked market orientation. As a result their products were aimed at poor potential markets and were out of step with existing products. The new product programme was costly, inefficient, plagued by failures and failed to meet the desired objectives. The overall performance was rated as producing moderate results, a high percentage of sales were achieved by new products but success rates were low and profitability was poor.

2. The balanced strategy.

Comprising the smallest group, these companies differed from the others in the degree of product fit and their market orientation. New products were aimed at familiar customers needs in high-potential markets. The firms tended to avoid custom products and new markets, preferring instead to develop quality products which met customer needs, in familiar high potential markets away from major competitors. These firms performed better than the others on virtually all the criteria.

3. The technologically deficient strategy.

These companies followed "imitative", low risk strategy which was basically defensive. They had weak R&D, and a poor new product fit with existing production facilities, but were relatively strong in marketing. The new product performance gave very poor results.

4. Low-budget, conservative strategy.

These companies also followed an imitative, low risk strategy but chose products closely linked to their existing technological, production and marketing expertise. The firms tended to be in low technology slow growth industries and new products formed a low proportion of sales. Nevertheless this safe product strategy resulted in good profitability and low new product failure rates.

5. High budget, diverse strategy.

These firms launched new products into high potential growth markets which were also radically new markets for the firms and were highly competitive. The firms had a lack of market orientation, and a very high proportion of resources were spent on R&D, without the new products complementing the existing capability. They suffered high new product kill and failure rates, and these companies were typically smaller than those adopting the other strategies. The strategy met with very poor results.

4.3.0 Analysis of New Product Success and Failure

From the above papers, the problems with the process of technological innovation are seen to be managerial, at source, rather than technical.

> "Our experience suggests that the problem may be managerial rather than technical."*(15)*

> "Managements attitudes prevailing within an organisation are of vital importance (possibly to the exclusion of other factors) to successful innovation."*(16)*

> "The most important factors to success were comprised mostly of variables over which the firm has control."*(17)*

Even where a technical problem existed e.g. that of poor or incomplete technical development, Nylen argued that the cause for the technical inadequacy might lie in a lack of management commitment.

The managerial factors, which have been identified as barriers to innovation or alternatively vital for new product success, can essentially be distilled into two broad categories. Those of the areas of communication and of the experience, of the management team. These are precisely the areas recognised as the strength and weakness respectively of the small business. They will therefore, be of vital importance for new technology based firms.

The Marketing Problem stands out in every study examined, and deserves special attention. Upon examination, it is essentially a subset of the two factors above. Nevertheless its prominence requires that it be examined in detail to determine causes, effects and cures.

4.3.1 The Marketing Problem

The importance of the marketing function cannot be overstated in the process of innovation. Every study draws attention to it and furthermore, when examined more closely it can be seen that the marketing function needs to be related to the other functions at all points in the innovative process.

Marketing input is identified with the selection of both the type of new product and its market. Cooper*(18)* found that in the successful strategy, new products were selected for markets which were already familiar to the innovative company, and in this way products were avoided which would be unsuccessful because of poor market potential or the highly competitive nature of the market.

So Rothwell*(19)*, Finkin*(20)* and Cooper*(21)* have stated:

> "Recognition of demand is a more frequent factor in successful innovation than technical potential."*(19)*

> "Most successful new products say 80% were developed as solutions to perceived market need."*(20)*

> "Successful products tend to be market derived."*(21)*

i.e. the inventive function in product innovation needs to be closely related to the needs of the market.

Testing, development and production require a similarly strong marketing input since the need to modify products after launch has been identified as highly detrimental to new product success. Conversely the ability to understand the user requirements and to educate users to new product capabilities are identified as favourable to new product success.

At the time of commercialisation, strong marketing effort and the quality of the product launch campaign are directly related to the success of the product. Cooper writes:

> "Astute management and well executed, good, product launch can do much to overcome a bad product situation."*(22)*

The requirement for good marketing skills in the identification of new products, customers and technical developments underlies some of the comments made regarding good communication. Communication is implicit for a marketing orientation, since the hopes and fears of both suppliers and customers can be identified more easily if there is good information flow into the management team.

The marketing need is particularly acute for small new technology based firms (NTBFs), because they operate with a narrow financial and resource base and they are highly dependent on new product success and vulnerable to new product failure. Furthermore, in the fields in which they operate, a trend towards shorter product lifecycles has been noted. Goldman*(23)* argues, that the shorter the time period the product is on the market, the more complex is the required marketing task, and the higher is the quality of marketing needed to deal with it.

The NTBF needs to obtain a good financial return on its short product lifecycle products and to avoid new product failures which could cripple the entire business. In order to achieve these objectives against larger competitors it must repond accurately and quickly to the market demand and opportunity. Goldman concludes this requires a highly sophisticated management team and an effective system of interdepartmental relations to ensure:

> "An early start on marketing, parallel to the R&D and production activities."*(23)*

Interestingly Rothwell and Zegveld*(24)* identify marketing as one of the few areas where a small, innovative firm holds an advantage over larger competitors, since they have the flexibility to react to market needs quickly and efficiently.

The reason why marketing skill features so highly in the list of attributes required for successful innovation, is probably due to the degree of neglect which many companies give to it.

> "The lack of manpower invariably showed up in the marketing function rather than say in production."*(25)*

Reasons for this orientation away from marketing are frequently attributable to the lack of management experience in small companies and the communication problem, mentioned above. Twiss notes a communication barrier exists between technologists and marketing managers because of totally opposite personal orientations, resulting in:

> "The linking of R&D and marketing in a meaningful partnership poses one of the most serious barriers to technological

innovation."*(26)*

Many entrepreneurs originate from a technical background and Millman, Clarke, and Adams all point out the lack of experience researchers typically have of the marketing function:

> "Marketing is so foreign to their experience that mistrust and fear of loss of control can cancel out any attempts to influence R&D programmes."*(27)*

> "Marketing represents another way of thinking, another discipline less exact and more qualitative than the researcher's own; it can embody such exotic concepts as social behaviour and attitudes. And to cap such difficulties the work will probably be carried out by somone else, outside the researcher's own organization, who talks another jargon and is continually complicating the whole thrust of his technical thinking."*(28)*

> "All the owner-managers responding had an engineering or technical background with no formal marketing knowledge or experience."*(29)*

> "Small business managers are more concerned with production than with customers, unaware of the value of market information, ignorant of marketing tools."*(30)*

Finally it must be recognised that in some cases the entrepreneur does not want to know accurate marketing information, because it may work against his interests in discussions with outsiders. This is epitomised in the "Two year breakdown problem"*(31)*. This problem, outlined from a case study, occurs because the heavy initial investment in new technology often means a NTBF cannot expect to breakeven within two years. However, in order to attract capital it must propose to do so. The entrepreneur therefore, fools himself and investors with unrealistic market figures.

4.3.2 The Communication Problem

Interdisciplinary communication features strongly in Burns and Stalker's classic definitions of the organic management structure, which they associate with the management of change or innovation.

> "The organic form is characterised by -
> - a lateral rather than a vertical direction of communication through the organisation, communication between people of different rank resembling consultation rather than command.
> - a content of communication which consists of information and advice rather than instructions and decisions."*(32)*

The role of product champion was characterised by the ability to use the informal communication channels of the organization.

> "He must know how to use the company's informal system of relationships."*(33)*

The need for good communication for innovation can be seen throughout all the disciplines of the organization. The importance of the marketing function in providing good information from external sources has been identified. Likewise, it is noted that good intrafirm coupling of marketing with the other departments engaged in the product innovation process is important to ensure a market orientation at all stages.

The communication problem is not just limited to marketing. Rothwell's review of several empirical studies showed the value of good communication in relation to the technical function. Collaboration with other centres of technological excellence, e.g. universities, has been shown to benefit product development. This is illustrated by a case study incorporated in the Little report, where the high cost of initial technological investment, typical in NTBFs, was relieved by carrying out initial work in a university.*(34)*

Little's case study material also draws attention to communication issues in the field of investment.

> "The Communication Gap Problem
> Generally the investor and the inventor/entrepreneur do not speak the same language. The problem lies with the inexperienced entrepreneur who normally has a product and a mission but little understanding of the financial accounting and marketing requirements, and even less ability to express his business concept in the financial terms which the investor requires. The venture capitalist expects an investment

memorandum but the science-orientated entrepreneur is typically not qualified to produce such a document and usually presents a technical specification sheet in its place. This frequently results in an overstatement of the potential for success."*(34)*

4.3.3 The Experience Problem

Most of the studies have brought out the importance of management experience in innovation, but we have also observed the limited experience typically available in most NTBFs. This fact is shown most clearly from considering the importance attached to strategic planning as opposed to 'muddling through'. Wyant links management inexperience with the lack of systematic planning, as the reasons for business failure.*(35)*

Cooper*(36)* is able to conclude that product performance and strategy are closely linked, Mayer and Goldstein*(37)* conclude that a major reason for failure was a lack of systematic planning, and Robinson when reviewing small firm strategic planning concludes:

> "Each study concluded that thorough planning was noticeably more prevalent in successful firms."*(38)*

In small new technology based firms, however the company is often based around the invention of a scientific entrepreneur, who is assisted by a small team of partners. They have limited experience of management techniques, planning methods and the marketing discipline.

The values and experience the entrepreneur brings to the business are of vital importance, hence the discussion of entrepreneurial characteristics and incubator environments made in Chapter 3. Studies show that where a company has more than one founder, the broader experience on hand favours new business success.*(39)* Similarly

Unni*(40)* reports that entrepreneurs with more exposure to planning in their education adopt more formal planning in their organizations.

This is, therefore, an area where NTBFs must recognise their weaknesses and act accordingly. The enterpreneur may adopt to use outsiders to make available a greater contribution of experience without adding to the staff of the firm. Robinson demonstrated the effectiveness of this for the purposes of strategic planning.*(41)*

However, a study of small UK firms showed that sources of outsider support were disjointed and largely unsatisfactory.*(42)*

> "Overall, small firms have been unwilling to rely on any one source for a comprehensive range of innovation support, relying on universities and government research institutions for R&D support and the Department of Industry's Small Firms Information Centres and trade associations for marketing advice. This provides for disjointed and discontinuous support lacking direction and balance."*(42)*

Greater use would have been made of universities if greater guidance and information was available on new product development.

4.3.4 The Education Problem

One outstanding but understated conclusion evident from the product innovation literature is that innovation is an interdisciplinary process, and must be treated as such from the outset if it is to prove successful. It is quite inadequate to treat the process as if it were a "pass the parcel" exercise between different functions.

> "Innovation is not as many managers believe simply a matter of R&D but should involve inputs from production and marketing departments throughout the course of the project."*(43)*

> "Success does not depend on doing one of a few things in a spectacular fashion; rather it depends on doing many things well."*(44)*

The evidence for this simple conclusion is overwhelming from history, psychological characteristics, organizational design, the strategic literature and the empirical studies of successful new products.

On the heyday of British technological superiority it has been written:

> "The rapidity of British technological development in so many fields ... was the direct outcome of close personal associations between persons with different expertises and resources. But the association of people like Watt, Black and Roebuck was founded not so much on their membership of a common profession or organization as on membership of a small integrated society. ... The members were to exchange views with each other on topics relating to literature, arts and science each contributing his quota of entertainment and instruction."*(45)*

The marginality of the entrepreneur to his existing discipline is recognised as an important feature of his character. Similarly the product champion is attributed with the need to extend his interests into many areas, thereby adopting an interdisciplinary approach.

With regard to the means proposed for organizing for innovation, project teams, new venture groups and matrix organizations, these all require the liaison of personnel from a variety of disciplines i.e. they are interdisciplinary in nature.

The outstanding feature of Burns and Stalker's organic management style, which is considered suitable for managing innovation, is the degree of interdisciplinary and interhierachical communication. In the prescriptive literature on strategies Goldman*(46)*, and Ansoff and Stewart*(47)* reported the importance to the corporate strategy of good coupling between the business functions for innovation. Similarly the communication problem is highlighted in every empirical study of new product success or failure. What in effect is being reported is the efficiency of interdisciplinary contact and the diversity of experience in managing the innovation. Indeed of the five key areas for product innovation identified by Project SAPPHO Madique writes:

> "The five key areas identified by the SAPPHO group are all interdisciplinary in character. The first is at the boundary of R&D and organizational behaviour; the second and third are at the interface between marketing and R&D; the fourth and fifth are at the boundary of R&D and the administrative system."*(48)*

The pipeline model of the innovation process pervades the innovation literature, education and thinking. However, because it implies that the interdisciplinary nature of innovation is sequential and not concurrent, it causes many innovators to follow a fallacious new product strategy and entrepreneurs in NTBFs are particularly prone to falling foul of this.

If the pipeline model is believed then, given that the majority of entrepreneurs in NTBFs have a technical background and limited marketing experience, the tendency after the idea is conceived is to pursue the technical invention and development of the idea with little reference to the market beyond that of their own understanding. Resources are, therefore, invested in these functions leaving investment in marketing and production until later in the belief that these functions are downstream, and have little to contribute until the technical work is complete. From the pipeline model this is "risk minimising" since good development work will ensure a satisfactory product is passed on to the "waiting" functions.

In fact the strategy is "risk maximising" because it enhances the possibility of a product in which the company have invested greater time and resources, having poor synergy with the production ability, marketing outlets or customer needs. Alternatively it lengthens the time required to obtain a return on the product because each department is only able to begin to plan its orientation to the new product when it is passed down the pipeline. However, we see the strategy being followed time and again, in product innovation.

> "Failure is associated with the 'we know best attitude' which is common amongst technical inventors."*(49)*

> "Right now I am developing the electric car. There have been lots of reports published in the House of Lords which show the electric car not making economic sense. I believe these reports are produced very genuinely and with great skill, and they conclude that electric cars do not make any sense. But they can be wrong."*(50)*
>
> Sir Clive Sinclair

> "Sir Clive Sinclair has been forced to call in the receiver for his electric car business. His efforts to revolutionize motor transport with the three wheeled C5 have been beset by problems since the launch in January, and they have culminated in a list of 110 creditors owed about £700,000. Sir Clive, who put more than £7 million of his own money into the venture, projected that he would make and sell 100,000 C5s this year.
>
> Production ground to a halt in July, however, and it is estimated that only 9,000 were made, of which probably half remain unsold.
>
> The receiver, Mr David Sapte, of Begbie's the London accountants, said he believed that Sinclair's main problem had been one of marketing. 'I think we have to try to sell this as a fun thing. They have tried to sell it as a means of transport and that has not worked.'"*(51)*
>
> The Times, October 1985

The model fails to highlight the need for interdepartmental coupling and good project synergy. In contrast a concurrent model of innovation does not allow investment to continue unchecked. It demands an interdisciplinary approach throughout the project ensuring good communication, project synergy and hopefully market acceptance. Perhaps a greater use of this type of model in the educational system, and a more interdisciplinary approach to education in our universities, would assist the process of technology transfer and encourage the better management of innovation particularly amongst NTBFs.

> "Innovation is the management art that spans the industrial process."*(52)*

CHAPTER 5

THE STRATEGY AND STRUCTURE OF THE COMPANY

"The Government .... has played and continues to play a major part in its (Dutom's) development - it has already invested considerable quantities of cash, expertise and curiosity in Dutom. And rightly so."

Dutom Meditech News, 1982

"The Dodo never had a chance. He seems to have been invented for the sole purpose of becoming extinct and that was all he was good for."

Will Cuppy

OUTLINE

This chapter introduces the reader to some of the corporate decisions and their results in the life of Dutom Meditech. The history of the company is outlined by describing features epitomised in the corporate strategy and structure which the firm adopted at various times. Small companies are reported as notoriously poor strategists, with flexible structures, nevertheless the strategies and structures as described in this chapter are largely derived from documents produced by the management of the company, and are therefore as accurate a reflection of the company over its history as it is possible to achieve. The chapter is intended to provide the reader with an overview of the company, a more detailed analysis of its successes and failures is made in following chapters by considering the strategy of individual product innovations.

5.1.0 Dutom's Corporate Strategies

The strategies adopted by the company at particular periods are described in this chapter by using the documents and decisions which the management of the company produced during that period. Of necessity this is a simplification of the complex behavioural patterns involved in running a company but the written statements and actual management decisions reflect both the theoretical and adopted strategies of the firm. The company accounts (Appendix C) show the financial results of the adopted strategies. However, it should be noted that published accounts are not available after April 1984 because the firm was taken into receivership prior to the financial year end.

Broadly speaking the firm can be said to have been characterised by the following phases.

5.1.1 Start-up and Recruitment Phase (June 1980 - October 1981)

The company was formed by the liaison of Mr J Dutton, an ex-financial director and trained management accountant, and Dr J Thompson, who had an academic background in analytical chemistry with a particular orientation towards the medical environment.

In early 1981 a Business Plan document was produced which illustrates the corporate strategy conceived for the company. With regard to the "domain" or "what business the company was in" the firm was essentially based upon the ideas and experience of Dr Thompson and some colleagues from Birmingham University and orientated to the medical/hygiene field. In particular Dr Thompson had gained his experience in the Department of

Anaesthetics. Thus the domain identified for the company was in serving the medical and hygiene markets.

> "The Dutom Meditech strategy is to develop as a major company in the field of medical products."*(1)*

Despite drawing some attention to industry in the business plan as a potential market, the primary market they conceived for the products was within the Health Service. This is reflected in the marketing plan they proposed in 1981.

> "Marketing is being concentrated in the Health Services (operating theatres, dental surgeries, clinical chemistry and histopathology laboratories), the foundry industries, the paint industry and major industrial users of paints and the petrochemical industry."*(2)*

The objectives of the company identifiable from the business plan, are set out not in terms of finance but rather in terms of the type of company that Dutom was to be. The company was obviously committed to growth, however, the overwhelming objective of this company as it was stated, was to be a new technology based firm.

> "High technology industry is now entering a new phase of discovery and innovation of far reaching consequences. The resultant new industries from this phase of discovery promise to be much more significant than those which developed from the post-war electronics discoveries."*(3)*

Dr Thompson identified advances in environmental monitoring, biotechnology and microelectronics; Dutom sought to embrace the new technology in all three of these areas. Furthermore, the company was committed to product innovation in these new technologies.

> "The company will develop, produce and market a range of products which incorporate the most up-to-date advances in: Analytical chemistry, Biotechnology, Microelectronics."*(4)*

The name chosen for the company formed by the partnership of Dutton and Thompson represents their strategic consideration of the domain and objectives. So the Dutton and Thompson Medical Technology company was formed as DuTom Medi Tech Ltd, a private limited company.

With regard to the strategic choices of this company the 1981 Business Plan makes two interesting statements firstly:

> "The Company Strategy is to provide a complete product package solution to a problem area so that the customer can deal with his problem whilst only engaging a single source of supply."*(5)*

i.e. the company was to have a well integrated product and service strategy. This was soon enshrined in the company's public image by the slogan: "If we can't find the solution you haven't got a problem".

The second statement committed the company to a strategy which sought a differential advantage which was both low-cost - high volume and latest technology - high quality. i.e. a strategy which was at best contradictory.

> "In summary, the strategy is to sell products, services and systems for use in human and veterinary medicine which are: low cost, high volume, latest technology, single source supply packages, high quality and reliability."*(6)*

During the period June 1980 - October 1981 the company was in a start-up phase. The how and where of its corporate strategy, were largely confined to acquiring resources. Time was, therefore, spent on staff recruitment, and in line with the new technology objective technological staff were appointed from January to October 1981. By October the company employed the two executive directors and eleven full-time staff, of whom nine were technical staff.

The company trading base was also established during this phase. Initially the Registered Office of the company was in Luton, and it was planned that this would become a Marketing and Customer Training base with an analytical laboratory. It was proposed that the research, manufacturing and main laboratory facilities would be located in the Midlands. A site in the Dudley Enterprise Zone was proposed costing £350,000. However, the integrated offices and laboratory in Warwick Street, Birmingham was finally acquired at a purchase price of £77,500. The location of the business was chosen strategically for ease of access to Midlands universities.

Venture capital for this NTBF was sought from government and private sources. Under government backed schemes the company was loaned £50k as a Business Start-up loan and £75k as a government guaranteed loan. A further £40k was provided by the bank and £60k by Mr Dutton's finance company. In total loans amounted to £269k and since the issued share capital of the company was only £2 the company was very highly geared.

5.1.2 The Company Launch Phase (October 1981 - September 1982)

Following the opening of the building and public launch of the company it entered a phase characterized by R&D work on some of the proposed products.

R&D was carried out within the Systems (microelectronics) Group working on information system packages and graphics packages on newly acquired hardware. Specifications of the Adsorba monitor were finalized and work commenced on the Desorba, a thermal desorption oven to complement the Adsorba. The company also applied for, and were awarded, a Department of Industry grant under the Microprocessor Applications Programme (MAP) to develop a microprocessor controlled miniaturized gas chromatograph (mini gc). This amounted to a further £85k of government finance payable over two years.

Biotechnology research applications were made for the financial support for R&D on two projects namely the production of antibodies to schistosomaisis antigens and for the development of an electrochemical immuno assay technique. The company agreed to fund research into mono clonal antibodies being carried out in the Department of Immunology at Birmingham University, commencing in October 1982.

Thus throughout this period the company incurred the expense of R&D with little return on products. This type of investment profile is typical for new product development and is illustrated by Blake.*(7)* At Dutom, records show a loss to the end of September 1982 of £398k on a turnover of £66k. (i.e. one year after the company established its trading base but representing 21 months of trading.)

5.1.3 The Product Launch Phase (September 1982 - April 1983)

Marketing expense was incurred for the Adsorba monitor, which was launched by press release in a number of safety and laboratory magazines from March to May 1982. This launch, however, seems rather premature. On a sales plan memo prepared by the Sales Manager in July 1982, he writes:

> "Dutom has at present only one product - Adsorba. It is incomplete due to a hold up in acquiring a suitable holder and providing sufficient researched data to enable a 'Common problem - Solutions Table' to be compiled."
> "Until such time as the Thermal Desorpton Unit (Desorba) is commercially available we are not going to sell large numbers of Adsorbas or offer an acceptable alternative to their (customer's) present methodology."*(8)*

By September 1982 most of the prototype development and testing of the Desorba was complete. The company had two complementary "in-house" products to offer the environmental monitoring market. Furthermore the analytical services laboratory in Birmingham was now fully equipped. In addition franchised products were added to the Dutom product range by negotiating agreements with companies who had related products.

Dutom held an open day on 4 November 1982 to which the press and potential customers were invited. The purpose was to educate potential users of Dutom's new products and to the research that the company intended undertaking. Similarly in an attempt to educate potential users Dr Thompson began lobbying the Department of Health and Social Security (DHSS), the Health and Safety Executive (HSE) and the Health Service Unions on the topic of a national monitoring service within the National Health Service (NHS) hospitals, particularly regarding anaesthetic gases.

The sales and marketing strategy at the onset of this phase is summarized by a statement of objectives prepared by the Sales Manager for the Managing Director. These objectives were re-echoed in a business plan document he prepared for the period January - March 1983. His objectives were:

> "a) Sales force to be increased in number
> b) Product development to be accelerated
> c) Other products be brought in as an interim
> d) A high degree of flexibility be operated with regards pricing to achieve a baseline for sales.
>
> Short term philosophy - better to sell 100 at small profit margin than to sell 1 at a high margin."*(9)*

The thinking behind the strategy is essentially that of the salesman and it is illustrated by some comments in a report to the directors made with regard to sales leads.

> "It would also enable cold calling to be performed to increase cost effectiveness. The sales call is the most important part of this whole process as being the future primary source of income."*(10)*

Dutom, however had no sales representatives, and several existing staff with other principal responsibilities were encouraged to spend more time "on the road". They were also to act as distributors of franchised products in order to increase the sales turnover. This sales effort, however, received little administrative support. e.g. The sales co-ordination role was passed to one of Dutom's part time staff, and only in February 1983 was any decision taken to produce a product brochure. This "decision" was still being proposed by the Board in July 1984.

Instead of fully implementing a distribution stategy based upon a company sales representatives Dutom moved towards a greater dependence on distributors and adopted a strategy to sell products on a world market. The US was identified as a particularly important market and after trying some preliminary advertising in the US it was decided that:

> "The unco-ordinated launch of Adsorba/Desorba may well have a detrimental effect. The US market is more responsive to 'New' innovative products launched in a major way. Therefore, dealership agreements are essential to co-ordinate major promotion."*(11)*

The Managing Director and Sales and Marketing Manager undertook visits to the US in order to investigate and negotiate a distributorship for Dutom products in the US as well as reciprocal agreements for Dutom to market goods in the UK. By the end of January 1983 the strategy of using distributors was established and distributors had been sought not only in the US but also in most of the countries in W. Europe including the UK. The finalizing of these distributorships was given as the essential priority by the Sales and Marketing Manager in a memo.

> "It is essential that the distributorships and potential distributorships are brought to a satisfactory conclusion. Therefore, to this end I shall be concentrating, over the next two months or so, so that the agreement with Dosimeter is finalized."*(12)*

The result of negotiating agreements for companies to act as distributors of Dutom products was that Dutom was committed to fulfilling large stocking orders for UK, US and Italian distributors without having first developed the techniques of production or quality control.

In order to facilitate product launch Dutom made use of another government scheme. Under the preproduction order scheme run by the Department of Industry, Dutom applied for and were granted an allowance of £1053 for each of the first 35 Desorba ovens sold. Product launch and development was also funded by an increase in the share capital of the company. A total of £150k was raised by issuing £17k of shares at a premium. The shares were taken up by the two founding directors and two outsiders, one of whom was made a director.

5.1.4 The Recapitalization Phase (May 1983 - August 1983)

Despite the stocking orders for the newly appointed distributors Dutom faced insolvency at the end of April 1983. They had liabilities ammounting to £570k pounds which could not be covered by the total assets of the company.

A decision was taken by the directors to recapitalize the company on the public market and the newly announced Business Expansion Scheme (BES) was selected as an appropriate vehicle for this. In order to fulfill the requirements for reregistration as a public limited company the directors of Dutom acquired an "off the shelf" private limited company. This company, reregistered as a public limited company, then acquired all the assets, liabilities and business of Dutom Meditech Ltd.

Finally its name was changed to Dutom Meditech plc. Dutom Meditech plc then offered shares for subscription on the public market, under the Business Expansion Scheme, to raise capital of £1.15M.

Dutom were precisely the small independent technological company that the BES was conceived to support. In 1983 they were pioneers of the scheme both in being one of the first independent companies to raise capital through the scheme and with regard to the amount of capital raised. The first year statistics for the scheme show that of the 400 or so companies using the scheme in 1983 90% raised less than £250k.*(13)* Dutom raised £1.15M and the issue was fully subscribed.

The subscriptions for shares were mainly in small amounts from independent investors but perhaps I may borrow the words of Dr Johnson regarding the details.

> "I have two very cogent reasons for not printing a list of subscribers - one that I have lost all the names - the other that I have spent all the money."*(14)*

From 3 May 1983, when the "off the shelf" company was acquired, to 8 August 1983, when the subscription was closed, the directors were engaged in meetings to ensure the reregistration and acquisition of the new company business was legal. They were also involved in the preparation of documents in support of the share issue.

5.1.5 The Expansion Phase (June 1983 - April 1984)

Concurrent with and immediately following the success of the share issue, a strategy of expansion of the organization and its operations was followed. Dutom was reorganised into four divisions; Occupational and Environmental Health (OEH), Biochemistry, R&D and Administration, and staff were recruited to all four areas.

The prospectus document for the share issue, which was publically issued in July 1983, contains a carefully prepared statement of company policy. This statement is reproduced in Appendix C and illustrates the theoretical corporate strategy at that time. From the company policy statement the company position with regard to many of the strategic variables described in Chapter 3 may be derived.

Thus the strategic posture of the company could be described as:

a) Growth orientated since it was an emerging industry in serving a growing market.

"The Directors have been concerned with the development of a product range for which there is likely to be an above average growth market."*(15)*

b) The firm had a policy of being R&D orientated in order to be an innovative firm.

"The Directors have undertaken a policy of undertaking a programme of R&D on products and services."
"The Directors expect the company to keep abreast of advances in both occupational and environmental health, and in biochemistry."*(16)*

c) The product range of the company was to be comprehensive and achieved both through product development and through acting as distributors for the goods of other manufacturers. i.e. the intended strategy was for an integrated product line. However, the firm was also prepared to increase the product range through diverse products.

"Furthermore they are aware of and actively pursuing other potentially profitable product opportunities."*(17)*

d) With regard to resources the company intended to use other companies for both the manufacture and marketing of the products.

> "The company intends to sub-contract all manufacturing and assembly of its own products, except in those cases in which quality control can only be achieved by in-house manufacture. Similarly, because of the substantial cost implications, the Directors do not propose to establish a large sales force but intend that the major selling effort of the company will be through a small number of carefully controlled distributors."*(18)*

Following these statements the decisions which the company actually made with regard to its products and markets reflect how the corporate strategy was realised throughout this phase.

Product Development

The relative importance of products and services of the company is illustrated by the Managing Director's comments on the OEH division objectives, and demonstrate that the corporate strategy was primarily product based and innovative.

> "The aim of the company is to develop new products for the health care market. The analytical/monitoring service is to give us close market contact, a training ground and a profit centre."*(19)*

Product development adopted an expansionist strategy, priority in the R&D division was given to the mini gc microprocessor application programme, and several staff were recruited for development work on this project. In OEH division some new product franchises were agreed from manufacturing companies and several products originally proposed in the 1981 Business Plan were again proposed for development. This expansionist strategy in OEH products as opposed to consolidation of existing products is illustrated by an OEH report to the Board*(20)* in which of six new products identified for development only one was an accessory to an existing product. Furthermore, the Board decided that with regard to the Adsorba monitor, Dutom's principal product, the strategy would be based on the monitoring of ethylene oxide. This required a totally new adsorbent for the monitor and was, in effect, new development work.

Similarly in Biochemistry division resources were devoted to a variety of ventures, e.g. setting up a joint venture company (APP Ltd - which supplied blood products for foodstuffs), applying for a research contract based on an electrochemical immuno assay technique, protein fractionation and sera production, and a distributorship for laminar air flow cabinets.

This change in emphasis away from a well integrated strategy is subtly illustrated by the change made in the company slogan:
from - "If we can't find the solution you haven't got a problem";
to - "Putting research to work".

Market Development

The marketing strategy for products at this time exhibited a number of contrary characteristics. Sales staff were recruited for the UK to increase sales, meanwhile the US was determined to be the dominant market.

> "Mr Taylor felt it was probably necessary for us to establish our home market first before making major moves overseas." "Professor Perry, however, commented that the US was a totally dominant market in this field and that for us to succeed we must have more US involvement."*(21)*

However, in the US the previously appointed distributor, Dosimeter Corporation, had achieved a very poor sales performance. This distributorship was terminated by agreement and a new distributor sought. The importance which Dutom allegedly attributed to the US market and this change of distributor, from Dosimeter to Digicolor, is summarized in a report on the US market presented to the Board in

January 1984.

> "In summary a lot of time has been spent setting up our numerous contacts in the US market and they are now starting to bear fruit, and it is hoped that 1984 will see a significant penetration of the US market, and as such a considerable amount of senior management time will be spent on this particular aspect of our business."*(22)*

Nevertheless, Dutom also recruited and began to train a genuine sales team to cover all Great Britain. This was the first time resources were committed to a UK sales team although the expressed policy was still to market products through distributors.

The type of market the company aimed to sell its products in was the subject of opposing statements and decisions. A comprehensive report made to the directors by the management consultants Coopers & Lybrand and issued concurrently with the prospectus reports:

> "The first problem arose from Dutom's policy to market a complete occupational health service to the National Health Service (NHS) ... the subsequent take up of the service to the NHS has been negligible. This caused Dutom to change its marketing policy during the second half of 1982 and concentrate its sales efforts in the industrial sector."*(23)*

Similarly Dr Thompson produced a report to the Board on the fragmented and cashless nature of the NHS in September 1983.*(24)*

However, a report to the Board in October 1983*(25)* contains plans to increase lobbying of the NHS regarding ethylene oxide, formaldehyde and anaesthetic gases. In the US the product was also to be targetted at the hospitals service.

> "The strategy for Adsorba and Desorba would be to promote them via American Health Services, targetting for specific concerns such as ethylene oxide."*(26)*

This new strategy was communicated to the new US distributor and introductions were made to an American manufacturer of hospital sterilizers.

Finally the product range strategy was to buy in other manufacturers' products for resale in order to generate cash flow and achieve a favourable market. While the marketing strategy was to sell-on goods to distributors since it recognised Dutom did not have the resources for a sales force.

The financial desire expressed by the directors was to achieve a breakeven of expenditure and income by the end of the accounting year in April 1984. However, the financial projections estimated a loss to that date of £259k. Instead of meeting these projections the company accounts reveal a loss of £916k during the 10 months to April 1984 on a turnover of only £58k. It was the extent of the failure to attain the financial targets which moved the company into the next phase of its strategy.

5.1.6 The divestment phase (April 1984 - April 1985)

In the period to April 1984 the company had continued to exhibit both a shortfall in sales revenue and an overspending on overheads versus their financial predictions. In order to reduce expenditure the company strategy underwent a significant change from this time.

The beginning of the change to a divestment strategy is first illustrated by two minutes of the board in April.*(27)*

1. The decision to dismiss two of the UK sales staff.
2. The warning from one board member that product development on the mini gc could only proceed if they could find a company to co-operate with its development.

Similarly in May 1984 the Board meeting minutes record:

> "Mr Dutton noted our philosophy was now to market our R&D potential which we had not done previously."*(28)*

i.e. a change in strategy away from a dependence on products to selling off projects.

In July 1984 the board proposed further staff reductions and the limiting of new product development for OEH division only to developments directly associated with existing products.

Negotiations were begun to try to sell off several research projects to major companies in return for cash and/or royalties. This strategy is described by the directors in a business plan they prepared in November 1984.

> "Under its new direction the company has adopted a philosophy of offering these projects for sale for a technology buy in fee, reflective of expenditure to date together with a full sponsorship programme financed by external companies in return for a royalty fee on sales of the end product."*(29)*

Also in November 1984 the company suspended its funding of the research project at Birmingham University.

In February 1985 the board decided to dispose of its stake in the joint venture company APP Ltd, however, none of these attempts at divestment realised the capital to prevent the company being taken into receivership in April 1985. They had liabilities of £512k and estimated the assets of the company to be worth only £209k. The company was finally wound up on 2 October 1985 and the assets liquidated.

5.2.0 Dutom's Organizational Structure

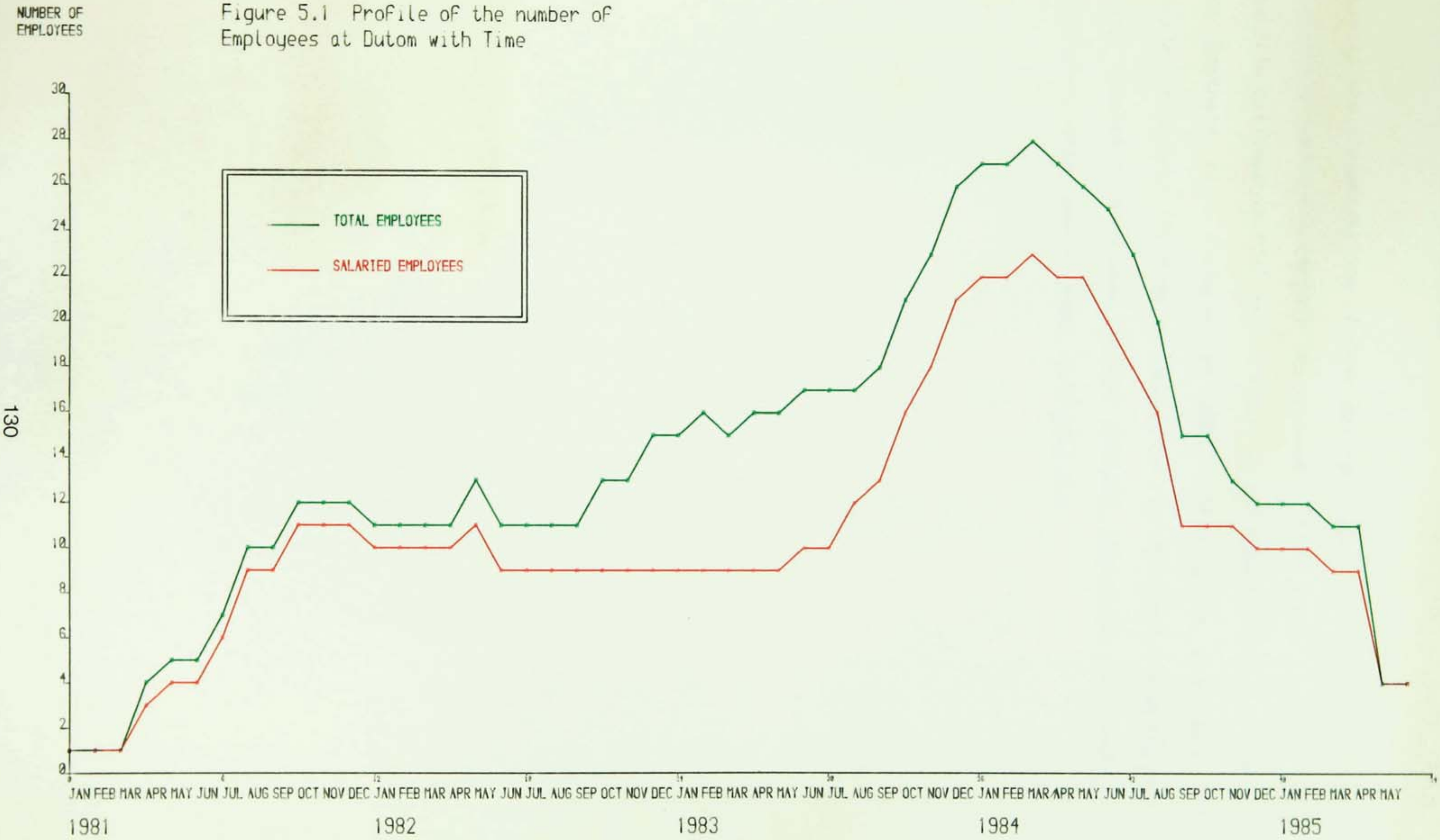
This section introduces the reader to the organizational structures which Dutom adopted. In any such rapidly changing environment not every individual slight change of role or structure can be represented. Nevertheless, most of the organizational charts are drawn from material released in official documents at strategic points in the firm's history. Therefore, they are cameos of how the company management saw the company structure.

5.2.1 Personnel

The company was formed through the association of two founding directors Mr Dutton and Dr Thompson. From the foundation of the company until his death in 1982, Professor R Belcher acted as the non-executive chairman.

In total 40 people worked at Dutom over the four years of its existence, however no more than 25 of these were full-time paid employees of the company at any one time. The levels of staffing employed by Dutom including contract or staff paid under various cooperative schemes are illustrated in Figure 5.1. The backgrounds of key personnel employed by the firm are briefly described in Appendix D. In addition Appendix D contains a list of the Scientific Advisory Panel and team of consultants which Dutom appointed in 1983. These advisors were publicized in the share prospectus and make very impressive scientific reading.

Figure 5.1 Profile of the number of Employees at Dutom with Time



5.2.2 Organizational Structures

Initially the vision for the company was for a multi division company in which each division was largely autonomous. The grand plan of this company is outlined in Figures 5.2 which is extracted directly from the Dutom Business Plan Document of 1981. This grand plan was never realised although at the time of opening of its Birmingham premises the company boasted three groups, namely: Systems, Analytical Chemistry and Biochemistry, organized as shown in Figure 5.3.

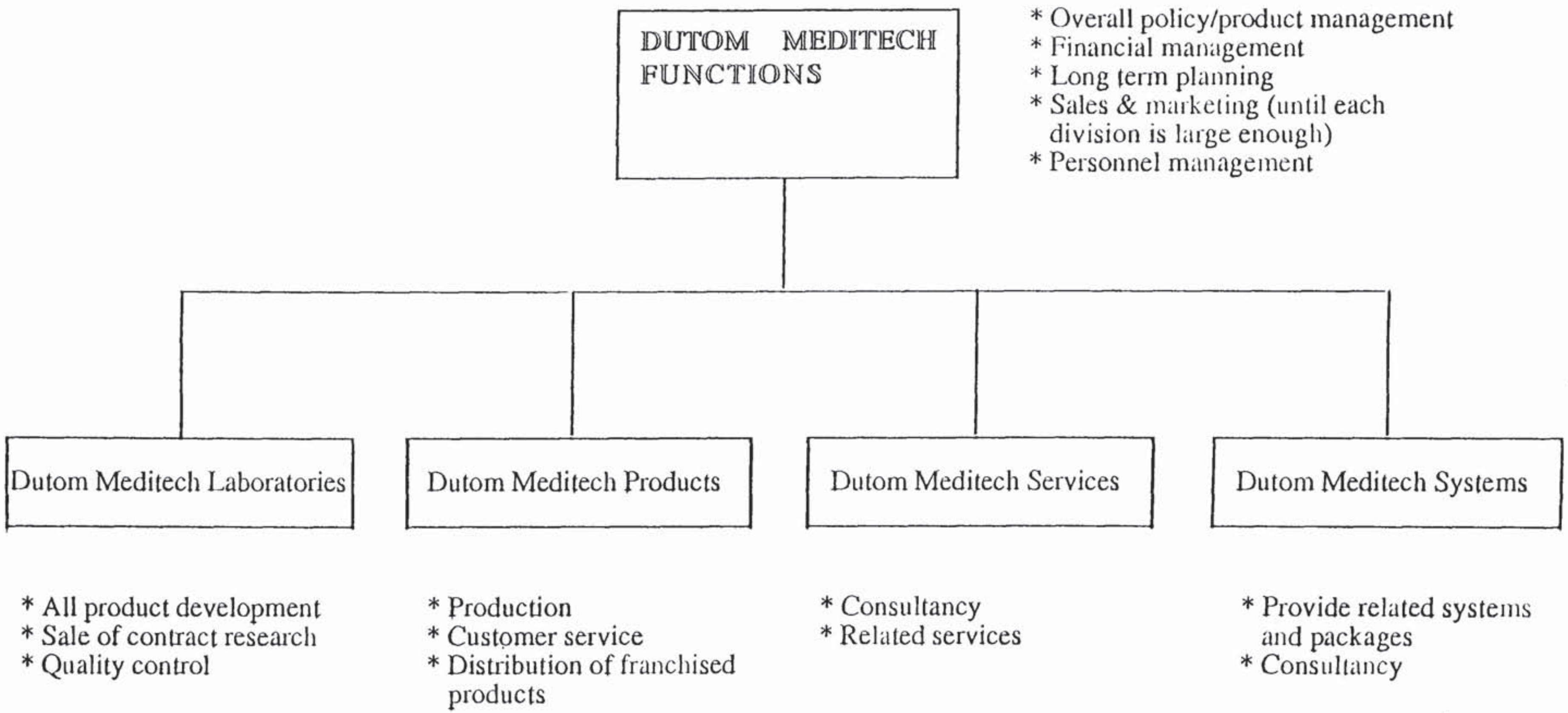


Figure 5.2 Structure of the multi division company
Adapted from the Dutom Meditech Business Plan 1981 *(30)*

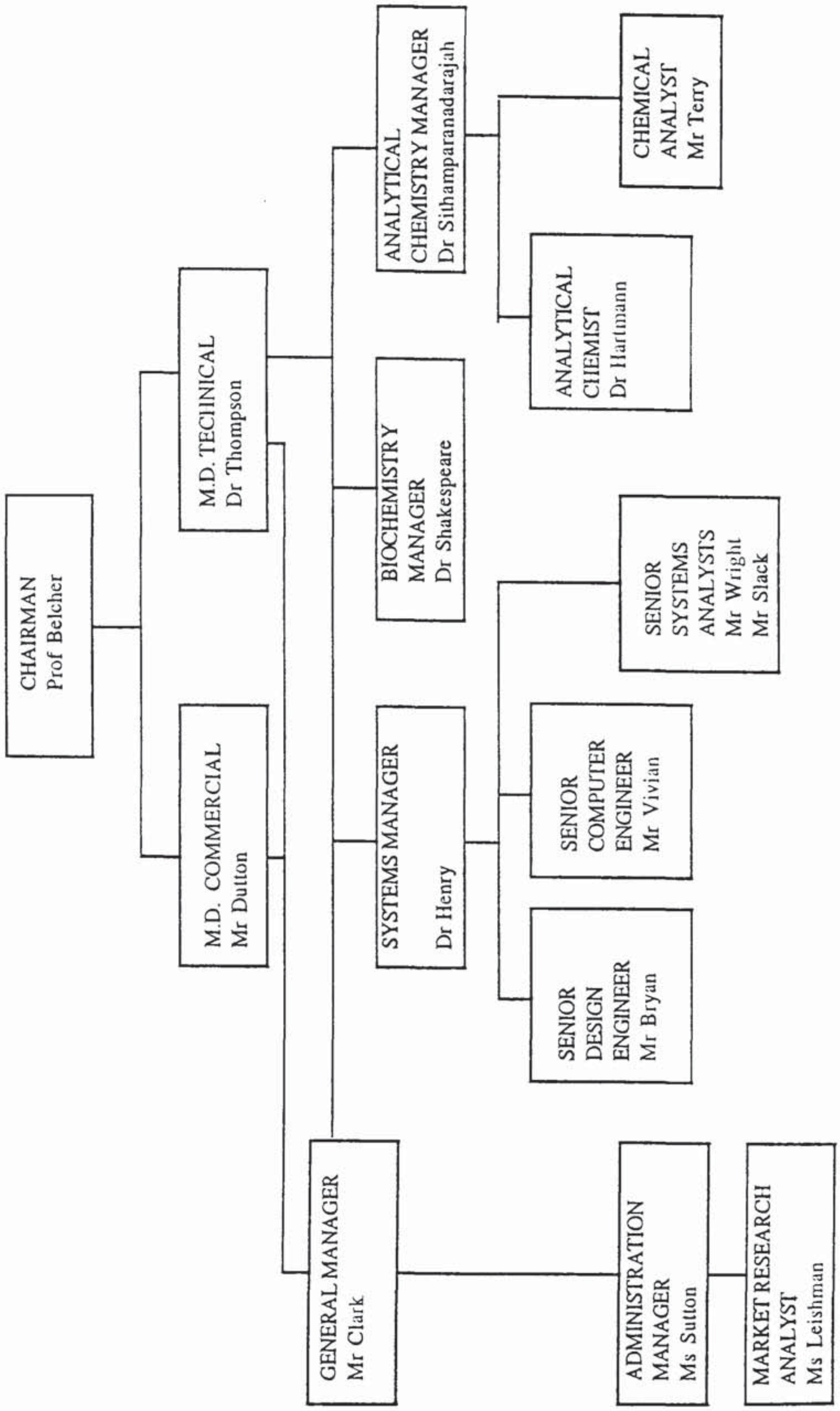


Figure 5.3 The structure of Dutom Meditech Ltd in October 1981
Adapted from a Dutom publicity document *(31)*

By the time I joined the company in October 1982, the structure had changed somewhat from that above. The Systems Group had been completely disbanded, and its Group Manager and both the Systems Analysts had left the company. The General Manager had also been moved to responsibilities in other companies of Mr Dutton's, and a Sales and Marketing Manager had been appointed. Professor Belcher had died and Mr Dutton had become the acting company Chairman, a position he retained until a new company Chairman was appointed following the public share issue.

Most of the company staff were based at the Birmingham site. However, Mr Dutton was only rarely in attendance at the premises. Accounts and pay were conducted through his Finance company, Kinrade Finance Ltd in Luton and reported directly to Mr Dutton.

The Market Research Analyst was also based in Luton and worked for Dutom only on a contract basis, reporting to Mr Dutton. The Sales and Marketing Manager spent a considerable amount of time out of the office, while the Sales and Marketing Coordinator split her time between office work and attracting customers. The Senior Analyst at this time was also being requested, much against his will, to spend more time "on the road" in a Technical Consultancy role. By January 1983 all these staff were being expected to perform greater sales roles at the direction of the Sales and Marketing Manager.

The Analytical Chemistry Manager had been appointed as Research Manager to manage the analytical laboratory, the computing work and the electronic design work being carried out. This situation is summarised in Figure 5.4.

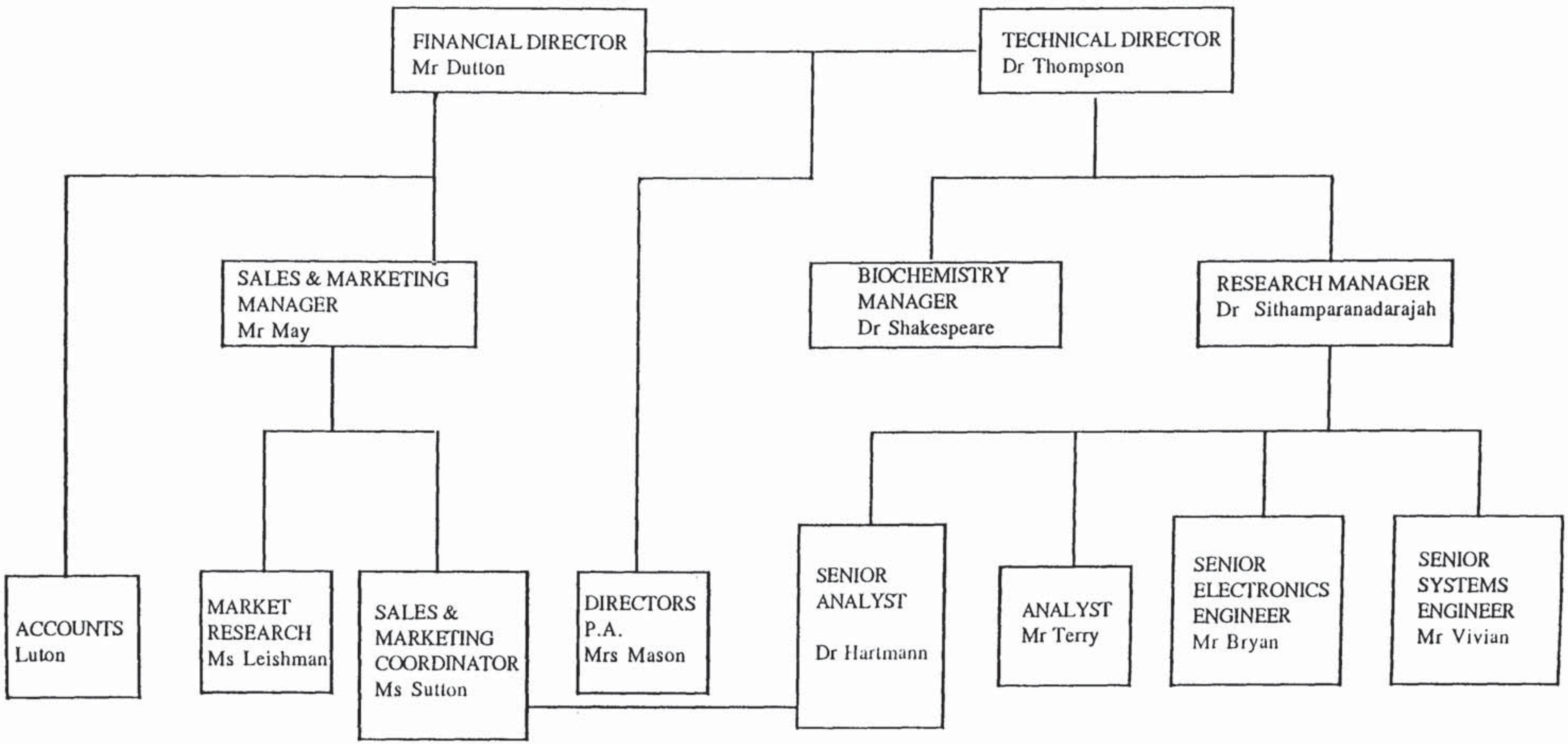


Figure 5.4 Dutom Meditech Ltd Structure at October 1982

By March 1983 the company hierachy was reorganised if only on a temporary basis. The purpose of this reorganization was to meet pressing stocking orders for Dutom products from its distributors, in the UK, US and Italy. The Senior Electronics Engineer was appointed as the Production Manager. Under him a team was formed consisting of the Analytical Chemist, the Systems Engineer and the two IHD students, which over a period of a month worked to develop the skills to manufacture and produce the Adsorba. Throughout this period the Senior Electronics Engineer reported directly to the Technical Director, while the Research Manager carried out some quality control work.

Immediately prior to the share issue, in the summer of 1983, the company had been recruiting staff largely under Manpower Service Commission schemes. Upon receipt of the capital of the issue the company was reorganised into four divisions - R&D, Biochemistry, Occupational & Environmental Health (OEH) and Administration. The plan behind this is given in Figure 5.5 and is extracted from a report to the directors by Coopers & Lybrand which was issued at the time of the share prospectus.

Contrary to the organizational chart in Figure 5.5, none of the posts marked "to be filled" were ever filled. The Market Research Manager reported directly to the Technical Director and in fact carried out very little market research, by October his title had been changed to that of Technical Administration Manager. Meanwhile the Marketing Services Manager worked entirely for another company of Mr Dutton's. In addition to the divisions shown on the chart Dutom were sponsoring research at Birmingham University.

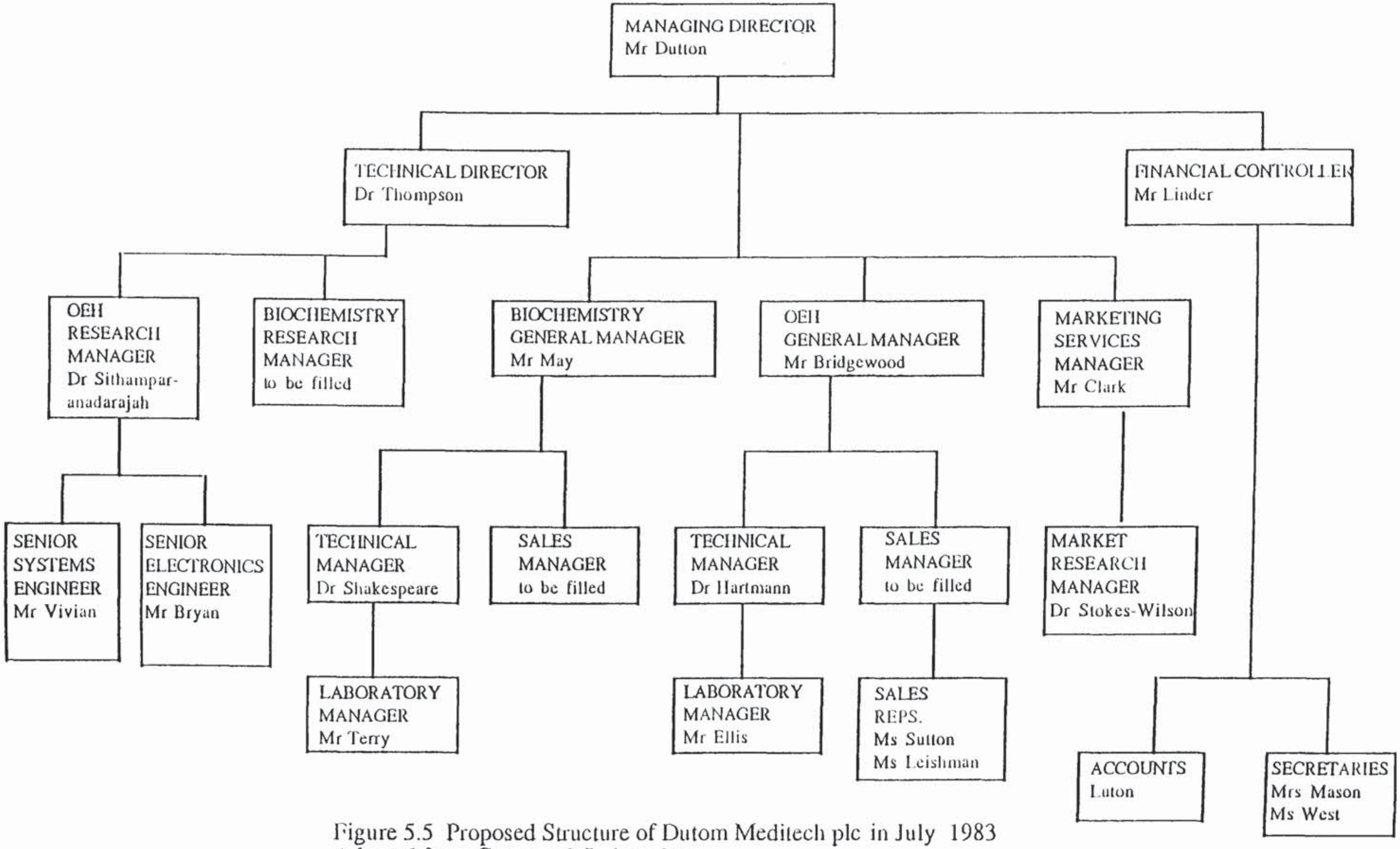


Figure 5.5 Proposed Structure of Dutom Meditech plc in July 1983
Adapted from Coopers & Lybrand(32)

The important feature of the change in the structure of the company was the divorcing of research from the commercial aspects of the company. This occurred at both a Director and a General Manager level. Dr Thompson was officially left only with R&D responsibilities and similarly the Research Manager was relieved of responsibility for controlling the analytical laboratory work and the production and dispatch of customer orders and reports. At Board level, non executive Directors were introduced giving the Board a mix of internal and external representatives, and a new Chairman (Sir N Marten) was appointed.

Towards the end of September 1983 two staffing decisions were made. One was to recruit a company sales team for the UK and hence to cease to rely on the UK distributor for product sales, the second was to recruit technical staff in order to complete the Microprocessor Application Programme, mini gc project. The OEH General Manager, therefore, recruited staff and formally divided Britain into four sales territories. Staff were recruited under the Research Manager for the MAP project and a similar staff structure to this was envisaged for a biotechnology project. Although this latter project never commenced, the staffing level after the recruitments represented the maximum attained by Dutom and is represented in Figure 5.6.

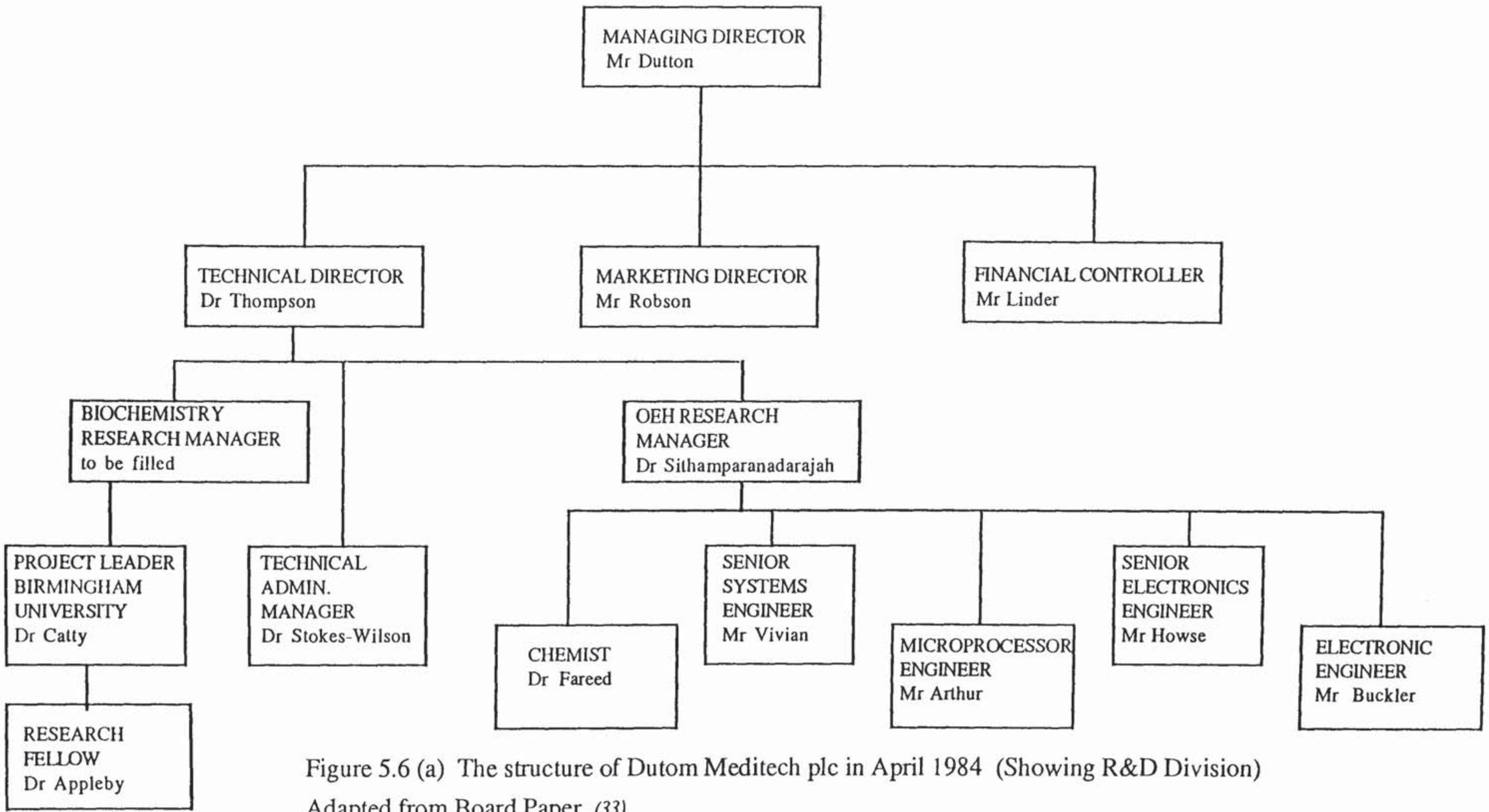


Figure 5.6 (a) The structure of Dutom Meditech plc in April 1984 (Showing R&D Division)
Adapted from Board Paper *(33)*

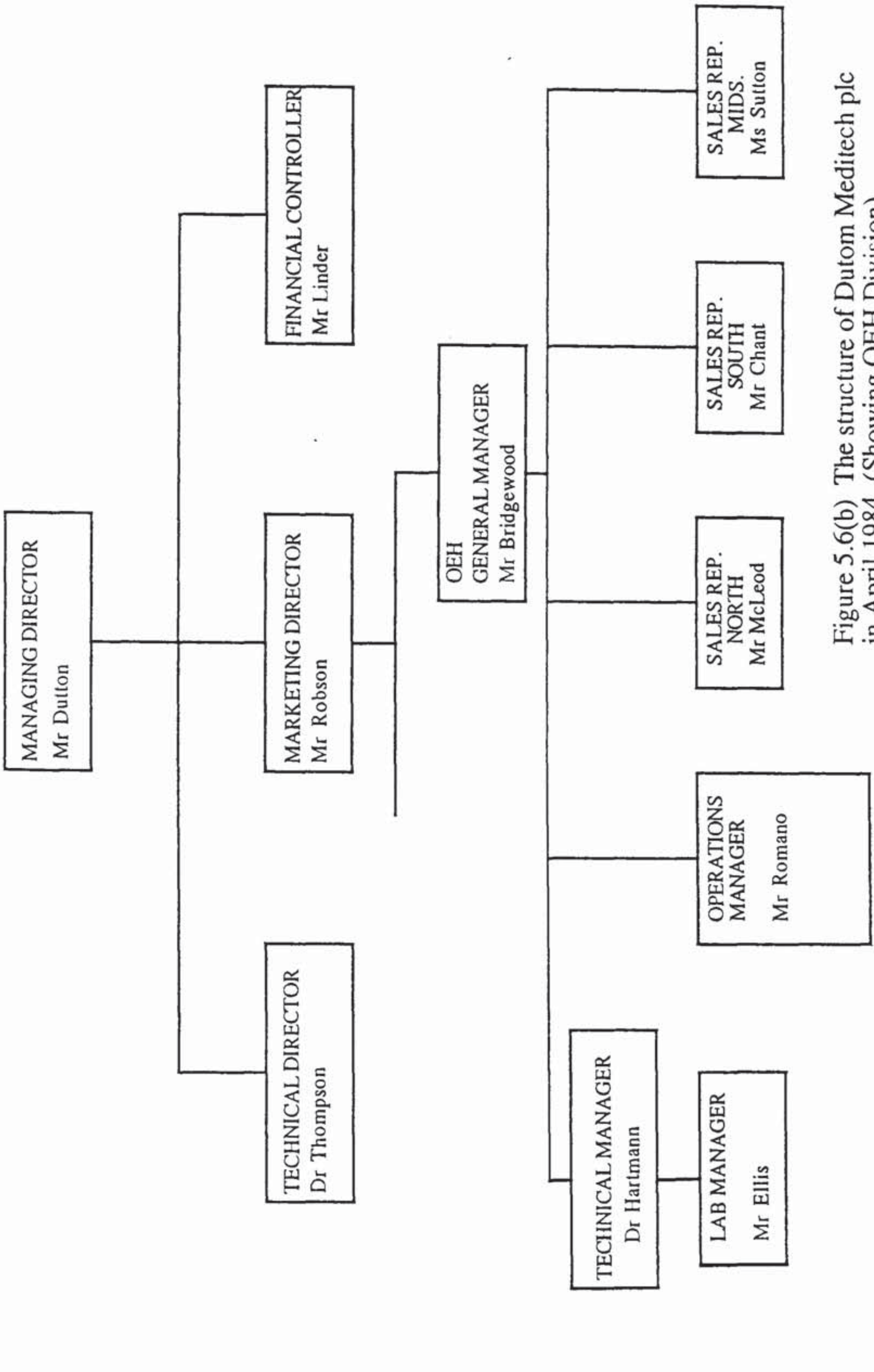


Figure 5.6(b) The structure of Dutom Meditech plc in April 1984 (Showing OEH Division)

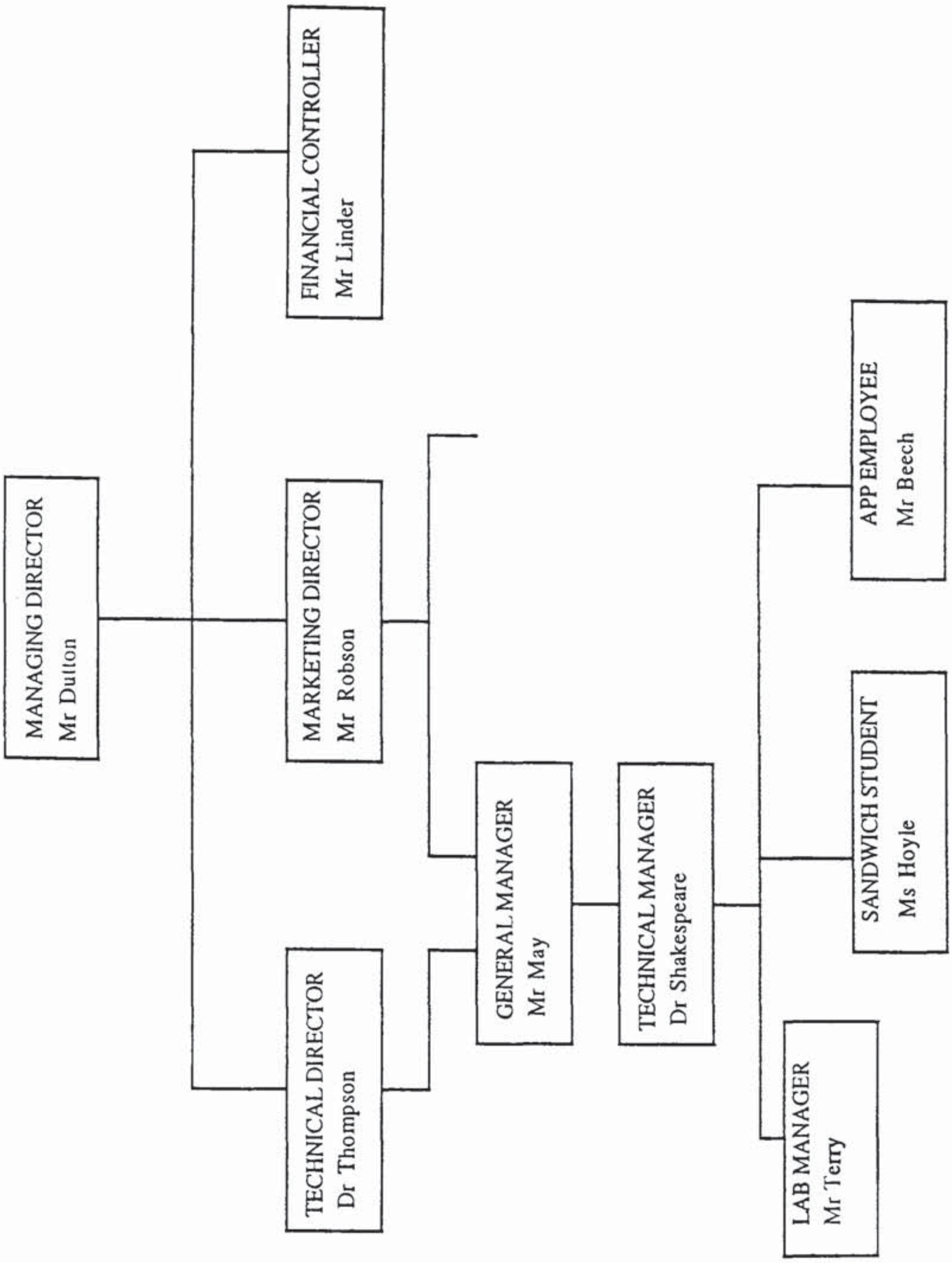


Figure 5.6(c) The structure of Dutom Meditech plc in April 1984 (Showing Biochemistry Division)

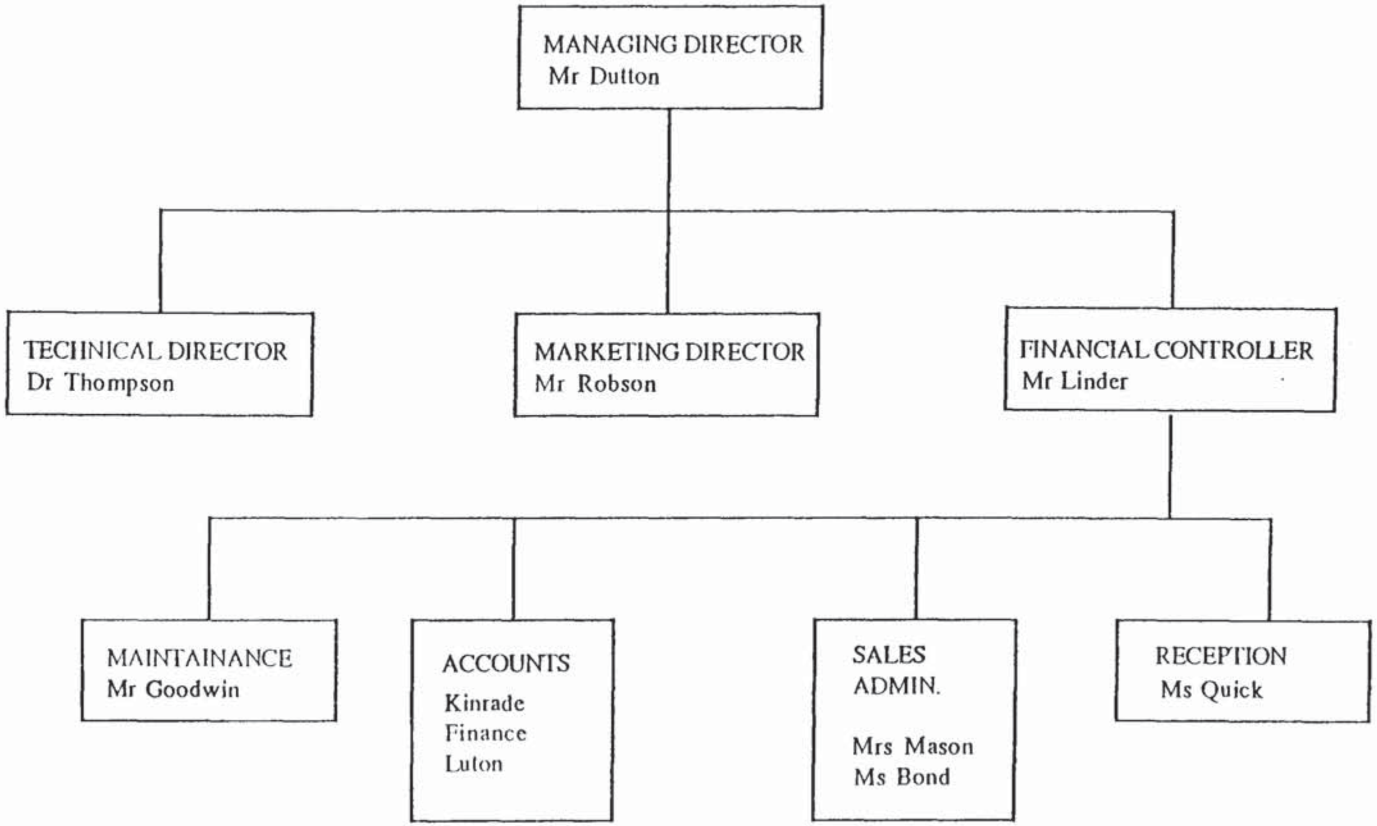


Figure 5.6(d) The structure of Dutom Meditech plc in April 1984 (Showing Administrative Division)

In April 1984 the board reversed its expansion strategy and staff began to be dismissed. The OEH General Manager and two of his sales staff were the first to go, rapidly followed by administration staff and the dismissal of two R&D staff. Those working on the MAP, mini gc, project were being urged to bring the project to a rapid conclusion, but they were aware that they were working themselves out of a job. By September all the R&D staff had left Dutom with the exception of the R&D Manager. Staff who had been working on the biotechnology joint venture project who were dismissed by Dutom were able to be re-employed directly by the joint venture company APP Ltd.

At Board level the Chairman, appointed after the share issue, had resigned immediately upon hearing of Dutom's outstanding liabilities to the Inland Revenue, and the Company Secretary was replaced. The Managing Director (Mr Dutton) had not attended a Board meeting after May and his resignation was demanded. This was finally received in October 1984.

By April 1985 when the receivers were called in the Dutom staff had dwindled to nine full-time employees, including the R&D Manager and Biochemistry General Manager, neither of whom had any staff under them. The remainder of the biochemistry staff were all then employed by APP Ltd which has since continued to trade and moved its base to Brierley Hill. The Technical Manager of the OEH division, after the liquidation of Dutom's assets, went on to form OEH Scientific Ltd, a private limited company, currently trading from the Aston Science Park and employing three of the former employees of the Dutom OEH division.

5.2.3 Recruitment Policy

The recruitment policy of the company shows three distinct phases. Firstly, the majority of the early phase of recruitment was made through personal aquaintances particularly of the founding directors.

Of the personnel recruited prior to the opening of the Birmingham premises, six were associates of Dr Thompson from Birmingham University. Dr Thompson continued to use his academic contacts by recruiting Professor Perry to the Board and several academics as Scientific Advisors and Consultants. Later his brother-in-law was recruited as a General Manager.

Similarly Mr Dutton recruited ex-colleagues from BL, initially to the posts of General Manager and Office Manager, and later as the Company Secretary. Personnel associated with his other business ventures were recruited on a contract basis e.g. accounting and market research were performed by staff working for his other companies. The wife of a business partner also was employed on a part time basis. Finally one of the sales staff recruited at the end of 1983 was an ex-colleague of one of the General Managers.

The second phase of recruitment to the company was characterized by a policy of reduced cost. This was achieved by recruiting from two main sources, students and Manpower Service Commission (MSC) Schemes. Thus Dutom recruited the services of two IHD students, one sandwich student and participated in research at Birmingham University which it hoped to exploit commercially. Other staff were recruited particularly under the Management Extension Programme, a Manpower Service Commission scheme, within which Dutom did not have to pay salaries for six months. Using MSC schemes Dutom recruited five staff, four of whom were eventually taken onto the Dutom payroll. This reduced cost recruitment accounted for most of the increase in staff from October 1982 - June 1983.

The company was characterized by having indistinct job descriptions, e.g. the General Managers were asked to write their own job descriptions in July 1983. For the staff recruited under the "reduced cost" approach this phenomenon of poorly defined job descriptions was particularly acute. Job titles and roles were changed frequently and there remained a continual uncertainty in top and middle management as to whom these staff were answerable to and what tasks were expected of them. For example one individual held the titles of Market Research Manager, Safety Officer and Technical Administration Manager in quick succession, while a trained production manager undertook stock control, customer contact and finally invoicing.

In the third phase of recruitment staff were recruited to perform particular limited tasks. These appointments were made after September 1983 and were in two main areas; OEH sales staff and technical staff for the R&D mini gc project. Almost all these positions were short-lived, and these were the staff who were being dismissed from April 1984 in line with the divestment strategy.

5.2.4 Some Organizational Problems

From the start the company had a high level of technical and academic experience but little experience of management or marketing. The recruitment of additional staff on the reduced cost basis resulted in certain organizational problems.

The outcome of the recruitment policies was that people were recruited to posts with grand titles but imprecise job descriptions. This assertion of the lack of understanding of tasks and of "too many chiefs" in the company is perhaps best illustrated by a comment made to the two IHD students by the Sales and Marketing Manager in Spring 1983:

> "We haven't got any workers at Dutom, except you two, everyone else is a manager."

Having so many "managers" with unclear task descriptions led to indistinct and duplicated lines of communication and an uncertainty regarding authority. This problem was made more acute by the frequent absence of the Directors. The result was a high level of frustration amongst the staff.

In particular, the positions of middle management were undermined and a general lack of confidence was expressed in the General Managers. This situation had been exasperated because the Board received a high degree of technical input and the lower managerial staff were all technically qualified whereas those appointed to the intermediate posts had less technical expertise and apparently were intimidated by both sides.

The lack of confidence in the middle management can be illustrated on several occasions. For example the General Manager in 1981, Figure 5.3, was in an anomalous position within the reporting structure of the management. He was removed from this post following a report made to the Managing Director on his performance which also illustrates the lack of a clear management authority in the company.

> "His (General Manager's) closing statement of 'I make the decisions' left the majority of people in the meeting confused and unreceptive as this was a direct contradiction to the true situation as defined by their M.D.."*(34)*

The Sales and Marketing Manager in 1983 similarly illustrates his lack of confidence in his position, when at the end of a memo to the Managing Director on sales objectives, he writes:

> "These proposals require maximum support from yourself both in the form of formal authorization to all relevant members of staff, so as to avoid the problems we are currently experiencing. In addition, sufficient funds will be necessary ... and more importantly your confidence in my ability to perform these tasks. With minimal supervision!"*(35)*

During the product launch phase the R&D Manager encountered difficulties because he was allocated the dual role of managing both the R&D of the company and the day to day commercial running of the laboratory. Given the diverse management styles typically required in managing these different functions and his lack of any commercial experience he tended to pursue R&D work to the detriment of managing the commercial side of the business.

The result of these problems was that middle management was frequently circumvented in discussion and informal communication channels became more significant in the firm.

CHAPTER 6

DUTOM MEDITECH'S PRINCIPAL PRODUCTS

"Over the Mountains of the Moon, down the Valley of the Shadow
Ride boldly ride, the Shade replied
If you seek for Eldorado."

Edgar Allan Poe

OUTLINE

Chapter 5 described how Dutom approached innovation from a corporate viewpoint. Here it is important to consider the product innovation process from the viewpoint of Dutom's two principal products.

Dutom had been founded upon work carried out in occupational hygiene monitoring and analysis. This field proved to be the mainstream of the company's activities throughout its history. Product innovations by the company in this field therefore represent the most important innovations with regard to the overall business of the company and describe Dutom's approach to innovation most comprehensively.

This chapter describes the two main products of the company, the Adsorba and Desorba, from invention to market reception. Chapter 7 examines some other product innovations attempted by Dutom in the same field which failed to be launched.

6.1.0 The Adsorba Monitor

6.1.1 Product Description

The Adsorba monitor was primarily designed as a personal monitor for gases and vapours in workplace air. As a personal monitor it was to be worn near the breathing zone and was conceived to be fitted into a clear acrylic holder which could be attached to the lapel. It could also be used for fixed site monitoring.

The Adsorba itself consisted of a stainless steel tube engraved with a ring and identification number, into which an adsorbent powder, typically a polymer or zeolite, was packed. This powder was held in place by two stainless steel mesh disks (frits). Air was either drawn through the tube using a pump (active monitoring) or diffused into the monitor (passive monitoring) where the adsorbent material trapped the polluting species by physical adsorption. When the Adsorba was heated in a suitable desorption oven (Desorba) the trapped species were released from the adsorbent material and could be flushed into an analytical instrument, typically a gas chromatograph (gc), by passing a stream of inert gas through the tube. The purged monitor could then be reused. Representations of the monitor are presented in Figure 6.1 and Figure 6.2 and a photograph of the monitor and its holder is reproduced in Figure 6.3.

The Adsorba monitor was invented during research carried out by Drs Thompson and Sithamparanadarajah at Birmingham University from 1976 to 1980. This research included monitoring the air in operating theatres and is described in Dr Sithamparanadarajah's PhD thesis.*(1)*

Patents for the device were filed in the UK*(2)*, and Europe*(3)* and the rights to these patents was held by the National Research Development Council (NRDC), a patent application was also made in the US. Dr Thompson explained to me that a major reason for the formation of Dutom Meditech was the failure of the NRDC to exploit the patents commercially, instead Dutom was granted a sole licence on the patents.

Thus the Adsorba was one of the primary products of Dutom from the foundation of the firm. In November 1984 a Coopers & Lybrand report issued to shareholders described Adsorba as "the company's mainline product",*(4)* and Dr Thompson in March 1985 still described Adsorba to me as:

"The cornerstone of the company products."*(5)*

The product was therefore viewed throughout the history of the company as a key product.

The ability and efficiency of the Adsorba to adsorb a particular polluting gas or vapour was dependent on the interaction of the adsorbent with that polluting species. In order to capture different pollutants one or more of a variety of adsorbents were packed into the tube. This specificity of adsorbent for pollutant meant that the Adsorba should be considered as a product range with each differently packed monitor treated as a new product.

By October 1982, two types had been conceived, an organic solvent monitor and a nitrous oxide monitor, and the name Adsorba was almost exclusively used of the organic solvent type. In October 1983 the Board decided that the strategy for Adsorba would be to develop it for specific markets and began by basing the strategy on an Adsorba for ethylene oxide. Development work therefore began on an ethylene oxide monitor and this work provides most of the subject material of David John's PhD thesis (in preparation).

6.1.2 Production

The Adsorba had been developed as part of a research project at Birmingham University and the first batch of monitors were produced using the facilities of a laboratory. Despite the product first being launched in the press in Spring 1982 few orders were received and these could be met from the original stock. The first call for the production of Adsorba monitors in quantity came with the stocking orders from the distributors in March 1983.

The Dutom production strategy was to assemble and condition the monitors "in-house" from bought in components, and a team was formed, which included the IHD students, to produce the monitors. However, the company had absolutely no experience of bulk manufacture so production techniques had to be developed from scratch. A number of problems were encountered during the scaling up of production some of which are described here.

Adsorbent conditioning

The organic vapour monitor developed by Dutom had used Porapak Q, a styrene-divinylbenzene copolymer, as the adsorbent. This polymer contains excess divinylbenzene which bleeds from the polymer when heated. In order to condition the material for thermal desorption this excess must be removed. However, Dutom could find no suitable way to condition the material in the quantities required. Instead a decision was taken to use Tenax GC, a 2,6-diphenyl-p-phenylene oxide polymer, as the adsorbent. This material could be conditioned more easily but Dutom had no experience of its performance. A more satisfactory oven for polymer conditioning was designed later.

Tube degreasing

The stainless steel tubing for the monitors was cut to length and engraved by outside contractors. This left a residue of cutting oil on the tubes. For small quantities, the tubes could be cleaned using an ultrasonic bath and an oven, for bulk quantities this proved totally inadequate for removing the oil residues and some tubes developed a tarnished appearance on heating. These tubes had to be polished and so all tubes produced after April 1983 were subjected to acid cleaning and electropolishing.

Fitting the frit

In laboratory manufacture this had been done by cooling the frit in liquid nitrogen and fitting the contracted disk into the tube. This was too expensive and time consuming for bulk production. Instead an air compressed hammer was built to force the frits to the correct depths in the tube. This led to a partial redesign of the tube after April 1983 so that instead of having a curved lip at the tube ends the interior was slightly chamfered to ease the location of the frit.

Packing the adsorbent

The adsorbent required vibrating to pack uniformly. Dutom staff were much amused when this required the Technical Director making a trip to Boots one evening to purchase several vibrators so packing could commence.

After the first distributor stocking orders were fulfilled in April 1983 no further major production runs were made for the organic vapour type monitors. The only other substantial production run was for ethylene oxide monitors which was made in Autumn 1984. The total numbers of Adsorba monitors produced with their packings are reproduced in Table 6.1.

Table 6.1. The production of Adsorba monitors

Date	Nos. produced	Adsorbent material
March 1983	2613	Tenax GC
March 1983	450	Mol. sieve 5A
August 1983	20	Mol. sieve 5A
Sept. 1983	30	Tenax GC
Sept. 1983	5	Carbosieve S
Sept. 1983	6	Carbo. S/Tenax
October 1983	40	Tenax GC
October 1983	25	Mol. sieve 5A
October 1983	14	Porapak Q
March 1984	78	Carbosphere
August 1984	50	JXC Charcoal
August 1984	50	Chromosorb 106
Sept/Dec 1984	7561	JXC Charcoal
November 1984	100	Chromosorb 106

The material costs of the Adsorba were dependent upon the adsorbent packing used. In April 1983 the cost of producing the organic vapour Adsorba "in-house" was estimated at £3.49 per Adsorba. In August 1984 the costs of producing the Adsorba were reassessed to include not only the material and assembly cost but also included costs for the development and testing of methodologies for adsorption and desorption, for literature and for quality control. The lowest estimates costed manufacture of the Adsorba at £5.28 per tube. The cheapest estimate of the R&D costs of developing a monitor and a methodology was given as £16300. Including all the factors and using the cheapest estimates of the fixed and variable costs gives a cost of £9.20 or £29.50 per tube calculated on production of 10000 and 1000 tubes respectively. Frankly some of the costs included in this estimate were of dubious derivation but they are indicative of the high R&D costs if full method and validation data were to be provided.

6.1.3 The Potential Market

Initially the anticipated market for the Adsorba monitor was considered to be the hospitals market since Dr Thompson had received some enquires from hospitals regarding the monitoring of anaesthetic gases after he had published a paper on the subject. However, when the product was actually launched in Spring 1982 it was aimed at the more general occupational hygiene market. As a reuseable monitor it was initially suggested that the monitor could be leased to users but the emphasis later changed to selling the monitor.

Selling to the occupational hygiene monitoring market the Adsorba had a number of competitor products. Naturally, every manufacturer of a thermal desorption oven also sold thermally desorbable monitors although none of these were sold preassembled like the Adsorba. Besides these thermally desorbable tubes there was a range of solvent desorbable tubes and detector badges on the market. Some of these competitor products are listed in Table 6.2 which shows the retail prices in mid 1983.

Table 6.2 Competitor products with the Adsorba

Manufacturer	Product	Retail Price
Dutom Meditech	Adsorba *1*	£12
Detectawl Ltd	V.A. tube *1*	£6.10
Quantitech Ltd	Century thermal *1* desorption tube	£8
MSA (UK) Ltd	Vapour Guard	£7
3M (UK) Ltd	3500 Organic Vapour Monitor	£4.97
Draeger Scientific	Polymeter tubes	£0.79
DuPont	Protek Badges - GBB - GAA	£8.38 £5.61
SKC Inc	Organic Vapour Badge NIOSH type tube	£1.76 £0.46

Note: *1* Thermally desorbable monitors

Dutom believed that the Adsorba might capture up to 10% of the occupational hygiene personal monitor market because they described the market as being made up as follows:

> "The industrial hygiene market may be defined by the following:
> i) That which can benefit from Adsorba.
> ii) That which requires other devices for monitoring not directly satisfied by Adsorba e.g. formaldehyde, phenol, etc.
> iii) That group which due to the infrequency of tests and budget limitations are unable to use thermal desorption.
> iv) People who dislike thermal desorption as a technique.
>
> Sectors ii)+iii)+iv) represent 90% of the current market potential. The maximum market potential stands at 10%."*(6)*

This figure of 10% is also given in the Coopers & Lybrand report.*(7)* Given these assumptions it is interesting to compare the predicted sales figures for the Adsorba presented in Table 6.3 with the estimates of the market size. In 1981 Dutom had estimated the total US market for NIOSH type monitors to be 20 million monitors annually. Working on the advertized figure of Adsorba being reusable 80 times and capturing 10% of the market gives a US market potential for thermally desorbable monitors of 25000 annually. The US was seen as the dominant market. In December 1983 the OEH General Manager assessed the total UK monitoring market as being worth £900k.*(8)*

When the strategy for the Adsorba was focused on the ethylene oxide monitor, the US distributor estimated the market potential for ethylene oxide monitoring to be worth $40m annually*(9)* and initial sales to be 65000 to 75000 monitors.*(10)* However, the total number of people exposed to ethylene oxide was understood to be 75000.*(11)* If one assumes one in three workers were to be monitored monthly using the reusable Adsorba monitor this evaluates to a market of 30000 monitors over a five year period.

Table 6.3 Predicted sales of Adsorba

Document	Sales Period	Sales nos.	Sales value £
A	1981	7000	175k
	1982	14000	350k
	1983	28000	700k
B	10 mths to Apr 84	8900 *1*	67k
	Apr - Apr 84/5	29400 *1*	234k
	Apr - Apr 85/6	47500 *1*	400k
C	5 mths to Feb 85	20000 *2*	165k

Notes on Table 6.3.
A - Dutom Meditech Ltd Business plan 1981 - 1985, April 1981
B - Coopers & Lybrand, "Financial projections", July 1983
C - Coopers & Lybrand, Report to the Directors, November 1984
1 - Using price of £7.50 per Adsorba as B para 114-5
2 - Based entirely on sales of the ethylene oxide Adsorba

6.1.4 Marketing of the Adsorba

Dutom first advertized Adsorba in the press in the UK and US and displayed it at the Pittsburg Conference of occupational hygienists in Spring 1982. This launch was recognised as being premature since the holder and the Desorba were still incomplete. The follow up sales efforts relied upon Dutom staff and resulted in few sales being generated between May and November 1982.

By November 1982 negotiations were in hand to market Adsorba and Desorba in both the UK and US through distributors. Since Dutom understood the US to represent the major market the performance of their products in that market was of great significance.

The US Distributors

The first US distributor selected by Dutom was Dosimeter Corporation of America (DCA) in Ohio, who were manufacturers of radiological monitors. They were seeking diversification and promised to set up a new industrial hygiene department. They were granted sole distributorship of Dutom products in the US and these products were to be sold under the Dosimeter label.

The initial response of Dosimeter to the Adsorba was very positive despite recognising that users would have to be trained in the technique of thermal desorption.

> "The Adsorba monitor has definite advantages over other available units (also some disadvantages). But as one distributor put it, the users would have to be trained in the advantages of its use."*(12)*

> "One of the biggest advantages of Adsorba is the fact that it is a prepacked column. If the Adsorba tubes can be shown to provide reproducible data over their lifetimes this will be a

tremendous advantage."*(13)*

Thus, Dosimeter began to demand from Dutom technical data regarding the reusability, reproducibility of performance and the degree of variation within a manufactured batch. They also began to request methodologies for the use of Adsorba for capturing and desorbing a wide range of chemicals from permanent gases to high boiling point oils. For each of the chemicals they wanted reassurance of the degree of breakthrough which may occur during sampling, figures for the adsorbative capacity, the desorption efficiency etc.

> "DCA is interested in validation data on Adsorba. DCA emphasised that such data was urgently needed and its absence would undermine the sales potential of Adsorba."*(14)*

The demand for complete and easily digestable information was accentuated because Dosimeter appointed only a sandwich student to handle the Dutom product line. He readily admitted he lacked the technical experience to understand the enquiries of customers, and this resulted in many trivial requests for information being telexed to Dutom.

> "I am not an analytical chemist nor is one of DCA's staff. No Chemical Engineering student will have a good working knowledge of analytical chemistry until he has completed the first quarter of the 4th year. (He was a third year student.) Dutom must give technical support to DCA to provide prompt correct information to customers so that orders may be secured."*(15)*

Two particular difficulties were encountered with Adsorba in the US market. First two patents for thermally desorbable monitors were discovered in the US, one by Boehringer and Lecky, the second by Perkin Elmer. DCA were concerned that the Adsorba infringed the former patent*(16)* and feared liability for legal action. Dutom and the British Technology Group (successors to NRDC) argued that the patents were not infringed because of differences in construction. However, the mode of operation was practically identical.

The second difficulty arose because regulation in the field of occupational health in the US is much more advanced than in the UK and the National Institute for Occupational Safety and Health (NIOSH) publish tested methodologies of monitoring procedures. However, NIOSH had published only one method using thermal desorption and many of their other procedures used a two stage sampling tube and solvent desorption. Customers were reluctant to use non recommended monitoring methods and particularly demanded information on sample breakthrough since the Adsorba is used without a backup section.

As a result Dosimeter sold only 182 Adsorba monitors and in September 1983 Dutom offered to buy back the stock*(17)* and seek a new US distributor. Agreement was reached between the two companies to terminate the Dosimeter US distributorship at the end of December 1983.

In November 1983 Digicolor Inc. also of Ohio, were contracted by Dutom at $5000 per month to evaluate the US market and to prepare to relaunch the Dutom product range in the US in March 1984. The President of this very small independent company had experience of selling the Century Thermal Desorption system. In December 1983 the US stock was transferred from Dosimeter to Digicolor and Digicolor became the US distributor. However, all the US stock was still labelled "Dosimeter" which was later to prove a problem.

The importance which Dutom attributed to this change in the distributorship and the relaunch of Dutom products on the US market was commented on in Chapter 5.

Adsorba and Desorba were again launched to the broad industrial hygiene market but the particular emphasis agreed between Dutom and the distributor was to target the Adsorba at specific chemicals beginning with ethylene oxide. Digicolor supported this change in strategy since it concentrated the marketing of Dutom products on a new market created by a change in the US threshold limit values rather than trying to penetrate the established industrial market.

> "The US market can be divided essentially into two main segments. The service industries segment and the equipment sales segment. Speaking first to the service industries segment it should be noted that the US service segment is already well supplied with numerous contract laboratory organizations providing environmental monitoring services to the industrial market place. Therefore entering this particular vertical market will be significantly more difficult than entering a new vertical market service segment.
>
> In light of that we have concentrated our efforts on the ethylene oxide monitoring market for the hospitals. This is because this particular vertical market segment will not exist until the promulgation of the new set of standards. As a result this is a totally new market to be exploited."*(18)*

This is precisely a return to the initial strategy first proposed in the UK for the Adsorba, with the product aimed at the hospital market with it being returned to the laboratory for analysis and recertification. However, this time the strategy was proposed on a massive scale.

> "AT LAST we have managed to get confirmed from J Pattison (Digicolor) the fact that a lot of the orders are linked in with service facilities direct to Digicolor. On questioning him as to how he could possibly turn round that quantity of tubes within any reasonable period of time he stated that he had every intention of setting up a laboratory with 6 gcs working 7 days on a 24 hour clock."*(19)*

Digicolor previously had no laboratory facilities or expertise until a gc was purchased and installed by Dutom staff. Dutom had apparently agreed to pay for this.

Digicolor developed contacts with the manufacturers of ethylene oxide sterilizers and with other environmental consultants to try to set up a national monitoring service for ethylene oxide. As a result Dutom received an order for 20000 ethylene oxide tubes on 8 October 1984 on a rolling call-off date arrangement with payment by renewable letters of credit. In total Dutom manufactured 7561 ethylene oxide Adsorbas and shipped over 4000 of these to the US prior to 28 November 1984. However, the letters of credit were not regularly reinstated and the order was never completed.

Dutom attributed the reduced demand for the monitor to be a result of Digicolor not carring out rapid analysis of the monitors for the customers, who therefore reverted to using competitors products.

> "He (Digicolor) has been largely to blame for the lack of success of launch of the Adsorba particularly in the hospitals market when involved with monitoring ethylene oxide. It appears that ... he did not report rapidly enough to satisfy customers' requirements, and that many of the customers ... have in fact reverted to the 3M badge, even though the 3M analysis service takes up to 3 weeks to arrive."*(20)*

The distributor agreement between Dutom and Digicolor was, therefore, terminated at Dutom's insistence on 25 March 1985. The Dutom Directors then sought to deplore the appointment of Digicolor as the US distributor.

> "Mr Robson (Managing Director) concluded that Digicolor had been in the outset an extremely bad decision and that the recent letter terminating the arrangements had been entirely appropriate under the circumstances. The Chairman commented that it had been yet another example of the former Managing Director's inability to select the right personnel / organizations for the task at hand. All members present agreed wholeheartedly with this point of view."*(21)*

The European Distributors

In the UK, Dutom had appointed MDA Scientific Ltd as distributors of the Adsorba. They had accepted a stock of 1550 Adsorba monitors in April 1983 and publicized the Adsorba alongside other monitoring products. The Adsorba (largely the organic vapour type) did not sell well and they never approached Dutom for any replacement stocks. Despite the exclusive distributorship verbally offered to MDA, Dutom approached some Scottish companies with a view to them offering the Adsorba to the Scottish oil market. In fact no agreement was ever concluded.

Dutom themselves had attempted to market the Adsorba from its launch in Spring 1982 until MDA were approached in December 1982. At that time they had no staff dedicated to a sales role and sales had been extremely low. They retained the right to market the Adsorba to certain industrial markets even after the MDA distributorship was agreed, and given the poor sales attracted by MDA actively began to try to sell to the UK market after they recruited a sales team at the end of 1983. This was the first time Dutom had sales staff in the field. The sales team, however, tended to attract analytical business for the laboratory and increased the sales of franchised products as opposed to greatly improving sales of Dutom products. The role of the Adsorba in the analysis work performed by Dutom should not be totally disregarded and the laboratory records demonstrate that Adsorba tubes were used in one third of the analyses performed.

On the continent Gelman were appointed as distributors in Italy and distributors were sought without success in a number of other countries. Sales of Adsorbas through these channels were few and the distributors still have stock remaining from their initial orders.

A result of adopting the strategy of using distributors to market the products was the requirement to offer them a margin on the sales. Thus, although the retail price of the organic vapour Adsorba was £12 in July 1983 the return received by Dutom was only £6.98 per Adsorba when calculated on all sales including the distributor stocks made up to that date.(22)

6.1.5 Technical Criticisms

The constant criticism made of the Adsorba was the need for validation data on the performance of the prepacked monitor.

In 1983 Dutom had failed to interest NIOSH in evaluating the organic vapour monitor, and because of the change in adsorbent Dutom had made during the production run Dutom had no experience of the performance of this packing. Enquiries made to Dutom were frequently referred to a paper by Brown and Purnell*(23)* for performance data, but this data was not gathered using the Dutom tubes.

The US market in particular needed reassuring as to the validity and reproducibility of the technique and required information on the adsorbative capacity of the monitor, the breakthrough volume, the reuseability of the monitor, methodologies for collection and desorption etc. It was as a result of such demands for information that my work was redirected to evaluate the performance of the Adsorba monitor. The outline of this technical work developing a complete evaluation system for the Adsorba is described in Appendix E.

The strategic switch to ethylene oxide monitors involved Dutom in totally different validation exercises, and much of this work was performed by David John and is to be described in his thesis. Several types of packing material were investigated before one was found upon which the amount of trapped ethylene oxide did not decay too rapidly.

Work was required to develop the monitor which determined the decay curves of ethylene oxide versus storage time for the various packings and to investigate the performance of the monitor for active and passive sampling. Furthermore the demand for validation data was such that Dutom sent monitors for independent performance trials at the Universities of Virginia and Tulsa before they had even completed their "in-house" development.

Every time it was proposed that the Adsorba be marketed as a means of monitoring for a different pollutant, validation data was requested. Thus, when it was proposed an Adsorba, containing yet another adsorbent packing, could be used to monitor nitrous oxide the request from the US was again for validation data.

> "It is also imperative that we have both product and technical literature by that time."*(24)*

6.2.0 The Desorba Oven

6.2.1 Product Description

The Desorba thermal desorption oven was designed to be complementary to the Adsorba monitor. It consisted of an electrically heated thermostatically controlled aluminium block which was shaped to the contours of the Adsorba monitor.

The unit is reproduced in Figure 6.4 which shows an Adsorba monitor held in place across the handle and supplied by an inert gas line. Raising the handle and pushing it towards the Desorba opens the jaws of the heater block and inserts the Adsorba into the oven. The species released from the Adsorba by heat can then be flushed into an analytical

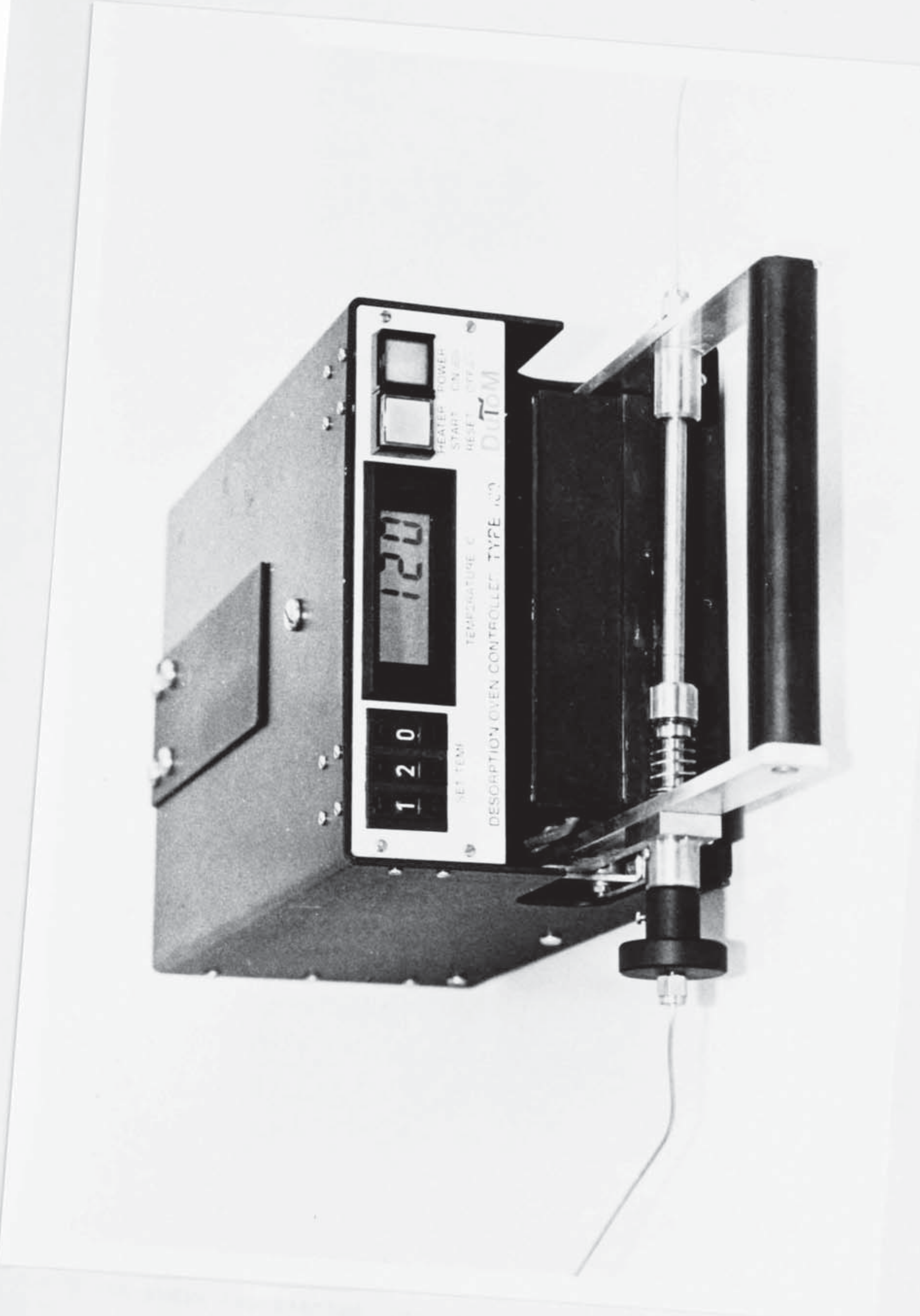


Figure 6.4 Reproduction of the Desorba oven

instrument, typically a gc by passing the gc carrier gas along the gas lines.

Two prototypes were designed, built, refined and tested in the year from October 1981 to October 1982 and these were being used for "in-house" work at the company when I joined.

6.2.2 Production

Unlike the Adsorba which was produced "in-house", production of the Desorba was entirely sub-contracted to J & S Sieger Ltd. Liaison and technical specification work for this manufacture was carried out by the Senior Electronics Engineer at Dutom. A price of £575 per unit was negotiated for production of units by Sieger Ltd provided 150 units were ordered in 1983. On 10th Jan 1983 Dutom therefore placed an order at this agreed price for delivery as follows:

> 10 units urgent delivery before end Feb 83
> 50 units urgent delivery before end March 83
> 90 units urgent delivery as soon as possible*(25)*

This delivery schedule was quicker than J & S Sieger had originally quoted to Dutom, and resulted in some production and quality control problems, but the production schedule was derived to meet the stocking orders for the newly appointed distributors of Dutom products. The Production Director, at J & S Sieger Ltd, later wrote about these units:

> "I have been informed that there were a number of complaints of 'Quality Control' problems with units which were delivered many months ago. ... I must remind you that at that time we were working entirely to instructions from Tony Bryan (Dutom) and that a considerable number of modifications were necessary to make the units work."*(26)*

The 150 units above represented the total number of Dutom Desorbas manufactured. Despite the initial immediate demand for production Dutom neither requested the delivery of all the 150 units in 1983 nor settled their account with the supplier. J & S Sieger finally insisted that Dutom accept receipt of all the order towards the end of 1983.

In all six Dutom staff dealt directly with J & S Sieger Ltd from 1983 to 1984 but the deteriorating relationship between the companies is illustrated by a letter sent from J & S Sieger Ltd to the Dutom OEH Division General Manager:

> "I believe in your telex no 0080 of 16th November 1983 you have deliberately attempted to confuse the facts, in order to cause yet another delay in the settlement of your account."*(27)*

Dutom also acknowledged that the relationship had been stormy:

> "I feel that the relationship between our two companies prior to my appointment has not been ideal. This has been due to a variety of factors including product quality and poor communications which I am attempting to rectify."*(28)*

In terms of the cost of producing the units the price agreed with J & S Sieger was indeed £575 per unit. However, a report by Dutom's auditors made in support of the application under the preproduction order scheme and allocating costs of overheads and R&D work proportionally, estimates the cost to Dutom spread over production of 500 units as £1956 per unit.

> "The total cost estimate ... of £1,956 is in excess of the retail selling price of the equipment. The company's current price list includes the Thermal Desorption Oven at a retail price of £1,800."*(29)*

The preproduction order scheme run by the Department ot Industry is a scheme designed to assist manufacturers launch new products. Under the scheme the DoI pays the manufacturer an agreed price while the user has the product under evaluation. The Desorba was accepted under this scheme and finance allocated for 35 Desorbas at £1053 per unit.

6.2.3 The Potential Market

The Desorba was ready for the European and US markets by April 1983 when distribution to the distributors commenced. Products with which the Desorba had to compete when launched are listed in Table 6.4.

The pioneer thermal desorption units had been the Bendix Flasher and the Century Thermal Desorption system. Several companies began to move into the market concurrent with Dutom and many of the competitive products listed in Table 6.4 were released in late 1982-3. By this time the Bendix Flasher had been withdrawn (they had manufactured only 240 units over six years*(30)*), and the Century Thermal Desorption system was established, but used a flared adsorbent tube contrary to the move towards an industry standard of a straight adsorbent tube of length 3.5 inches (consistent with the Adsorba).

Predictions as to the potential sales volumes are given in Table 6.5. MDA (the UK distributor) had also supplied information which evaluated the UK market demand for an "inferior" oven to be 500 units. In July 1983 they were still estimating sales to the UK market as 50-100 per annum despite having sold only one unit between April and July.*(31)*

MANUFACTURER / PRODUCT FEATURE	DUTOM PLC	PERKIN ELMER	FOXBORO CORP.	NUTECH CORP.	ENVIROCHEM INC.	ANALYTICAL INSTRUMENTS DEVELOPMENT	CALORIMETRIC ANALYTICAL LABORATORY SYSTEMS	E.M.S.	BENDIX (DISCONTD)	CHROMPAK	VACCO
NAME & MODEL	DESORBA 100	ATD 50	CENTURY PTD	MODEL 380	MODEL 810A	MODEL 380	MODEL 823	EMS-FHD	FLASHER	-	-
AUTOMATIC OPERATION	NO	YES	SEMI	SEMI	SEMI	SEMI	SEMI	NO	NO	SEMI	SEMI
MAXIMUM TEMPERATURE IN DEGREES C	250	350	350	300	800	300	700	350	350	300	350
HEATED LINE	OPTL	STD	NO	STD	STD	STD	OPTL	NO	NO	YES	YES
COLD TRAP	NO	YES	NO	YES	NO	YES	NO	NO	NO	YES	YES
INJECTION VALVE	OPTL	STD	STD	STD	STD	STD	STD	OPTL	STD	STD	STD
MULTIPLE INJECTION	NO	NO	YES	NO	YES	NO	NO	YES	NO	NO	NO
TUBES INTER-CHANGABLE	YES	YES	NO	NO	NO	YES	NO	YES	YES	NO	NO
PRICE ($) PRICE (£)	3200 1550	20000 10900	- 3050	3900 -	8000 -	3550 2500	7995 -	- 1220	- -	6500 -	6500 -

Table 6.4 Competitor Products of the Desorba

Table 6.5 Predicted sales of Desorba

Document	Sales period	Sales nos.	Sales value £
A	1983	190	380k
	1984	425	935k
	1985	345	835k
B	1983/4	136	136k
	1984/5	372	372k
	1985/6	543	543k

Notes on Table 6.5.
A - Application to Department of Industry under the preproduction order scheme for financial assistance, October 1982

B - Coopers & Lybrand, "Financial projections", 113, July 1983

6.2.4 Marketing of the Desorba

Desorba was marketed through the same distribution network as the Adsorba monitor, but market evaluation of both the products immediately demonstrated that technical development was not completed in line with the market needs.

Early reports from Dosimeter in the US of 3 March 1983 and 28 July 1983 outlined the technical criticisms made of the Desorba and reported below in section 6.2.5. The Desorba had a number of immediate competitors and when the US distributor first evaluated the Desorba against these competitors in the US market they reported to Dutom as early as March 1983:

> "The bottom line is that the Dutom Desorba unit as presently designed will not be competitive in the US market."*(32)*

The Dutom Desorba was regularly compared to the poorly received Bendix Flasher and was lacking in accessories to enable it to be sold as a complete package. As a result of this the distributor lost confidence in the unit and had sold only one Desorba by the time the distribution arrangement was cancelled in December 1983. All the remaining stock was bought back by Dutom and transferred to Digicolor.

The President of Digicolor had previously acted as an agent for the Century Thermal Desorption Oven and hence had experience of Thermal Desorption Units. The Desorba was marketed largely to the industrial hygiene sector, again using the Pittsburg conference of hygienists as the launch pad for this. From enquiries generated there he estimated a sales of potentially 10-15 units in the year. However, he also commented on the need for accessories for the product to make it acceptable for the American market. These were exactly similar criticisms as Dosimeter had made a year earlier.

> "As far as accessories for the current Desorba system we would again strongly recommend the completion and availability of the multialiquot chamber accessory."*(33)*

He reported that without the additional features which would be provided by the accessories the Desorba had received a "historic poor exposure". Because of this he commented that the strategy of both US distributors had concentrated on the Adsorba tubes:

> "Neither Digicolour nor Dosimeter have promoted the oven (Desorba), but have tended to concentrate on Adsorba tubes."*(34)*

As the strategy continued to move towards providing a service for the ethylene oxide hospitals market he was later to comment as follows about the neglect of marketing of other Dutom products:

> "You must again express to all your staff that they must remember that the primary emphasis has been on the direction and marketing of Adsorba tubes only and only in the field of etyhlene oxide, and that no substantial marketing has transpired with respect to the sale of Desorba units or with respect to active sampling applications of this system ... We would therefore not anticipate significant sales in that area as that is not our marketing direction."*(35)*

i.e. in the absence of the technical accessories to make the product acceptable to the US market the product had been practically abandoned by both US distributors.

European distributors

In the UK, MDA Scientific Ltd had been appointed as sole distributors except for certain account areas retained by Dutom. MDA had purchased 50 Desorbas in April 1983 as initial stock but sales were extremely poor and they had placed only two Desorbas by the year end. A result of the weak sales achieved by MDA and the need to increase the turnover of the products was that Dutom appointed their own sales team towards the end of 1983 and again began to market the products. However, the lack of marketing support this team received was graphically illustrated when I accompanied a sales representative on a follow up visit regarding the Desorba. Upon discovering the reason for our visit the client declared:

> "Oh that! I sent the enquiry in so long ago I had forgotten all about it."

The result of the efforts of the sales team was to place two Desorbas at universities for evaluation, one of which was purchased.

Gelman Spa in Italy had been appointed as distributors at the same time as Dosimeter in the US. Their experience with Desorba seems to have been very similar to the US experience. By November 1983 they were seeking to return seven of the ten units they had originally bought. They had only sold one Desorba and had two on trial at universities,*(36)* they reported that the company had undergone numerous internal reorganizations and hence had not succeeded in promoting the product.

An interesting if trivial feature of this distributorship is that although Dutom declined to accept the return of the Desorbas from Gelman they did accept payment for five of them "in kind" in the form of a dust particle gauge. This instrument then sat idle at Dutom until the company was closed.

During 1984 a French distributor was sought and two units were sent to France for evaluation. Distributors were also sought in Germany, Belgium and Scandinavia but despite negotiations with companies in all these countries no agreements were reached. The net result was that approximately ten Desorbas were sold-on to customers in Europe before Dutom closed.

As regards pricing policy the Desorba had been launched on the UK market at £1800 and in the US at $4500. In the face of the competition it was recognised that these prices were not competitive and they were subsequently reduced to £1550 and $3200 respectively. As with the Adsorba these did not represent the returns to Dutom due to the distributors margins. Dutom supplied the distributors at £1029 and £950 per unit in the UK and US respectively.*(37)*

6.2.5 Technical Criticisms

Particular technical criticisms of the Desorba were received from potential customers in the US and these were related to Dutom by the US distributors.

The unit was recommended for use only up to 200°C and this was considered a limitation if high boiling compounds were to be analysed. In fact Dutom had decided to increase the operating temperature to 250°C as early as August 1982 but because they had not updated the user manuals the Desorba was still being advertized in 1984 as limited to 200°C.

For the analysis of high boiling compounds a heated line accessory was considered as a prerequisite for good thermal desorption. Dutom produced a prototype for use in their laboratory but none were ever sold.

The Desorba was a single stage thermal desorption unit in which all the sample was flushed directly from the Adsorba into the analytical instrument. Two criticisms of this were made:

Firstly, all the sample is used at once. Some analysts prefer a facility to allow replicate analysis in case the first attempt proves unsatisfactory. Some of the competitors, therefore, developed a multi aliquot device for the thermal desorption units. This simply consisted of desorption into a gas reservoir which could then be repeatedly sampled.

Secondly, for good resolution in gc analysis it is preferable to inject the sample over the shortest possible time period in the smallest possible volume. With the Desorba the desorbed species had to be flushed the length of the Adsorba (which acted as additional column length) before they entered the gc column itself, this can lead to poor resolution. Some competitors, therefore, inserted a "cold trap" between the desorption oven and the gc. This reconcentrates the desorbed species and allows lower desorption temperatures to be used, which may be important if thermally unstable compounds are being analysed.

The Desorba as supplied was also incomplete. It required a four port gas sampling valve correctly connected to the gc in order to be operative. This was not integral to the unit and had to be purchased separately from another supplier.

The above criticisms were drawn to the attention of the Dutom management not just by the US distributors but similar comments were also received from a UK market survey and from a shareholder.

> "Adsorba and Desorba: Prospects are poor largely due to the customer requirement for two stage desorption."*(38)*

> "After several discussions with Mr H Newton-Mason (Shareholder) it was his considered conclusion that Adsorba and Desorba, in particular, were negative products and in his opinion really gave no opportunity whatsoever to provide revenue for the company."*(39)*

Considering the extent and source of criticism Dutom were remarkably sluggish to make any response. In July 1984, some twenty months after the Desorba had been launched the Board noted:

> "The Desorba needs to have a cold trap and heated line as accessories, particularly for export markets; without these very few units are likely to be sold from the distributors' stocks or from Dutom. This problem has been known in R&D for over twelve months."*(40)*

Dutom eventually responded and commenced development work on the required accessories. The heated line was designed but only the prototype was ever built. Work on a mulitaliquot device was begun in August 1984, but it remained incomplete when the company closed. The cold trap was investigated and some components purchased, however, no Dutom prototype was ever built. Thorn-EMI purchased the technology of all these products after Dutom closed but they have informed their distributors that the cold trap would not be available until September 1986 and the multialiquot unit until the year end (1986).

6.3.0 Project Evaluation

Adsorba and Desorba were intended to be complementary products in that chemical analysis cannot be performed without the user possessing equipment to perform each of the functions. As such one expects the market acceptance of the products to demonstrate a synergistic effect be that for good or ill. The two products were marketed through the same channels and to similar markets and hence are treated together here.

6.3.1 Technical Implications

Neither product was new to the world although the technique of thermal desorption was still at the forefront of technological progress. Since each product had predecessors some experience was available from the users of the pioneer products.

The Adsorba, as a prepacked reuseable monitor, was technically more sophisticated than many of its competitors. Its thermally desorbable nature differentiated it from the cheaper solvent desorbable badges and tubes, but it was also complete when compared with most of the competitor thermally desorbable tubes which came unpacked. This should have made it more acceptable to the untrained user who had no access to laboratory facilities. However, supplying the monitor prepacked moved the responsibility for the performance of the monitor from the jurisdiction of the user to the manufacturer, hence the need to reassure users with validation data.

In contrast the Desorba was less sophisticated than many of the competitors since it was supplied without a number of accessories which could have extended its applicability and performance. Further, Desorba was not automated and hence was less suitable for bulk analyses of similarly contaminated monitors compared to its competitors. Viewed against the competition like this the two products were less complementary than might have been originally thought and neither were fully developed.

The importance of the products having a full range of functions and good sevice support was clearly illustrated to me when I applied for a job. The company had just purchased a Perkin Elmer ATD50 thermal desorption unit and adsorbent monitors. They readily admitted the instrument would be under-used but they had bought it because of the completeness of facilities, information and service from a single source of supply. The ATD50 was launched concurrently with the Desorba and Perkin Elmer were known to have sold over 125 of these units in the UK prior to December 1984. The absence of assessories for Desorba and validation data for Adsorba was seen therefore as highly detrimental to sales.

6.3.2 Marketing Implications

Dutom was a new company founded upon technological advances made in academia and the staff had a lack of market contact and experience. The repeated preference for the hospitals market may have been due to the fact that Dr Thompson had some experience in that field. Generally the management underestimated the efforts required to market a new product and showed a limited understanding of the nature of the market and its needs. This is illustrated in a number of ways when one examines the elements of the marketing strategy, and was admitted by the OEH General Manager:

> "Currently our knowledge of the markets we serve is totally inadequate."*(41)*

The management made no attempt to segment the industrial market except upon the broadest industry classifications. The only report which examined a particular industry by size with regard to the market potential for Dutom products was made by the researcher. Those selling the products were poorly supported by marketing and administration as evidenced by the lack of a product brochure, the long lead time before enquires were passed on and the demands for more support from all the distributors. Instead of segmenting the market to identify specific needs at which the limited resources of the company could be directed the products were promoted generally and sales representatives were encouraged to make cold calls on an area rather than industry basis.

In selecting the markets for the products and the means of selling into them the Dutom management chose to distance themselves yet further from the potential users. The strategy to sell products on a worldwide basis with the main emphasis on the US required Dutom to compete in a foreign market which was recognised as different in character from the UK. Long communication lines were created to the market and the distributors themselves and good communications with the distributors was not achieved. Thus a shareholder commented:

> "Some of the criticisms from Dosimeter were reasonable particularly as the communications from Dutom had not been good."*(42)*

Regarding the choice of distributors, Dosimeter had a wide distribution network but lacked technical expertise to sell the products on a general market and successfully bridge the technical/marketing interface that Dutom had neglected. Digicolor had technical experience of the types of products but no analytical facilities or experience. Yet when they assumed the role of distributor the strategy adopted was to base new market penetration upon an analytical service facility. This represents a poor matching of the appropriate strategy to the capabilities of the distributors.

6.3.3 Financial Implications

The accounting policy of righting off R&D costs as they were incurred may have caused the management to underestimate the costs of this function. Certainly on the occasions when estimates of the R&D costs were included in the unit costs of Adsorba and Desorba they indicated the high cost of this function to the company.

The anticipated margins on these products were reduced for three reasons. Firstly, the products were found to be uncompetitive at the intended retail price, secondly the strategy of using distributors cut the margins to Dutom and thirdly rushed production schedules incurred additional costs. The use of distributors was probably the greatest single factor here especially since Dutom tended to incur cost from distributors without realising cash return; e.g. Dutom bought back stock from Dosimeter which had been labelled with the Dosimeter logo at Dutom's expense, Dutom paid consultancy and expenses to Digicolor, and accepted payment for goods "in kind" from Gelman.

The company had intended to breakeven by April 1984, but in the ten months to April 1984 they had allowed overheads to increase substantially. Against this expenditure the only source of income for the company was provided by the OEH division in which Adsorba and Desorba were the principal products. If one assumes that the OEH income should not cover the losses predicted for the Biochemistry division, then the breakeven point for the company corresponded to sales, in the ten months to April 1984, of 43 Desorba units and 2000 Adsorbas per month. These figures are in excess of the opimistic estimates of the potential market made by the Dutom management and hence indicate that financial control was inadequately coupled with the other business functions. The situation which developed, in which the company failed to break into the market with these products let alone achieve this breakeven volume resulted in a loss over the ten months to April 1984 of £916000.

CHAPTER 7

SOME INCOMPLETE PRODUCT INNOVATIONS

"Until recently there was no satisfactory way of monitoring for formaldehyde in such complex mixtures. Now using an appropriate powder, we can selectively trap this chemical in the Adsorba monitor and recovery and subsequent analysis is very reliable."

Dutom Meditech Ltd Business Plan, 1981

"Id quod neque est neque fuit neque futurum est."

Plautus, 553

OUTLINE

This chapter introduces a series of diverse product innovation attempts made by Dutom: in computer products, formaldehyde monitoring and a sophisticated miniature gas chromatograph. Despite their apparently unrelated nature all three projects described here were intended to complement the Dutom range of occupational hygiene products. The second feature they have in common is that none of the projects realised a marketable product for the company. Together with the Adsorba and Desorba they represent the product innovations attempted by Dutom in the mainstream of its business.

For the purpose of this thesis the amount of technical reporting has been kept to a minimum, although I have allowed myself to include a brief technical report of the experimental work carried out on the formaldehyde monitor in Appendix F, since Dutom originally approached IHD with a project for new product development of a formaldehyde monitor. It was envisaged at the time that this aspect would form the major part of the thesis.

7.1.0 Computer Products

7.1.1 Reasons for New Product Development

At the conception of the company the fields of microprocessors and computer software were seen as areas of high technology which Dutom wished to embrace as a new generation company. A specific Systems Group was formed to develop this technology and the group was envisaged as having two functions, both of which were intended to be complementary to the thrust of the company into the occupational hygiene products market. These functions were:

1. Product development of the microprocessors component of sophisticated detection devices.

2. Software development for record keeping.*(1)*

7.1.2 Resource Commitment

Dr Henry was appointed as Systems Group Manager early in the life of the company, April 1981. At this time he was already working on computerised information systems for GPs. By the time the company premises were opened in October 1981 the staff of the Systems Group had increased to five thereby representing the largest project group in the company. All the staff were technical staff, the group itself employed no-one in a sales or marketing post. Customer enquiries, and therefore potential sales for the group and the company as a whole, were handled by the Office Administration Manager. This office based post allowed little opportunity for customer contact or liaison. The structure of the group is illustrated on the organizational chart. Figure 5.3.

At the end of December 1981, Dr Henry left the company and this left the

Systems Group without a leader. The expertise and ideas on software for information packages had been brought to Dutom by Dr Henry and now left with him. (They had not been developed as a Dutom product at this stage.) Dutom was, therefore, left with a limited product line, restricted expertise and without the product champion for the Systems Group.

The end of May 1982 saw the complete disassembling of the group. It had functioned without a manager for five months and was in disarray. It had encountered technical difficulties with the hardware it was using, and had no sales force to show a return on software, hardware or media products. The two systems analysts left the company at the end of May, the General Manager who had dealt with much of the negotiation, was moved to Luton to a post with another of the Dutton group of companies. At a meeting of the staff on 27 May 1982, it was announced that there would be:

> "No pure in house 'Systems Group' .... systems are for use by the other groups in whatever way is most practical."

7.1.3 The BASF Product Lines

Contact had been established with BASF (UK) Ltd in July 1981 and BASF, at a meeting in August, were given to believe Dutom had under review: information systems for GP's, dentists, occupational health records, an educational system and a graphics package.*(2)* Dutom therefore applied for a dealership selling BASF products as franchised products and developing software on the BASF machines for occupational hygiene records. BASF set out their dealership terms namely:

> *BASF advertize the computer hardware and pass on contacts to the local dealer.
> *BASF supply full engineering support and BASIC software support.

*Software packages advertized by the dealer and demonstrated as working are either distributed to all dealers for sale, or a one off payment is made and the package is sold as integral to the BASF system.
The dealership margin on the computer hardware is 20%-30%.(3)*

BASF supplied brochures and salesman training support. Dealers were expected to turn over their stock of media products (£5000-£20000) in a period of four to six weeks.

Dutom formally asked for approval as BASF dealers, in letters of 8 September 1981.*(4)* This was for dealership of the 7100 series microcomputer. Sales were to be achieved using existing Dutom personnel and substantial resources were to be dedicated to developing software products. Regarding media products, the estimated Dutom turnover was put at 1000 floppy disks per two months.*(5)* Under the terms of the dealership BASF offered to Dutom three computers to enable them to begin software development. Prices on all three machines were agreed although two were received on reviewable three month loans.

Dutom acknowledged the BASF letter on 9 December 1981, however, in the interim BASF had announced increased prices on their hardware, allegedly despite assurances given verbally that no price increases would be announced until the dealers had been consulted.

Hardware

The increase in prices of the computer hardware soured relationships between Dutom and BASF. BASF had promised delivery of a 7120 computer in January and a 7130 computer in March. The problems with the availability of CP/M for the system, which Dutom had been aware of for some time, were promised to be ironed out and CP/M made available during April 1982. Dutom actually received the first BASF computer on 8

February 1982. The Dutom staff found that because the CP/M system had not been developed the machine was difficult to use and technical support from BASF was poor.

Dutom found a further point of grievance with BASF by believing that another product dealer had been appointed in the locality, namely Spa Software Ltd in Leamington Spa. In fact Spa Software were simply working on software development.

BASF provided detailed publicity material for the hardware as promised, but Dutom had neither sales staff, nor an extensive established customer contact list. It is no surprise that Dutom actually sold no computer hardware. Dutom renounced the hardware distributorship on 14 September 1982. This was after BASF had issued a final reminder for non payment of the outstanding account prior to commencing legal action.

Software

As mentioned above, the resignation of Dr Henry left Dutom without both the originator and product champion for the information systems software. Problems with the hardware were not resolved until 23 March 1982, and the effect of these two factors was that little progress was made with software development and certainly no saleable package was ever completed.

Media products

Confusion existed between Dutom and BASF regarding the price quoted for media products, namely floppy disks, at which BASF would supply Dutom. This position seems to have been exasperated by a confusion by BASF as to whether Dutom were to be treated as a Birmingham based customer or a

Luton based customer since they had different sales representatives for the two areas. Problems first arose when Dutom queried an invoice dated 30 April 1982 for a total of £1614.60 for media products.*(6)* The amount in question being £312.23. The difficulties encountered over fixing a price for the products hampered Dutom at this time in closing a potential deal for these products. Sales of media products by Dutom were further hindered by Dutom's organizational structure. Sales were being co-ordinated by the Office Administration Manager. Such a diversity of function resulted in weak sales activity and opportunities for the sales of media products being lost.

The total expenditure by Dutom on media products was £3711.55 and the total sales of floppy disks brought in revenue of £3389.71 over an 11 month period to September 1982. This approximates to a turnover of 440 disks per two month period. However, it is important to note that these sales were mainly made to Local Government and not to the medical/hygiene market which Dutom had been conceived to serve.

The financial dispute

Dutom placed a hold on all payment of BASF invoices on 6 July 1982 because of a disputed invoice. Additional invoices for a computer and media products made the total outstanding to BASF, in July 1982, £8523.80 (less the disputed amount) which represented the total for all goods Dutom had received from BASF. The disagreement over the queried invoice was never resolved and BASF finally sued Dutom to obtain payment. Dutom were taken to court and lost.

Following the ruling, Dutom paid the outstanding invoices by three post dated cheques amounting to £8213.80. Following payment, BASF filed a claim for the interest accrued on the sum outstanding. The final memo on the matter is dated 1 July 1983*(7)* which is almost exactly two years after the initial contacts were made.

7.1.4 Autoplot

Autoplot was a graphics package developed by Dutom for CP/M machines. Development work was carried out particularly on the Superbrain computer, which had no screen graphics facility. Unlike the information systems work this product outlived the life of the Systems Group. The graphics facility was considered to be an important add-on feature to a number of devices which Dutom considered they would develop in due time i.e. the mini gc, the lung function analyser etc. These products are outlined in the Dutom Business Plan 1981.*(8)*

Development work commenced in December 1981 and a package written in BASIC was complete by early 1982. However, the graphical information could not be stored and the package was redeveloped in FORTRAN between February and April 1982. The package enabled numerical information to be reproduced in graphs, tables, pie and bar charts.

Marketing of this package was envisaged as being carried out by a computer dealer and Jaemma, the suppliers of the Superbrain were approached. Their response was initially favourable and they requested a copy for trial purposes and to gain experience of the package. However, the Dutom General Manager negotiating the deal feared for the security of the development. Dutom had no patent on the software and software is relatively easy to copy. He therefore pressed for payment for the package, valued at £25000 by Dutom, before allowing Jaemma to receive a copy. Jaemma declined to pay this for a package they had no experience with. They never received a copy for evaluation purposes and interest waned. Dutom with no sales outlets themselves were unable to market the package and no copies were ever sold. Meanwhile the computer graphics market was developing rapidly and new micros have since been launched with good on screen and printout graphics packages.

7.1.5 Project Evaluation

The innovations attempted with regard to computer products have been reported at length because in one short-lived product division they offer a microcosm of Dutom Meditech Ltd. A number of problems can be identified and the company as a whole could have learned much from the product innovation failures of the Systems Group.

Finance

The importance of the existence of this group should not be underestimated with regard to the ability of the company to raise finance. The company was selling itself to the financial institutions as a New Technology Based Firm, and was able to claim expertise and the ability for product development in the fields of microelectronics and computer software. The existence in the company of a Systems Group was an important asset in the applications made by Dutom for venture capital: i.e. the Small Business Start-Up Loan - £50k, the Government Guaranteed Loan - £75k, the bank Medium Term Loan - £40k, and the finance raised through the microprocessor application project (MAP) submitted to the Department of Industry (see 7.3.0).

In terms of the expenditure versus return generated by the projects, expenditure was vastly out of proportion with revenue. The only source of income was generated by media sales raising £3390 but expenditure on media products alone accounted for £3711. High overheads were incurred on salaries for the five staff (plus the time devoted to the computer products by other Dutom staff). Over the twelve months of the group's existence salaries alone amounted to £25000 but no return was received from products brought to the market.

Capital was invested in equipment specifically for the innovations in this field, when the projects were terminated this equipment stood idle offering no return on the investments. A willingness to incur debts with major suppliers is also apparent from the dispute with BASF. Wherever the blame lies for the onset of this dispute, poor relationships with a major supplier are highly detrimental to the fortunes of a small business. Furthermore the poor reputation and lack of credit worthiness of Dutom engendered by the dispute is against the interests of a company trying to establish itself in a consultancy business, where reputation and credibility are of the utmost importance.

Product development

Dutom demonstrated an overconfidence in their ability to carry out technical development believing they could succeed where others failed. Dutom were made aware, at an early stage, of some of the limitations of the BASF hardware and absence of a fully operational CP/M system. This did not deter them from selecting this hardware.

In retrospect, the hardware can be seen to have been a poor choice, but by no means all the blame for this rests with Dutom. The machine had technical difficulties inherent in it and the manufacturer offered poor technical support. Other software houses report that they failed to write or sell software for the system and that their loaned machines still lie idle. BASF themselves have since left the market altogether.

The products selected for development, originated within the company rather than from market demand. Technical screening of the products when related to the fast moving computer market seems weak. Commercial screening regarding feedback from the market was severely hampered because Dutom had no commercial interface.

Management

The loss of the Systems Group Manager in December 1981 had effects both on the organization and success of the group, since he represented the innovator and product champion of the software development. Nevertheless prior to his departure and possibly contributing to it, a number of management features can be noted.

Lines of authority and responsibility were badly defined, resulting in poor delineation of authority and tasks. The anomalous position of the General Manager, sandwiched in authority between the Technical Director and the Group Manager, was commented on earlier. Both the General Manager and Technical Director neither of whom had any computing expertise were drawn into technical meetings, where they were unsuccessful in evaluating the commercial value of the projects. The result of this apparently was not to give the flexibility renowned as advantageous to small firms but instead to have led to contradictory decisions being made.

The administration in the company was demonstrably poor regarding the management of these product lines. Despite the difficulties that BASF may have caused Dutom by confusion over area representatives etc, accurate keeping of records, minutes and prompt and clear letters should have rapidly overcome the confusions that arose over prices. Again this may be due to many people being involved in negotiation with unclear dividing lines of authority.

Marketing

There was no concept in the company either of a marketing role or the personnel to perform a sales function with regard to these products. The tasks in these areas were grossly underestimated when Dutom offered to act as a dealer to market hardware, software and media products. Furthermore the market to which Dutom actually sold some computer products bore very little relation to the market the company strategy aimed to serve.

Table 7.1 The BASF Dealership - A summary of the significant dates.

17.7.81	Contact established by Dr Henry (Dutom). It is agreed that without the CP/M available software can be written for the machine.
21.7.81	BASF understand Dutom interested in writing software.
8.9.81	Dutom confirm they wish to have dealership for 7100 series computers, floppy disks and software.
15.9.81	BASF acknowledge Dutom's request.
7.10.81	BASF set out terms of the dealership.
4.12.81	BASF notify of price increases on 7100 series.
9.12.81	Dutom agree to terms of BASF dealership as set out on 7.10.81
15.12.81	BASF acknowledge Dutom letter and state delivery dates for computers as January and March 1982 with CP/M available April 1982.
31.12.81	Dr D Henry leaves Dutom.

8.2.82	Dutom receive first computer.
30.4.82	Dutom are invoiced for computer and some media products (disks).
12.5.82	Dutom dispute prices for disks and invoice for computer.
31.5.82	2 Systems Analysts leave Dutom. General Manager moved to a "group" position. The end of the Systems Group.
12.8.82	BASF request payment of outstanding balance £8523.80. Dutom claim to have overpaid £312.23 for disks.
1.9.82	BASF issue final reminder before commencing legal action.
14.9.82	Dutom terminate 7100 series sales agreement and ask for price clarification on disk prices. Issue a complaint regarding other distributor in the area.
22.9.82	BASF issue writ against Dutom for £8213.80
11.10.82	BASF solicitors inform Dutom of intention to proceed to judgement.
20.12.82	Dutom decide not to pursue counter claim regarding loss of sales, judgement is made against Dutom.
18.1.83	BASF solicitors inform Dutom they will accept payment by 3 post dated cheques.
7.2.83	3 post dated cheques issued by Dutom 8.2.83 £3000 31.3.83 £3000 30.4.83 £2213.80
3.3.83	BASF request outstanding £310.
9.3.83	Dutom solicitors explain this is due to overpayment for disks from previous price changes.
27.4.83	BASF issue Affadavit for interest on money owed £185.19 plus costs.
9.5.83	Solicitor advises it is cheaper to settle than to contest.
1.7.83	Internal memo says the matter is finally closed.

7.2.0 New Product Development - Formaldehyde Monitor

7.2.1 The Reasons for New Product Development

Fashions in occupational hygiene come and go as in most other fields. During 1981-3, a high level of interest was expressed in formaldehyde, to the extent that in 1983 the British Occupational Hygiene Society held a full day symposium on the compound. Formaldehyde is an odorous, lacrymatory and physiologically active compound. Topical interest was stirred because of two factors. American studies had established that the compound was mutagenic and carcinogenic in rats. Over a corresponding period, formaldehyde based foams had been used for home insulation and some complaints of irritation and nausea had arisen after home insulation treatment. This highlighted the exposure of the public to a potential carcinogen.

A number of reviews of the toxicity of formaldehyde were published*(9),(10),(11)* and these were followed by a series of epidemiological studies.*(12),(13)* In the interim a number of papers were published on the detection of formaldehyde. e.g. in houses.*(14),(15)* A trend towards lower threshold limits values had also been followed in some countries see Table 7.2.

Table 7.2 Some International Threshold Limit Values

Country	Date	Type of limit	limit mg/m^3
USA	1961	Time weighted average *1*	6
	1973	Time weighted average *1*	3
	1976	Time weighted average *2* recommended	1.2
Sweden	1979	Ceiling	1.2
	1980	Proposed limits for new plants	0.6
Denmark	1979	Time weighted average	1.2
	1983	Proposed limit	0.4

1 American Conference of Goverment Industrial Hygienists
2 National Institute for Occupational Safety and Health (NIOSH)

7.2.2 The Product Specification

In this climate, the Dutom management in 1982, proposed the need for a new type of sensitive formaldehyde monitor. They evisaged the development of a monitor comparable to their other "in-house" products, namely a solid trap which is then thermally desorbable. This was the new product development project proposal originally put to IHD, in July 1982. The very suggestion of such a project makes a nonsense of the claim made in the 1981 Business Plan that Dutom already had such a product. In fact the concept they had for a formaldehyde monitor was no more than a cursory scientific idea.

Given the objective of a thermally desorbable formaldehyde monitor, two problems were identified at the onset. First, the problem of capturing the formaldehyde. Formaldehyde is a reactive gaseous substance and is not stable on some solid sorbents (e.g. on alumina the collection period is limited to 30 minutes). Second, is a problem of detection. The company's preferred analytical technique was to use thermal desorption followed by gas chromatography (gc). The widely used flame ionisation detector (f.i.d.) is not very sensitive to formaldehyde. Also the Research Manager at Dutom believed poor column performance and detector damage resulted when formaldehyde was introduced into the gc. These conditions mean that the formaldehyde monitor must be substantially different from the other Adsorba monitors since the formaldehyde must chemically react on the monitor to fulfill the above criteria.

The resulting scientific constraints for the monitor as set by the management are laid out in Table 7.3. This was presented to the supervisors and to the IHD Research Senate Committee.

Table 7.3 The scientific criteria for a thermally desorbable formaldehyde monitor.

Physisorption is the adsorption of molecules to a surface without the formation of chemical bonds, and this is the mechanism by which the Dutom Adsorba Monitor traps molecules. For formaldehyde monitoring physisorption was not suitable because of:

a) The instability of formaldehyde on a solid sorbent,
b) The requirement that free formaldehyde was not introduced to the gc

Chemisorption is a chemical bonding of the adsorbed molecule to the surface either to a reagent coated onto a solid support or to the surface of the support itself. For a formaldehyde chemisorbed monitor a reaction was sought such that the reagent, derivative and solid sorbent have the following specific characteristics.

The surface coating reagent must:

a) Be readily available
b) Be chemically stable on a solid sorbent at temperatures up to 200^{o}C
c) Be non volatile below the desorption temperature
d) React with formaldehyde at room temperature, on a solid sorbent
e) React to yield one product in quantative yield over a wide concentration range
f) React selectively with aliphatic aldehydes
g) Be inert to probable interfering agents
h) Trap all formaldehyde present, i.e. have a low breakthrough volume, over a wide range of flow rates.

The derivative is the chemical species formed by the reaction of formaldehyde with the reagent, for a thermally desorbable monitor this must:

a) Be physically stable on a solid sorbent at working temperatures for a long period.
b) Chemically stable on a solid sorbent
c) Inert to interfering agents
d) Chemically stable at elevated temperatures
e) Volatile at elevated temperature, with a desorption temperature lower than that of a reagent
f) Separable from other carbonyl derivatives by gc
g) Non corrosive to the column detector
h) Detectable by f.i.d., yielding a sharp peak
i) Detectable over a wide linear range with good reproducibility.

The solid sorbent is the static medium of the monitor onto which the reagent is coated. This must have the following properties:

a) It is thermally stable
b) It may catalyse the reaction but not alternative reactions
c) It does not trap other reagents
d) It may easily be coated with the selected reagent.

7.2.3 A Literature Review

Having identified the problem set, an extensive literature review was undertaken, of the means to capture and detect formaldehyde. This formed the basis of a review paper published in Talanta, (See Appendix B) and the reader is referred to this for the literature review.

Developments since the paper was written include the addition of some further spectrophotometric methods to the list.*(16),(17)* One of which has led to the development of a solid sorbent monitor, giving an "on-site" reading when the exposed monitor is washed with an acetone-water solvent and compared to a standard chart.*(18)*

Comparisons of the effect of interferences of common spectrophotometric methods have been made*(19),(20)* and a number of commercial badge monitors evaluated, most of which show poor reproducibility.*(21)* The insensitivity of the flame ionization detector (f.i.d.) to formaldehyde was noted during these studies. Following the failure of the ion chromatographic method because of collection by a solid sorbent, an impinger has now been proposed,*(22)* and a laser based analytical device has been patented.*(23)*

The literature study established that there were few routes open for a thermally desorbable formaldehyde monitor. Two reactions were selected for further study.

7.2.4 Technical Aspects

Xylene reaction

A reaction with xylene in the presence of sulphuric acid forms the basis of detector tube monitor. This was the reaction which the Technical Director and Research Manager at Dutom considered suitable for a formaldehyde monitor. They claimed that, if xylene on a sorbent was first exposed to formaldehyde and then sulphuric acid was added, a dark colour appeared. However, if xylene on a sorbent was exposed to formaldehyde and then the sorbent was heated (thermally desorbed) prior to acid addition, no dark colour formed. These cursory observations formed the basis of the company believing a thermally desorbable formaldehyde monitor was feasible. I found no documentation of any experiments of this work nor any record of further development work. The reaction was therefore investigated and a brief description of the experimental work and its findings is to be found in Appendix F.

Analysis of the mechanism and products of the reaction of formaldehyde with xylene demonstrated that the reaction had no potential whatsoever for the development of a thermally desorbable monitor.

Propane-1,3-dithiol reaction

From a study of aldehyde reactions I proposed that propane-1,3-dithiol may react to trap formaldehyde on a monitor since it is used in synthesis as a protecting agent for the carbonyl group.*(24)* If the cyclic reaction product was formed on the monitor this would probably be thermally desorbable and very easily detected using a flame photometric detector. The reaction was investigated and again the experimental work is briefly reported in Appendix F. The conclusion to these experiments was that the proposed reaction does not occur under the conditions imposed by a solid state monitor. This reaction is therefore not suitable as the basis for a thermally desorbable monitor.

The research demonstrated that neither reaction was suitable for a thermally desorbable formaldehyde monitor and that the development of such a monitor according to the specification outlined above is technically unfeasible.

7.2.5 The Market Interest

Throughout the duration of the study only four commercial orders for formaldehyde analysis were received, although some "in-house" work was generated during an epidemiological study. The total value of these orders amounted to less than £500, which does not justify the resources spent on product development.

In the interim, epidemiological studies had failed to establish a clear connection with human cancer. Furthermore the government had advised the public that formaldehyde was not a dangerous substance.*(25)* The National Health Service, a large user of formalin and a place where histology technicians may be exposed to high doses of formaldehyde, was under severe financial pressure from the government. The iron and steel industry, where formaldehyde based resin is used as a binder in sand, was in recession and a number of local foundaries closed. e.g. Round Oak steel works. The market for bulk formaldehyde monitoring was therefore depressed. Enquiries made in October 1985 of competitors' products demonstrated this weak market for formaldehyde monitors. 3M, makers of a formaldehyde badge, had discontinued the badge in April 1984 because of poor demand. Shaw City, who market the DuPont badge, reported that the demand was so poor they had cut back on stocks and increased the prices for the badges to £259 for a pack of 10.

Prior to commencing new product development Dutom already held a distributorship agreement to market the SKC formaldehyde tube, and a licence to analyse these tubes. This tube retailed in 1982 at £2.75 and was analysed by a relatively well established colourimetric technique. Dutom had a 30% discount agreement on this product.

7.2.6 Project Evaluation

At the technical level the constraints of a solid sorbent, thermally desorbable, laboratory (gc) analysed detector tube were proved unfeasible. With regard to the market, interest in the product was very weak and declined rapidly after the product was initially proposed. This was compounded by a serious lack of purchasing power in some market sectors where formaldehyde products were used.

Given the technical difficulties and uncertain market response to a formaldehyde monitor, the project should never have passed the preliminary screening stage. There was a weak demand for analysis of this compound, insufficient to fund product development work. This was either not understood because of the inadequacy of marketing information available within Dutom or it was incorrectly believed that the new product could overcome it. If the company believed that the development of the new and more expensive style of monitor would generate the market demand then they were deceived by "the myth of the better mousetrap".*(26)* Dutom already had a cheap and reliable product on the market, offering a reasonable rate of return. Successful new product development would have undermined sales of this product, which is "product cannibalism".*(27)*

The exercise demonstrates poor screening of new product development and the inadequacy of market research at a preliminary stage of project initiation. The product development strategy adopted is more characteristic of academic problem solving rather than business management on two counts. Firstly, the innovative process appears to have been viewed as complete when a new product idea rather than a physical entity had been arrived at, since the company were prepared to announce the existence of the innovation when they had derived only an idea. Secondly, the importance of the new product appears to be derived more from the interest expressed by academia than by the marketability of the product. The rate of return required of a new product was also clearly never understood.

Screening of the project according to technical, marketing, financial or business criteria should have rejected the project. Instead resources could have been more fruitfully invested in other areas at this vital stage in the company's history.

7.3.0 The mini gc (MAP project)

7.3.1 The Product Specification

This research project, referred to as the mini gas chromatograph (gc), the MAP project or project Ester, lasted the lifetime of the company without ever producing a product for the market.

A portable mini gc suitable for "on-site" analysis was reported as a product development opportunity in the Dutom Business Plan document of 1981. Dutom committed themselves to developing this product in an application made to the Department of Industry in 1981 under the microprocessor applications programme (MAP).

The idea was for a portable gc which could provide on the spot analyses for a flexible range of chemicals. The instrument should automatically sample and analyse the ambient air. Controlled by a microprocessor, the unit was to have the facility to print out the concentrations of the chemicals detected on both a display and a chart, to record the data and to sound an alarm if certain preset concentrations were exceeded. The unit would typically be calibrated for up to five compounds at any one time.

7.3.2 Reasons for New Product Development

The opportunity for the development of this product arose from technical developments in the fields of microprocessors and analytical chemistry.

Microprocessor chips had increased in power and availability and decreased in price and size over the late 1970's. These advances opened up the possibility of using microprocessors in a range of scientific instruments for both control and mathematical analysis of the results. Gas chromatography which requires a simple integration calculation to interpret the results is a particularly suitable application.

Gas chromatography itself had been used as a technique for some twenty-five years but recent advances in the technique made it suitable for miniaturisation. In most gas chromatographs the bulk of the machine is the oven into which a prepacked column is placed. The introduction first of capillary columns and recently of columns etched onto a silicon wafer radically reduced the size of the column itself and with improvements in thermostatic control the oven size for gc could be substantially reduced.

The market for pollutant monitors had demonstrated the desire for instantaneous results from the popularity of the Draeger monitoring tubes which gives a semi-quantitative instantaneous reading. Given the trend of decreasing threshold limit values for pollutants and the complexity of pollutant mixtures in some atmospheres, a unit which could separate species and give an instantaneous accurate printout was viewed as providing a good product opportunity.

7.3.3 Resource Commitment

From the application made under the MAP scheme to the Department of Industry Dutom received a grant of £85k payable over two years to assist the development of this product. The first contribution was received by April 1982. Throughout 1982, however, the project proceeded slowly. It was described to me by one of the staff working upon it as being:

> "Always the last priority unless a visit from the Department of Industry was imminent."

Throughout this period the computing and electronics personnel who were developing the mini gc were also occupied with the development of the Desorba and Autoplot products.

The project work only began in earnest after capital had been raised under the Business Expansion Scheme in 1983. Specifically for the project Dutom recruited an additional two electronics engineers, a microcomputer specialist and a chemist. These staff joined the company in December 1983 and January 1984. The project then became the major brief for the newly formed R&D department.

Regarding the commitment of the company to the project as a whole, some queries were first raised at the Board meeting of October 1983 regarding the risk of the project and the lead time of potential competitors.

> "Mr Robson (later Managing Director) noted that from his recent US trip, ... there appear to be currently three chromatographic units under evaluation by NIOSH. These units appeared to be well priced and he was concerned how long it would take these manufacturers to miniaturize further."*(28)*

> "Professor Perry (later Chairman) said that the gc is the only viable product coming out in the future and that the prospectus committed us to its production."*(28)*

> "Mr Robson stated that in his best estimate the mini gc was a 40-60 risk at present."*(28)*

As the company entered the divestment phase of its strategy, the resources committed to this project were eroded. This arose because the company wished to reduce the level of its expenditure and this project required considerable overheads generating no immediate income. The effect of this project on overheads was stated in a paper submitted to the Board on the subject of manpower:

"The problem:- The company's overheads are primarily the costs of employing highly qualified staff and competing for those staff with industries who can afford to pay higher salaries. The company has also geared its manpower to undertake the development work of project Ester."*(29)*

Note: In May 1984 salaries were responsible for over 60% of the overheads in the month and 36% of the salaries were directly attributable to the R&D division.

Staff for the project began to be reduced from the beginning of May 1984 but the recommendation put to the Board was that all R&D staff except the Technical Director be dismissed if no further contracts were forthcoming. Once the mood of disillusion had set in it is no wonder that progress on the project slowed as staff recognised they were working themselves out of a job. So, the Technical Director reported to the Board in July 1984:

"During the period January to March 1984, rapid progress on the project was observed; since then the project has decelerated due to sub-contract problems, staff demotivation and lack of project management."*(30)*

"The project team has been reduced considerably since the beginning of May. Two chemists have been made redundant. An electronics engineer and a microprocessor engineer have also left the company. Progress during May and June was affected by poor morale."*(31)*

By September 1984 only the Research Manager remained in the R&D department, work however was still incomplete and the microprocessor work was only completed by the company paying staff previously employed to return in a spare time "contract capacity". With no remaining project team little further development work was carried out. The Managing Director finally wrote about the project:

"We have terminated all research and development work on this project and are basically seeking a sponsor company with which to develop the product to its final marketing stage."*(32)*

Expenditure on R&D and manufacture of the first prototype was reported to have reached £320k, nett of grant income, by January 1985.*(33)* This was prior to any money to be spent on the product launch.

7.3.4 Technical Aspects

Technically the project represented a harmonization of microprocessors, electronics and analytical chemistry beyond anything undertaken by Dutom to this point.

Microprocessor - The unit was to be fully controlled by a microprocessor which was programmable for analyses of a flexible range of compounds by use of a full QWERTY keyboard. The microprocessor was to control the operating system of the gc as well as perform the functions of data logger, data processor and information storage. Besides the technical difficulties of writing the software for the microprocessor to handle all the required functions some problems arose with supply of some of the integrated circuits. The lead time for some of the required chips was nine months which required decisions to be taken as to the number of units that would be produced as Mk I prototypes, so these circuits could be ordered.

Detector - The unit needed to incorporate a miniaturized detector for the ambient pollutants. The decision as to the type of detector was repeatedly changed. Originally a piezo electric detector was proposed but by Autumn 1983 a photo-ionization detector (p.i.d.) was being favoured. However, by April 1984 a flame ionization detector (f.i.d.) and photo adsorption detector were being discussed. The prototype finally contained the more widely used f.i.d..

Gas supply and control - the unit was to have its own gas supply with automatic control of flow rates and pressures. The number of gases required for the instrument were dependent upon the detector selected.

The choice of the f.i.d. increased the number of gases to be carried to three, and in fact the demonstration model as late as May 1985 was run from laboratory gases rather than from internal supplies.

Column and area - Dutom selected a capillary column as opposed to a silicon etched column. This cheaper but bulkier column could be replaced as appropriate.

The power supply for the oven was reported to have been designed and tested by January 1984, but the technical specification was modified in April 1984 in response to a market survey. By March 1985, which was several months after the intended completion date, a prototype was working in the Dutom laboratory but development work still remained incomplete:

> "We have a working prototype at the moment and there is some development work both in the production engineering side and the computer development side to be finished."*(34)*

7.3.5 Marketing

The report by Coopers & Lybrand*(35)* published concurrently with the prospectus predicted sales for the mini gc would be as given in Table 7.4. These figures were based on the Dutom estimates.

Table 7.4 Predicted sales of the mini gc

Year	1984/85	1985/86	1986/87
Units	68	274	475
Turnover £k	144	615	1132

The product was the subject of a market survey carried out by a firm of independent consultants in March 1984 who reported favourably on the market:

> "Portable chromatographs are not extensively used at present but ... The right product at the right price would be attractive to many."*(36)*

The estimate of the UK market was given as 15 units in the first year rising to 30 in the second year assuming a good track record.*(36)* This small size of the market potential caused some Board members to call into question the continuation of the project. However, again the US was claimed as the proposed market:

> "Mr Dutton (Managing Director) stated that the market for Ester was primarily the US and that the UK alone would not justify development costs."*(37)*

In this he was clearly correct, given the stated development costs, ex-marketing, of £320k and predicted contribution of £1k per unit.*(38)* Despite estimates of the production costs and potential sales price having risen substantially in the time between these figures being calculated and the discussion reported here, the UK market alone could not offer an adequate return on investment.

By April 1984 the Board had begun to recognise that it had neither the resources to develop the product fully nor to market it properly.

> "Mr Taylor noted that the Company should only proceed if we find a company to take on the development work."*(39)*

> "He (Director) noted that we could not market Ester by ourselves and should seek a distributor."*(39)*

The company therefore actively sought major companies to buy out the mini gc at its current state of development. Thus Ferranti, after expressing interest, were asked for £100k as a prepayment to keep their option on the project, but they declined. The prototype unit was also taken for demonstration to Draeger Safety in Germany where it failed to function.

Meanwhile at the Detroit conference of Occupational Hygienists in May 1984, three competitors demonstrated fully developed products.

Microsensor Technology Inc. - exhibited *Micromonitor*. This was a fully automatic micro gc with a column engraved on a silicon wafer. It was fully self contained and retailed at $11,700

Sentex Sensing Inc. - exhibited *Sentor* - A fully automatic portable gc which was self-contained and self-calibrating. It retailed at $12,500 or $14,500 depending on the detector.

AID - exhibited the *421 Automatic gc* - Not portable but an automated fixed site gas sampling instrument. They also had a non-automatic but portable self-contained instrument.

After Dutom was taken into receivership in April 1985 Thorn-EMI bought out the technology invested in the mini gc project. However, to date they have issued no projections of a launch date for this instrument.

7.3.6 Project Evaluation

The project ran throughout the history of the company and was at different times the lowest and highest priority R&D project. It proved to have been a major drain on the resources of the company without realising any income in return. It was clearly a project at the forefront of new technology which offered a genuine commercial potential, as is demonstrated by the results of the market survey and the release of comparable competitor products. However, it demonstrated a lack of management acumen at Dutom organizationally, financially, technically and commercially.

Organizationally Dutom between 1981 and 1983 were not in the position to be able to support the development of the project and the small amount of R&D completed on the project subsequently resulted in a loss of lead time versus competitors. Recruitment is a costly and time consuming business yet the staff recruited at the end of 1983 specifically for the project team represented the last to join Dutom and the first to leave. To hire and fire staff within six months demonstrates a very poor management concept of the implications staffing levels had on the overheads of the company versus project advancement. The reports of poor morale and staff demotivation further illustrate an inability of the management to obtain the best from its staff.

Financially the project proved to be beyond the resources of the company despite the grant income received from the government. In total the company spent over £400k on the project, at a time when income from the other operations could not sustain this level of expenditure. The lack of evidence of discounted cash flow or similar calculations suggests that the management did not understand the implications of the costs of the research. This had "Catch 22" type consequences.

The company believed themselves to be financially committed to the project but had lost lead time through a lack of organizational resources and technical difficulties. In order to reduce the development time additional staff were recruited thereby increasing overheads. Since the company could not afford these overheads staff were soon dismissed, reducing the staffing on the project, demotivating the staff remaining and again increasing the time to completion.

The project was proved to be technically feasible, unlike the formaldehyde monitor, by the advances made by competitors. However, Dutom were unable to manage the technical development of the project to completion. The technical specifications were altered on several occasions and several other product sidelines were proposed as "spin off" products of the project. From August 1983 the project tied up the R&D resources of the company limiting any technical improvements being carried out on other Dutom products.

The company had committed itself to technical development before it assessed the market potential. No market information was gathered until well into the lifetime of the project i.e. two years after the project was conceived. This demonstrated that projects originated from the opinions of the directors as opposed to being market derived. When the market information was sought it affected the technical specifications of the instrument. Had market information been sought at an earlier stage it could have settled the technical specification problems and saved time and expense wasted in technical development.

The project also demonstrated that the company were to be totally dependent on the US market. This was despite their very limited access to that market and the inherent difficulties of selling to a foreign market. Finally the project graphically showed the switch of strategy which the company made from selling products to attempting to sell the R&D work that had been carried out.

CHAPTER 8

A DISCUSSION OF DUTOM'S STRATEGIES AND PRACTICES

"Between the ideas and the reality between the motion and the act falls the shadow"

T. S. Eliot

OUTLINE

This chapter is a synthesis of the strategic management of innovation derived from the exemplary experience of Dutom and the reported wisdom of the literature. The thesis is a longitudinal study of the management of innovation at the company and has researched the management strategies and practices adopted within the company. In a NTBF both the strategies and practices adopted are intimately associated with the success or otherwise of the product innovations and hence with the viability of the enterprise as a whole. The bankruptcy of Dutom Meditech was directly linked to the management of the innovations the company attempted. The failure of the company and its products is therefore analysed in this chapter in the light of the prescriptive literature on strategy and the empirical literature on new product management.

8.1.0 Dutom Meditech as a New Technology Based Firm

Freeman when assessing small firms and the contribution they make to innovation in the economy wrote:

> "The innovative small firm is the rare exception and not the general rule."*(1)*

This thesis has demonstrated that Dutom Meditech attempted to be one of these exceptions. The company by aspiration was dedicated to new technology and innovation. It was endorsed as a NTBF by the financial institutions, at the time when it raised over £1M on the public market, and by government departments through its successful grant applications. The highly qualified academic experience of many of its staff also enabled it to be viewed as a vehicle for technology transfer from academia to industry. So the firm belonged to the classification of a New Technology Based Firm as used by Rothwell*(2)* and the Little report*(3)* and embraced the policy of industrial regeneration through small firms expressed by the government.

Despite the mood of expectation engendered by such a firm the management of change is recognised as a difficult task, e.g. Basil and Cook write:

> "The management of technological change is not easy. Few organizations have found the desired balance between doing too little and pursuing too many rainbows."*(4)*

The launch of Dutom as a NTBF imposed upon the Dutom management the need to adopt appropriate corporate strategies and management practices to cope with the acknowledgeably difficult task of product innovation. The performance of the company reflected in the loss of £1.7M inside four years illustrates the extent of the failure of the management to achieve their aspirations.

The reasons why a company becomes insolvent are numerous but in the case of Dutom the accounts (see Appendix C) show a consistently small turnover against large overheads. This was a case in which the company products were simply not sold in the market and the innovation process was incomplete. The high level of overheads represents the development of innovations not all of which ever became commercial products. Other companies trading in similar business areas with similar products and services, concurrent with Dutom Meditech and since its closure, have not suffered a similar fate. It is therefore my assertion that the failure of the company is intimately linked with the strategies and practices it adopted with regard to innovation. This thesis which has researched the management of innovation from within a NTBF seeks therefore to draw comparisons between the experience provided by Dutom and the contributions available on both strategy and practice within the literature.

8.2.0 Strategy Formulation

8.2.1 The Environment

The company traded from 1981 to 1985 during which time the environment exhibited certain characteristics some of which were favourable and others detrimental to the business of the company.

The economic climate of the UK throughout the trading period has been described as that of "recession" although some would argue that there have been signs of a recovery in the later years. The rate of inflation declined progressively over the period but interest rates remained high. The output of manufacturing industry declined steadily to the extent that a House of Lords Select Committee warned of a bleak future for the UK economy(5), while the unemployment figures showed an upward trend throughout. Politically one party remained in government and operated a monetarist economic policy. In this climate both industry and the public sector (e.g. the NHS) were working to reduce overheads hence the market for non productive activity such as occupational and environmental monitoring and analysis was depressed.

Against this the government has been actively encouraging the small business sector and especially innovation by small businesses as a means of industrial regeneration and job creation. This has seen many measures passed to reduce control and to improve the financial support of such companies. Dutom were able to take advantage of a number of these schemes to finance the company and its products e.g. the Business Start-up loan scheme, the Business Expansion scheme, the microprocessor application programme.

In addition there has been an observable social trend towards a heightened concern for the environment and effects on health. This is reflected in the concern expressed over food additives and acid rain for example. Further, public awareness of the potential dangers of industrial pollution was heightened by the explosion at the Union Carbide factory in India in 1984 - "the Bhopal disaster". The response of governments to this social pressure has been to reduce 'acceptable' occupational and environmental pollution limits. Examples are the move towards lower limits of lead in petrol and the decreased thesholds and increased number of control limits published by the Health and Safety Executive as threshold limit values. This social trend is potentially advantageous to the business of analysts and hygienists.

8.2.2 Personal Values

The two founding directors of Dutom Meditech Ltd both had close connections with universities. One, Dr Thompson, had a largely technical background gained in academia while Mr Dutton held accountancy qualifications and had also worked in a subsidiary of a large company. Their decision to trade in three technological areas committed the company to recruit technical staff in three scientific disciplines leading to high technical staffing overheads. Most of the staff and consultants appointed to the firm were scientific and from academic backgrounds with the company values subsequently reflecting this.

Cooper*(6)* has discussed the effects of the incubator environment as the provider of management skills and Twiss*(7)* outlined the difference in values of the researcher and marketeer. Neither founding director had experience of the marketing function and hence the orientation of the company was away from the market and towards research. Hence, despite the business experience of the accountant, the objectives of the firm were expressed in terms of technology and not in terms of profit, turnover or return on investment.

The predominance of the "theoretical" over the "practical" in new product development was illustrated by the management of the formaldehyde and Adsorba monitor projects, in which new products were announced when an idea had been derived as opposed to tested. The company structure similarly reflected the dominance of "theoretical" over "economic" values in that R&D was retained centrally within the company while the marketing, sales and accountancy functions were contracted out. The effect of these functions operating at a distance was that they were not closely controlled or integrated with the other functions of the company.

8.2.3 Intended and Emergent Strategies

Given the environment within which the firm operated and the values of its executive staff the company evolved a strategic posture which was not always in line with the intentions expressed.

One of the overwhelming strategic objectives of the company was for it to be innovative in nature. It also adopted a growth strategy. The aspiration to grow is most clearly reflected in the chart of the number of employees at the company against time (Figure 5.1), but it was expressed through the business areas sought, and the expansion of activities in seeking new products and markets for the company.

Initially the directors had expressed the intention that the company adopt a well integrated product and service strategy. It is apparent from the history of the company that in order to pursue the deliberate strategies of innovation and growth the above intention became an unrealised element.

The emergent diversification strategy derived from the desire for Dutom Meditech to embrace new technology. The 1981 Business Plan*(8)* had proposed that Dutom as an innovative NTBF would function in the fields of: Biotechnology; Microprocessors; Analytical Chemistry. It envisaged the company could trade simultaneously in three different business areas based on three different technologies. As such, it provides one of the early illustrations that the management had the ability to initiate ideas but lacked the experience to appreciate the implications of adopting them.

Basil and Cook warned of the dangers of attempting to undertake too much technological diversification.

> "In some cases failure may be accentuated because the aspiring firm was too widely diversified in several major technology projects."*(9)*

Of the generic strategies followed by companies for innovation Cooper*(10)* identified both the "technically driven strategy" and the "high budget diversified strategy". He had reported very poor performance resulting from the diversified strategy in which poor synergy and a lack of market orientation dissipated large R&D resources targeting new and competitive markets. The technically driven strategy, more typical of firms engaged in new technology, he equated with producing only moderate results; costly development programmes were plagued by failure due to a lack of market orientation.

Dutom with a technically driven and diverse strategy exhibited features common to both of Cooper's generic types above. The lack of synergy at Dutom is demonstrated from the business areas approached, the projects selected and the markets penetrated.

The Biotechnology business of Dutom Meditech never had any common products or markets with the analytical and occupational hygiene aspects of the company and therfore has received little treatment here. Even within the biotechnology division diversified projects were undertaken only one of which, blood products sold as food additives, has formed the basis of a company i.e. APP Ltd, the joint venture company.

Interestingly Rothwell(11) noted that biotechnology has not proved to be the commercial growth area expected of it because it has required long programmes of research. He observes that companies continuing in the field have predominantly been joint ventures between a small technological unit and a large parent. APP Ltd which has survived the liquidation of Dutom Meditech is a further example of this phenomenon.

The early development work by Dutom on computer systems for GPs and a business graphics package also lacked synergy with the rest of Dutom's business. It involved selling different products into different markets. The lack of synergy both within the division and with the company's other activities is illustrated by the majority of computer media sales being made to local government, an area largely divorced from both GPs and the occupational hygiene profession.

The individual projects also exhibit features in which the intended strategy of the business plans was not followed but was superceded by an alternative practice. Examples are provided by the change of markets at which the Adsorba was targetted and by the recruitment of a sales team despite the expressed strategy of using distributors. Therefore although the company formulated strategies it did not always implement them.

A result of diversification and the changes in strategy was that the projects undertaken at Dutom Meditech exhibited poor product, poor market and poor research synergy. A reason for this was that the projects were inadequately screened according to their business, financial, technical or market potential. Adams(12) reported that in many small companies lacking in management experience, projects were frequently selected by "gut feel". At Dutom, the failure of the computer records package and of the formaldehyde monitor both on the grounds of technical feasibility illustrates poor technical screening. The unwillingness of the company to respond to the market criticisms of the Desorba and the late investigation of the market for the mini gc illustrates that projects were not market derived. The absence of financial information regarding the payback potential of the formaldehyde and mini gc projects indicates poor financial screening. The majority of the projects were initiated by the founding directors using ideas derived from their previous experience. i.e. the project selection procedure shows a lack of coupling with the other business functions and a lack of evaluation by them, which is symptomatic of the "gut feel" approach.

The divestment or retrenchment strategy adopted during 1984 was a conscious change of direction by the Dutom management which came about because of the poor performance of the company. As such, it provides an example of a crisis which precipitates strategic change. By adopting a retrenchment strategy the Dutom management sought to reduce overheads and focus upon the perceived strengths of the company. In so doing the company withdrew its sales force; i.e. it focused attention away from marketing and onto the technical functions namely the R&D and analytical work of the company. Even when embracing this retrenchment strategy the implemented strategy for the Adsorba was based upon launching a new product into a new market, i.e. this was not a retrenchment strategy based upon established expertise.

8.3.0 Technology Strategy and Management

8.3.1 The Pattern of an Emerging Technology

Thermal desorption was the innovation upon which Dutom's principal products, Adsorba and Desorba, were based. The advances in thermal desorption ovens can be closely related to Utterback and Abernathy's*(13)* innovation model and Porter's*(14)* description of the characteristics of an emerging industry. These authors point to the second and third generation products improving upon the pioneers, to the trend towards standardization in the products and the industry, and to the demand for increasingly sophisticated information on performance. All these features were observed with thermal desorption and are reported in Chapter 6.

The Bendix Flasher and Century Programmable Thermal Desorption oven had pioneered the technology. After these pioneers a number of products were introduced, of which Desorba was one. Most of the subsequent products offered improved sophistication. The first industry standard of the adsorbent tube length was agreed and with time there was an increased demand for information and methods for which thermal desorption systems were appropriate.

Ansoff*(15)* argued that a NTBF could either adopt a "pioneer" or a fast "follower" strategy while being at the leading edge of technological change. Given that the pioneer products had been developed, Dutom was restricted to a "follower" role. Rickards*(16)* and Freeman*(17)* have pointed out this requires efficient R&D and a clear understanding of the market reaction, in order to develop superior products more closely suited to the market need. Dutom, with a weak interaction with users resulting from their marketing strategy, ignored the criticisms received via their distributors and did not continue to develop Desorba. So, as standardization began to occur with users requiring the greater sophistication of two stage desorption, the Dutom Desorba was left behind in the emerging technology and frequently likened by potential users to the obsolete pioneer product, the Bendix Flasher.

> "The Desorba does the same thing in the same way as the Bendix Flasher."*(18)*

Similarly the requests for more sophisticated information on the application of Adsorba and Desorba for an extended range of chemicals was consistent with the predictions of Utterback and Abernathy's model.

8.3.2 Technical Management

The technical orientation of the majority of the staff and advisors of the company was noted above. Adams*(19)* had warned that in small firms employing largely technical staff there was the tendency to overestimate the technical abilities of the company and underestimate the needs of marketing. Both accusations may be made of Dutom. On several occasions Dutom exhibited on overconfidence in their research ability, which resulted in incomplete development work and overconfident pronouncements of product performance being made. Thus, Dutom undertook R&D work on the BASF computer despite the lack of a fully developed operating system. This proved too great a task for them and no product was ever fully developed. The mini gc project also over-ran its budget and development time without producing a fully working prototype. The company announced they had developed accurate and reproducible monitors for formaldehyde and ethylene oxide, both claims were made before the monitors had been tested and both were fallacious. The ethylene oxide monitor was developed only after much more work examining different adsorbent materials and deriving sample decay curves. Hence one of the major shareholders expressed his criticism of the management and of communication within the firm, particularly the technical management.

> "Mr Newton-Mason said he felt the major fault was a lack of management throughout the company and that communication was poor. He was concerned on the technical management and took the ethylene oxide Adsorba as an example."*(20)*

8.3.3 The Coupling of R&D

In contrast to the number of technical contacts maintained with extra-company organizations e.g. universities, the technical functions demonstrated poor coupling with other business functions. This can be attributed in part to the resource allocations adopted by the company, which maintained R&D as an internal operation while contracting out some of the financial, marketing and production functions.

The poor coupling of R&D with financial management is illustrated by the organizational structures, in which the financial and R&D management were separated through being performed in different companies operating in different locations. The absence of financial calculations on the cost of research and the necessary rate of return has been reported in the formaldehyde and mini gc projects. The result for the mini gc project was that the company committed resouces to a project only to discover that it could not afford it. This resulted in lengthened development time and an incomplete product offering no return on the investment. This lack of management information relating cost to development and other functions was listed by the auditors in 1984 as a major reason for the shortfall in the company predictions:

> "The lack of detailed management and costing information which obscured the true situation of the company for a significant time."*(21)*

Products underwent poor transition from the R&D into production. This was particularly apparent for the Adsorba because it was produced "in-house". As reported in Chapter 6, the production initially suffered a series of technical difficulties because the scaling up of production from the prototype stage had not been adequately prepared. The deterioration in relations between Dutom and the sub-contracted manufacturers of the Desorba due to poor communication, the requirement to modify the prototype and non-payment of the account has also been referred to in Chapter 6.

The lack of coupling between R&D and marketing was demonstrated in all the projects. The selection of R&D projects was seen not to have been market derived. Indeed, the market input throughout the R&D projects proved to have been extremely limited, thus market information was only sought two years into the mini gc project and the comments of the market on the Desorba were ignored for over a year.

Thus, R&D exhibited poor coupling with other business functions and marketing, finance and production all provide clear examples.

8.4.0 Marketing Strategy and Management

8.4.1 Resource Allocation

The importance of marketing to the success of product innovation was stressed in all the studies reviewed in Chapter 4. In particular Goldman*(22)* concluded that because of the short life cycles of products in which NTBFs competed, these companies required a sophisticated and effective marketing team. Rothwell and Zegveld*(23)* had proposed that because of their flexibility, small NTBFs held a competitive advantage in marketing. The Little report*(24)* and an OECD report*(25)* on innovation and small businesses had made similar observations regarding the importance of marketing in an emerging industry and the advantage this offers to a NTBF.

> "In the case of a new market, responding to still emerging needs, the firm must, over a longer or shorter period, develop products which either cannot yet be standardized or have not yet been perfected technically, so as to keep matching them more and more closely to the still evolving requirements of its customers. The flexibility of small manufacturing enterprises helps them in this constant process of adaptation and enables them to keep in close contact with the customer. Indeed the provision of service to the customer counts at least as much to the customer as the product itself."*(25)*

Dutom was operated by a staff who were highly qualified technically but limited in marketing experience. Given the ignorance and mistrust of marketing information and tools which has been attributed to researchers and small business managers by Clarke,*(26)* Millman,*(27)* and Adams*(28)* Dutom followed the established pattern of many such businesses by largely neglecting the marketing function.

Instead of developing a sophisticated marketing team and strategy Dutom oscillated in strategy between using distributors and Dutom personnel in the marketing function. The more frequently expressed strategy and one used exclusively in overseas markets was to use distributors.

The result of this passive marketing strategy was effectively to screen Dutom from the market in which its products were to be used. The interaction of the Dutom management with potential customers was reduced to a minimum and the impressions of the market and how it perceived the

Dutom products were only received through the intermediary of the distributor along long lines of communication.

The initial negotiations with the distributors were viewed as of utmost importance and a great deal of senior management time was invested in negotiating the agreements. Cohn and Lindberg*(29)* warned of the dangers of top management becoming too involved in the "bread and butter" sales and of the dangers of buyer manipulation but both occurred. Dutom incurred high costs in negotiating the distributorships *viz.* the Dosimeter logo, the Digicolour consultancy and equipment costs, and reduced profit margins. The service of the distributors, however, received notably less attention and the poor communications and deterioration of the relationships between Dutom and all its distributors was subsequently observed.

The result of this strategy was that the company displayed features which were exactly contrary to those features equated in the literature with new product success. Thus Roth*(30)* had described the benefit to development of market contact as:

> "A prime input to development is the field sales organization."*(30)*

Rothwell*(31)* had equated active sales and marketing with success. Millman,*(32)* Twiss*(33)* and Cooper*(34)* had warned of poor corporate performance and a high product failure rate resulting from a lack of market orientation. In particular strong market interaction was one of the features indentified with the "follower" innovation strategy which Dutom were committed to. Instead by choosing to distance the company from the potential customers the Dutom management could be accused of abandoning the marketing advantage attributed to NTBFs and the ability to respond quickly and flexibly to the market needs.

In the UK Dutom did make two attempts to sell products directly to customers using its own personnel. Both occasions illustrated the poor degree of support allocated to the marketing function. Hence, in 1982 the marketing and sales functions were performed by staff of whom, one was part-time, one was based away from the company and employed on a contract basis and one performed an office based administrative task as her principal job description. The lack of a product brochure, the long lead time in following up enquiries and the absence of market information is indicative of the lack of administrative support made available.

8.4.2 Differential Advantage

One of the marketing tools acknowledged as an important means of ensuring successful new product launch is that of market segmentation and targeting, in order to concentrate limited resources upon the most advantageous segments and the early adopters.

> "Segmentation analysis is the key to establishing a brand or product on the market by more effectively meeting the needs of more tightly defined, closer knit groups."*(35)*

Dutom's strategy for the launch of new products was that of blanket coverage based upon the techniques of advertizing and the cold call. The only segmentation and targeting of the market which was performed was the differentiation between the "hospitals market" and the "industrial market". Initially Dutom had proposed to sell to the "hospitals market" but when this showed very slow rates of adoption of Dutom products it was replaced in 1983 by a policy to sell to the "industrial market", only to revert again to the "hospitals market" policy during 1984. This limited use of marketing tools and preference for the "hospitals market" reflects the previous experience of the senior management.

The blanket approach to marketing occurred not just across industrial classifications but also geographically through the strategy to sell to a world market. Progressively the company became more entangled in this worldwide strategy. Top management engaged in numerous discussions with potential overseas distributors and the company came to acknowledge its dependence upon the large but highly competitive US market, if the Adsorba and mini gc were to prove commercial successes. This dependence upon overseas markets was adopted despite the limited contact and long communication channels the Dutom management had with the potential customers in these markets. The Scientific Advisory Panel had also noted that there would be marked differences between the overseas and the home markets.*(36)*

In chosing to market a diversity of products on a world market the company had abandoned the niche or focused strategy both technologically and as regards the market. In so doing the management dissipated the resources of the firm and abandoned a second strategic element advocated by Rothwell*(37)* and the Little report*(38)* as a major competitive strength of a NTBF. Furthermore, the products were launched in a competitive market, which Cooper*(39)* had isolated as one of the factors which tends to be equated with product failure.

With regard to the actual launch of the products, Cooper*(40)* had argued that a well executed product launch could overcome many potential disadvantages of the product or market. The result of the dissipation of resources by Dutom was that the Adsorba, the Desorba and Autoplot, the graphics package, were all reported by the Dutom management to have suffered from weak product launches and slow rates of adoption.

The lack of market segmentation and the selection of overseas markets obscured the potential market size from the Dutom management and relatively little data on markets was held by the company. This may have resulted in the over optimistic predictions of the sales potential of the Dutom products. It provides an example of the "Two year breakdown problem" and the "Communication problem"*(41)* in which the management were neither competent nor desired to acquire accurate market information lest it shattered their illusions. Certainly the predicted sales of the Adsorba and Desorba were over optimistic when compared with the market size.

Having abandoned one of Porter's*(42)* three generic strategies, the "focus strategy", Dutom tried both of the other two in an attempt to establish a differential advantage. In this case technology and cost. The confusion between the two strategies at Dutom may be first noted in the 1981 Business Plan.*(43)* Initially the products were marketed on the basis of their advanced technology. However, as the technology and industry standards advanced beyond the Dutom products, Dutom progressively advertized their products in terms of the cost benefit. Thus, the final strategy to sell the Adsorba in the UK was based on a direct cost comparison versus the Perkin Elmer tubes, i.e. a small company without a good distribution network attempting to compete with a large competitor on the basis of cost. Dutom can be shown therefore, to have chopped and changed their strategies with regard to the differential advantage sought, the market targeted and the distribution network used. Porter*(44)* had warned of the dangers of switching between strategies and of the tendency of firms in difficulty to do just this. Dutom substantiate his observations both in their strategic choices and in the results for the company.

8.4.3 The Assertive Element

Porter*(45)* proposed that the "active" firm could enable the standards adopted by an emerging industry to be set so as to be favourable to the company. The distance the company placed between itself and the market did not equip the company for this "active" strategy. However, Dutom did periodically attempt to lobby the regulating bodies regarding the appropriateness of the Dutom thermal desorption system, and approaches in the UK were made to the Health and Safety Executive and the National Health Service. In the US similar approaches were made to the National Institute of Occupational Safety and Health (NIOSH). The lobbying of these organizations came to nought. Indeed there is some evidence, revealed in the independent market research survey*(46)*, that Dutom's attempts at "active" lobbying for single stage thermal desorption had engendered opposition to the company and its products because the company methods were not seen to fit with the user requirements.

The degree of inertia of the government bodies in the approval of methodologies with regard to thermal desorption provides an example of how regulation and standards may restrict the potential growth of an emerging industry.

8.5.0 *General Management*

8.5.1 *Financial Management*

One aspect of business at which the Dutom management proved particularly adroit was the raising of capital for the business. The use they were able to make of government grants and schemes indicates that over the period 1981 to 1985 there was no shortage of finance available to firms which were able to persuade investors that they were innovative and new technology based. As such it counters the widespread rumour that there is no investment available in the UK for innovation because the financial institutions are not prepared to accept the inherent risks. In particular the £1.15M raised under the Business Expansion Scheme by a small company with a track record which indicated it had lost over half a million pounds during the previous two years demonstrated that there was finance available for the small business sector which was being looked towards to provide industrial regeneration.

Although the management showed the ability to raise finance the ability to control it was noticeably absent.

Dutom Meditech Ltd was very highly geared at a time of decreasing inflation and high interest rates. The interest payable on the loans increased the overheads of the company at a time when the company was engaged upon product development and could expect little income.

The inadequacy of budgeting of R&D against the payback potential was particularly noticeable in the mini gc project. The fixed and variable costs of producing the Adsorba and Desorba were never fully understood and both products have been costed above their price. The contribution of each product was never documented and the strategy of using distributors squeezed this margin. The accounts for 1983/4 (Appendix C) show the turnover of the company (£58k) to be less than the sum paid out in Directors' emoluments (£61k), and indicate a company in which the financial management is out of control. Thus the auditors wrote in 1984:

> "We consider the standard of accounting and control is significantly below what we would expect in a public company."*(47)*

Similarly in a statement to the shareholders, issued in November 1984, the company Chairman wrote:

> "Proper accounting control over administration and research expenditure in the period (1983/4) has left much to be desired and the company has been badly lacking in management information."*(48)*

The inadequacy of financial control was only realised by the Board during the prolonged absence, due to illness, of the founding Commercial Managing Director. For example it was the revelation of the company's accumulated liability to the Inland Revenue of £111000 which led to the immediate resignation of the company Chairman, and the Technical Director admitted he had been unaware of several other agreements e.g. the Digicolor consultancy and expense agreements. However, this serves only to illustrate the poor coupling and communication between functions within the firm.

One concludes therefore that the grants and schemes initiated by the government have made finance available to NTBFs and encouraged them to participate in innovative activity. The degree of control the schemes have exerted over the good use of the money has been very limited. It appears that simply making financial provision for innovative activity is inadequate and potentially a waste of public and private financial reserves; the problem which needs addressing is how to equip entrepreneurs to make wise choices in the strategic and practical management of innovation.

8.5.2 Personnel Management

The personnel of a small company have been recognised as one of its major assets. At Dutom the employees frequently worked longer than normal office hours in order to perform work for the company. Despite this the company was not a happy working environment. Kennedy*(49)* observed that conflict is more prevalent in small companies and at Dutom the growing frustration and disillusionment of the employees was noticeable.

A potential reason for this was that because the top management lacked management experience they were unable or unwilling to delegate responsibility. Through choice or necessity the Directors were frequently involved as the final arbiters in conflicting decisions. Meanwhile the employees grew frustrated by conflicting decisions and the frequent absence of the top management which prevented decisions being taken and work authorised. Furthermore they were frequently given imprecise responsibilities poorly matched to their established skills. The decline in staff motivation and the use of informal communication channels provide evidence that the company had lost some of the personnel advantages attributed to the small firm.

Potentially "product champions" of the three technological fields could have emerged within the company, namely each of the technical or project managers, since they had both the technical expertise and some market contact. Instead of encouraging this potential top management interposed the General Managers in roles which proved unsatisfactory and denied the Technical Managers the authority to champion each of the business sectors. The Technical Managers of the OEH and Biochemistry Divisions have since proved their "champion potential" by both managing companies in the same business lines as they were engaged in at Dutom. The third area, the Systems Group, ceased to function shortly after the resignation of its potential champion.

8.5.3 Administration

Given the poor synergy of the company activities, the weak coupling between the business functions and the imprecise personal responsibilities of the employees, the communication network within the company was placed under severe strain. The level of confusion in communications with suppliers and distributors is indicative of the fact that the company did not develop an efficient administrative system. The Company Secretary summed this up in a letter sent just prior to closure:

> "I must state to you that the standard of record keeping maintained in the early days was nothing short of appalling."*(50)*

8.6.0 Summary

This chapter has examined the strategic and practical management of innovation in a company which was recognised as a NTBF in conjunction with salient features identified in the prescriptive and empirical literature on product innovation. It has argued that the failure of the company was directly associated with the management of innovation at the firm and has identified features in the strategies and practices of the company which were at odds with those defined to be appropriate for a NTBF.

The company management evolved a strategy which was not fully consistent with expressed intentions. Because the strategy embraced growth, diversification and changes in direction, the vital elements of synergy and integration were lacking. A reason for this is that the projects undertaken were inadequately screened. The result was that the company was overstretched and its limited resources were ultimately wasted by attempting to launch products based in differing technologies in wide and diverse markets. In the aspirations encapsulated in its strategy the company management can be accused of "chasing too many rainbows".

The company were technically orientated and much effort was spent on R&D, nevertheless projects were rarely managed to completion. Emerging industry characteristics were such that the innovative principal products of the company required a "fast follower" approach. This required a flexible response to the needs of the market which the company declined or were unable to make because of their lack of market orientation and their preoccupation with diversification.

Since, the company was orientated away from the marketing function, it failed to use marketing tools in order to derive an appropriate marketing strategy or to support R&D. The company abandoned a strategy recommended as advantageous for NTBFs which focuses upon a niche in the market. Instead it adopted a worldwide marketing strategy independent of end user classification. The result was to screen the company from the market needs because the company became dependent upon long communication channels to unfamiliar markets. The company products came to be viewed as being without a differential advantage.

A major resource of the small firm is its personnel. At Dutom Meditech there were some examples of personnel skills being misdirected and potential champions of innovations were not encouraged. The use of outsiders can extend the expertise available to a firm but two detrimental aspects emerged from the use of outsiders. The pre-eminence given to technical consultants in advising the company reinforced the technical values of the management to the exclusion of others. The use of outsiders in marketing and accounts reduced the coupling of these functions with the "in-house" work of the firm.

Capital for the company was available from several sources but financial control was seriously lacking. There is evidence that the costs of R&D, of production and of staffing were not understood.

There was poor coupling between the different business functions and examples have been shown were breakdown of communication occurred between all the following: financial management, marketing, production and R&D.

As such Dutom has been shown to have exhibited certain weaknesses in all three areas specifically isolated in Chapter 4 namely: experience, communication and marketing.

CHAPTER 9

IN CONCLUSION

9.1.0 Product innovation in a new technology based firm
9.1.1 The place of new technology based firms
9.1.2 Deriving an innovation strategy for the NTBF
9.1.3 The contribution of experience

9.2.0 Recommendations
9.2.1 Guidelines for managers of NTBFs
9.2.2 For further research
9.2.3 Some concluding remarks

"Now all has been heard here is the conclusion of the matter: fear God and keep his commandments for this is the whole duty of man. For God will bring every deed into judgement including every hidden thing whether it is good or evil."

Ecclesiastes 12v13

OUTLINE

The perspective of this thesis has arisen through the researcher having been a participant within a new technology based firm. The discussion of Chapter 8 examined and analysed the practices of a NTBF and related them to the concepts of strategy and innovation management as derived from the literature. As longitudinal research it thus fulfilled the criteria demanded of grounded theory. The analysis of Chapter 8 identified areas of strategy and management in which Dutom Meditech were specifically deficient. However, in order that the experience of that company is made available for wider discussion this chapter draws some broader conclusions on the role of NTBFs and their conduct of innovation.

9.1.0 Product Innovation in a New Technology Based Firm

9.1.1 The Place of New Technology Based Firms

The establishment, recognition and encouragement of new technology based firms is a recent phenomenon. This thesis has observed the change in opinion of the theorists and policy makers of the role of these small firms. This has moved away from a belief that innovation is the monopoly of the large established firm and towards a recognition that small firms have a contribution to offer. New technology based firms in the small firm sector have been identified as the seedbeds for radical innovation especially where the investment threshold is low.

Since the late 1970s the contribution to the economy of established large manufacturing industry has declined. Large firms have shed jobs and increased the pool of unemployed labour. In contrast the innovations and wealth generated by the small firms of Silicon Valley have set an example which entrepreneurs and governments have sought to emulate.

New technology based firms are currently viewed therefore, as a means of providing wealth, technology transfer and jobs. This has been reflected in the measures introduced by the government to encourage these firms and by the increased media attention devoted to them. Hence the NTBFs, staffed largely by scientists applying the latest technology, are believed to carry with them hopes of prosperity not just of their founders but also of society as a whole. However, when assessing the potential of these firms it should be remembered that radical innovation is recognised as high in risk and difficult to manage successfully.

Through having been a researcher and participant in a NTBF, this thesis offers a novel perspective on the work of such firms. As a result it has been a longitudinal study and has subjected the company to a more intense examination than is commonly available. It provides a contribution of experience which has been tested in the commercial world.

9.1.2 Deriving an Innovation Strategy for the NTBF

The thesis sought to derive a strategy for innovation which was appropriate for a NTBF. The strengths and weaknesses of the firm were assessed against the features identified with successful innovation. In approaching the difficult task of radical innovation the new technology based firm exhibits a number of potential assets and liabilities.

A major potential asset has been attributed to the staff. They are typically strong on technical experience, having previously worked at the forefront of the technology in industry or academia. They are scientists becoming businessmen with the business founded upon scientific expertise. The small size of the firm enables the staff to have short communication chains both within the firm and with the market. The firm therefore has the potential to react quickly and flexibly to the changing demands of the technology or the market.

Against these assets the firm has a number of liabilities, some of which may also be attributed to the staff. The staff frequently have limited experience of business and especially of the marketing function. Highly qualified techical staff represent a high proportion of the overheads. In addition the firm has none of the advantages of the large firm e.g. it does not have the capacity for mass production nor an established distribution system. Nor does it have the resources to establish them. Finally the company and its products are without reputation in the market place.

The thesis proposed that the corporate strategy of the firm would significantly affect the success of its innovations. This was able to be assessed because of the characteristic strengths and weaknesses of the NTBF and its place in an emerging industry. An appropriate strategy for a NTBF was derived.

This strategy should combine the intention to grow in line with the emerging industry while acting to define the standards of that industry. The firm is commited to trade at the forefront of new technology. Hence it may pioneer new products in the market. Alternatively it may evaluate the pioneer product, both in terms of the technology and the market response, in order to rapidly introduce new products which improve upon the pioneer product in line with the demands of the market.

The limited resources of the firm and absence of a distribution network require the company to sell its products to a niche in the market. In order to make full use of limited resources, the products and services of the company should be well integrated, but the company may extend its resources by the use of outsiders.

9.1.3 The Contribution of Experience

The thesis reports and analyses the experience of a NTBF throughout its attempts at radical innovation. The experience documented was one of costly failure. As such, the first contribution is to issue a warning to policy makers, government, entrepreneurs and investors. It acts as a reminder that radical innovation is a process high in risk and uncertainty. If the performance of this company is repeated throughout new technology firms in general, then the NTBF sector will be unable to attain the aspirations foisted upon them. A cross company and cross industry study would be necessary to substantiate whether NTBFs have realised their potential.

Chapter 8 analysed the strategies and practices of a NTBF and identified mismatches between those adopted at the firm and the appropriate strategies and practices derived from the literature. These mismatches represent areas which contributed to the failure of the firm in the pursuit of innovation. Some general principles can be drawn regarding NTBFs.

New technology based firms trade in emerging industries. The features observed in the requirements of the industry validate the patterns proposed for these emerging industries.

The proposal that the corporate strategy of the firm must be conducive to innovation or it will prove detrimental to the company's management of their innovations, is supported. The corporate strategy provides the framework for innovation defining the means and tools by which the innovations are to be brought about. In the NTBF this link between the corporate strategy and product innovation can be identified because of the small size of the firm and its commitment to innovation.

The research has demonstrated that certain strategic postures inhibit the success of innovation while highlighting the importance of others. In particular attention is drawn to the importance of synergy in the strategy. The effects of synergy are revealed both in the degree of integration of the products and services offered by the company, and in the degree of coupling between the business functions. Through adopting a synergistic strategy it can be ensured that the limited resources of the NTBF are well used.

The interaction between synergy in the strategy and coupling in the management of innovation is dynamic. The interaction arises because neither the elements of strategy nor the stages of innovation are solely dependent upon one business function. Implicit in the formulation of the synergistic strategy is the intent that the different business functions support and complement each other. This requires good coupling if the strategy is to be implemented and an understanding of the contribution of coupling if the strategy is to be formulated.

Innovation is an interdisciplinary task and should be managed as such. The literature and the experience of the NTBF provide examples of the breakdown of innovation occurring at the interdisciplinary interfaces. The importance to innovation of good coupling between business function is therefore substantiated by this longitudinal research. Further, the link between synergy and coupling noted above occurs because both strategy formulation and innovation management are interdisciplinary tasks. As such the process of innovation has an interdisciplinary character throughout, i.e. it is laterally interdisciplinary. This should be reflected in the models which are used of the process, and the "pipeline model" of innovation is found to be deficient at this point.

The importance of synergy and coupling to the NTBF is such that two caveats may be issued regarding the resources sought and the pursuit of technology.

The literature had proposed that the NTBF could benefit from the use of outsiders, thereby extending the resources available to the firm. While not refuting this, this research has identified potential problems can arise from the use of outsiders. The use of outsiders may reduce the degree of coupling between business functions. If this occurs it will prove detrimental to the management of innovation. Secondly, they should not be used merely to reinforce the existing values of the firm.

Because the interdisciplinary nature of innovation is misunderstood a particular danger for NTBFs is to concentrate management attention upon R&D which is perceived as the strength of the company. The "pipeline model" reinforces this misconception through segregating innovation into sequential "research", "development" and "commercialisation" stages. Instead of a sequential approach to innovation, the technical functions need to be complemented by a suitable marketing function, throughout. The importance of this has been particularly illustrated when a "follower strategy" was required. A strategy which emphasises R&D at the expense of the other business functions is likely to be inadequate. This is not to argue that the NTBF must develop expertise in all the functions of business internally. It simply argues that good coupling between the functions is essential at all times, whether they are located within or without the NTBF itself.

In order to encourage successful innovation by NTBF the government has introduced measures to encourage the financial support of innovation in small firms. This research has demonstrated that these measures have made financial support available to the NTBF. However, financial support alone does not guarantee successful innovation and the additional resources available may be squandered by firms through inappropriate strategic and practical management of their innovations. Hand in hand with the provision of finance must go the education of the entrepreneur in the correct management of these resources.

9.2.0 Recommendations

9.2.1 Guidelines for Managers of NTBFs

This thesis results from industrial and academic collaboration. So the following guidelines have been compiled to assist the managers of new technology based firms to avoid the pitfalls identified in this thesis.

On innovation

1 Radical innovation is a high risk activity and there are many inponderables within the process.
- Err on the side of the pessimistic in predictions.
- Identify and be prepared to learn from mistakes.

2 Innovation is an interdisciplinary task throughout. Treat it as such.
- Seek contributions from the different business functions at every stage.

- Especially ensure early contributions are made by marketing and market research.

On strategy

3 A correct strategy is fundamental for success.

- NTBFs have strengths in being small flexible organizations able to react quickly to changes in the market and technology.
- NTBFs are based in emerging industries which follow a recognisable demand pattern.
- The company strategy should be based on the above strengths and targetted to meet the requirements of the market.

4 Synergy is vital to the strategy to ensure best use is made of the limited resources of the firm.

- Carefully define the business of the company.
- Reject diversification unless it can be shown to complement the existing trade of the firm directly, within the business definition.
- Ensure the different business functions contribute to the strategy formulation.
- Offer well integrated products and services to similar customers using similar technology or production capacity.
- Ensure projects are screened for business, technical, market and financial viability. Do not allow projects to develop because of "gut feel".

5 Identify a market niche for the products.

- Reject a strategy to sell products to a vast market, requiring an extensive distribution system.
- Reject trying to sell products on cost benefit.

- Adopt a strategy to sell the latest technology products modified to meet the user requirements.

6 Use resources outside the firm to extend the expertise and facilities available to the firm e.g. production, distribution. But:
- Ensure the outsiders are well coupled to the internal functions.
- Do not simply delegate these responsibilities.
- Use outsiders to complement existing values not to reinforce them.

On R&D

7 R&D is frequently perceived as the strength of the company. But development often overruns both time and budget.
- R&D ability is frequently overestimated.
- Allow marketing contributions to direct R&D effort.
- Do not concentrate resources on R&D to the detriment of other functions.
- Budget R&D projects for their discounted cash flow.
- Develop the technology to fit the requirements of the emerging industry.
- Ensure scale-up to production is fully prepared.

On marketing

8 This is frequently a major weakness of the company, because of the absence of training and experience. The importance, contribution, tools and language of marketing are misunderstood and ignored.
- Marketing has a contribution to make throughout the innovation process, not just at the commercialisation stage.
- Act to strengthen this area, not to ignore or simply delegate it.
- Use market research to provide direction to R&D.

- Use marketing tools. Segment and target the market.
- Seek a market niche.

On organization

9 Staff represent the greatest asset of the firm and also a major proportion of the overheads. Ensure their full potential is realised in line with the business strategy.

- Encourage champion potential.
- Appoint to meet clearly defined needs.
- Encourage good communication across the firm.
- Delegate responsibility clearly.

9.2.2 For Further Research

Two recommendations for further research arise from this work. These should assist the policy makers and government assess the return to be gained from encouraging the new technology based firm sector.

1 There is a need to assess the cost of investment in new technology based firms. The overall performance of NTBFs should be researched in terms of the successes and failures of the innovations they have attempted, the wealth generated and the number of jobs created. The cost and success rate of pioneering new technology could then be evaluated. This should then be compared with estimates of the costs and success rate of encouraging a policy of imitating the leading technology as opposed to trying to pioneer it.

2 This work has identified some of potential pitfalls of the NTBF. It has noted that public money has been invested in NTBFs but that the provision of finance alone is insufficient. If public money is

invested in NTBFs, the public require some assurance that it is being used to good effect. Some research into the type of assistance these companies would be prepared to receive to assist them avoid some of the errors reported in this work, would be of value. By providing this assistance, concurrently with the funding of innovation, it may prove possible to protect the whole investment and yield a greater return.

9.2.3 Some Concluding Remarks

This research has demonstrated that industry requires interdisciplinary training, and government papers have expressed the policy that universities should increase their industrial contact. If the university system is to equip students to be the future managers of innovation in industry, then some interdisciplinary training and research at the interface with industry is necessary. This would be consistent with the needs identified and the policy expressed.

The IHD Scheme has attempted to embrace both of these goals. Yet it is currently viewed by the planners at this university as inconsistent with the "university mission". This has come about because the anomalous IHD "Unit structure" and action research methodology does not concur with the criteria established by the University Grants Committee to evaluate basic research.

Collaborative research of the IHD type exhibits uncertainties and changes in direction atypical of basic research. These can be detrimental although some argue that they are the constituents which make the research such a valuble training. The IHD Scheme has attracted projects which have enabled innovation to be studied at first hand. Whether the Scheme can continue to do so after the reduction in staff, the loss of its Unit status and the reduced pool of academic supervision in the university as a whole, remains for time and future theses to tell.

****

APPENDIX A

DUTOM MEDITECH NEWS

APPENDIX B

THE DETERMINATION OF TRACES OF FORMALDEHYDE

APPENDIX C

EXTRACTS FROM DUTOM MEDITECH PLC SHARE PROSPECTUS

PLUS THE COMPANY ACCOUNTS

DUTOM MEDITECH PLC
(formerly Gavinmain Limited)

ACCOUNTS

30 APRIL 1984

Coopers & Lybrand
Chartered Accountants,
Birmingham.

DUTOM MEDITECH plc
(formerly Gavinmain Limited)

Profit and loss account
for the period from 22 June 1983 to 30 April 1984

	Notes	1984 £
Turnover	3	58,614
Loss on ordinary activities before taxation	4	(535,181)
Tax on loss on ordinary activities	9	-
Loss on ordinary activities after taxation		(535,181)
Extraordinary item	10	(380,895)
Loss for the financial period		(916,076)

STATEMENT OF ACCUMULATED LOSSES

Loss for the financial period	(916,076)
Accumulated losses at 30 April 1984	(916,076)

The notes on pages 9 to 18 form part of these accounts.

Auditors' report page 5.

DUTOM MEDITECH plc
(formerly Gavinmain Limited)

Statement of source and application of funds
for the period from 22 June 1983 to 30 April 1984

			Period 8 February 1983 to 21 June 1983	
	£	£	£	£
SOURCE OF FUNDS				
Issue of share capital		1,187,498		12,502
Sales proceeds of tangible fixed assets		27,000		-
Loans		190,139		-
Total source of funds		1,404,637		12,502
APPLICATION OF FUNDS				
Loss on ordinary activities before taxation	(535,181)		-	
Adjustments for items not involving movement of funds				
Depreciation	35,576		-	
Loss on sale of tangible fixed assets	296		-	
	(499,309)		-	
Loans repaid	(13,333)		-	
Purchase of goodwill	(380,895)		-	
Purchase of tangible fixed assets	(324,238)		-	
Share issue costs	(147,715)		-	
Total application of funds		(1,365,490)		-
		39,147		12,502
INCREASE IN WORKING CAPITAL				
Increase in stocks	45,305		-	
Increase in debtors	206,163		-	
Increase in creditors falling due within one year, excluding bank overdraft, loans and lease creditors	(288,287)		-	
		(36,819)		-
Movement in net liquid funds:				
Cash at bank and in hand	97,598		12,502	
Bank overdraft	(21,632)		-	
		75,966		12,502
		39,147		12,502

The notes on pages 9 to 18 form part of these accounts
Auditors' report page 5.

DUTOM MEDITECH plc
(formerly Gavinmain Limited)

Balance sheet - 30 April 1984

	Notes	30 April 1984		21 June 1983	
		£	£	£	£
FIXED ASSETS					
Tangible assets	11		261,366		-
CURRENT ASSETS					
Stocks	12	45,305		-	
Debtors	13	206,163		-	
Cash at bank and in hand		110,100		12,502	
		361,568		12,502	
CREDITORS: amounts falling due within one year	16	(343,699)		-	
NET CURRENT ASSETS			17,869		12,502
Total assets less current liabilities			279,235		12,502
CREDITORS: amounts falling due after more than one year	17		(143,026)		-
			136,209		12,502
CAPITAL AND RESERVES					
Called up share capital	18		100,000		12,502
Share premium account	19		952,285		-
Accumulated losses			(916,076)		-
			136,209		12,502

These accounts were approved by the Board on 22 November 1984

C A ROBSON)
) Directors
R C PRICE)

The notes on pages 9 to 18 form part of these accounts.

Auditors' report page 5.

No company accounts were filed for the year 1984/85 since Dutom Meditech plc were taken into receivership two weeks prior to the year end. Instead the directors filed the following statement of affairs.

G

Form No. 109

109

THE COMPANIES ACTS 1948 TO 1976

Statement as to affairs

Pursuant to section 372(1)(b) and 373(2) of the Companies Act 1948

In the matter of a debenture or series of debentures registered on 5TH JULY 1983

Please do not write in this binding margin

For official use

Company number 1697521

Name of Company

Please complete legibly, preferably in black type, or bold block lettering

DUTOM MEDITECH PLC ~~Limited~~*

* delete as appropriate

Statement as at the SIXTEENTH day of APRIL 1985 being the date of the appointment of the Receiver

Please refer to notes on back page

We, COLIN ANTHONY ROBSON

of 147, LICHFIELD ROAD, STONE, STAFFORDSHIRE,

a director of the above-named company

and DR. JOHN MICHAEL THOMPSON

of 44 MANOR ROAD NORTH, EDGBASTON, BIRMINGHAM B16 9JS.

the secretary thereof declare that the statement made overleaf and the several lists hereunto annexed marked † are a full, true and complete statement as to the affairs of the above-named company on the SIXTEENTH day of APRIL 1985 being the date of the appointment of the Receiver. And we make this solemn declaration conscientiously believing the same to be true, and by virtue of the Statutory Declarations Act 1835

†Note The several lists annexed are not exhibits to the declaration

Declared at Birmingham

this 18th day of October 1985

Before me [signature]

Signatures of declarants: John M. Thompson; Colin A. Robson

‡or Notary Public or Justice of the peace or Solicitor having the powers conferred on a Commissioner for Oaths. The commissioner is requested to read note 2 overleaf

A ~~Commissioner for Oaths~~‡ Solicitor authorised to administer oaths

Presentor's name, address and reference (if any):	For official use Liquidation section	Post room
MESSRS. THORNTON BAKER & Co, CHARTERED ACCOUNTANTS, KENNEDY TOWER, ST. CHAD'S QUEENSWAY, BIRMINGHAM B4 6EL		

page 1

Statement as to affairs of* Rotan Medtech PLC

on 16th April 1985 being the date of the appointment of the receiver showing assets at the estimated realisable values and liabilities expected to rank

Please do not write in binding margin

Please complete legibly, preferably in black type, or bold block lettering

*insert full name of company

ASSETS NOT SPECIFICALLY PLEDGED (as per list "A")	Estimated realisable values £
Balance at bank	–
Cash in hand	–
Marketable securities Investment in Advanced Rotan Products Limited	40,000
Bills receivable	–
Trade debtors	–
Loans and advances	–
Unpaid calls	–
Stock in trade UK & USA Stocks of Components & Finished Goods	20,000
Work in progress	–
Freehold property	–
Leasehold property	–
Plant and machinery / Furniture, fittings, utensils etc	15,000
Patents, trade marks, etc.	–
Investments other than marketable securities	–
Other property	–
	75,000

ASSETS SPECIFICALLY PLEDGED (as per list "B")	a estimated realisable values £	b due to secured creditors £	c deficiency ranking as unsecured £	surplus carried to last column £
Freehold property	100,000			
Tank Destroyers	8,188	145,000	34,450	–
KAT Repayment	2,362			
Leased Assets	24,258	47,902	23,644	–
	£134,808	£192,902	£58,094	£ –

Estimated surplus from assets specifically pledged –

Estimated Total assets Available for preferential creditors, debenture holders secured by a floating charge and unsecured creditors (carried forward to next page) 75,000

†please refer to note † overleaf before completing this form

Summary of Gross Assets	d £
Gross realisable value of assets specifically pledged	134,808
Other assets	75,000
Gross Assets	£209,808

page 2

Gross Liabilities £		£	£
	Estimated Total Assets available for ~~Preferential Creditors~~ Debenture Holders secured by a floating charge and Unsecured Creditors* (brought forward from preceding page		75,000
	LIABILITIES (to be deducted from surplus or added to deficiency as the case may be)		
134,158	**Secured Creditors** (as per List "B") to extent to which claims are estimated to be covered by Assets specifically pledged (item (a) or (b) on preceding page whichever is the less) (insert in "Gross Liabilities" column only)		
82415	**Preferential Creditors** (as per List "C")		82,415
	Estimated Balance of assets available for Debenture Holders secured by a floating charge and Unsecured Creditors*	£	7415
34450	**Debenture Holders** secured by a floating charge (as per List "D")		34450
	Estimated ~~Surplus~~ Deficiency as regards Debenture Holders*	£	44,865
	Unsecured Creditors (as per List "E"):	£	
–	Estimated unsecured balance of claims of Creditors partly secured on specific assets brought from preceding page (c)	–	
103,763	Trade Accounts	103,763	
–	Bills Payable	–	
900	Outstanding Expenses Payment in Lieu of Notice	900	
900	Redundancy Payments	900	
32917	PAYE/NIC	32,917	
23 644	Lease Creditors	23,644	
	Contingent Liabilities (state nature)		
20,007	(DOI) Pre-Insolvency Award Scheme	20,007	
68818	D.T.L. Microprocessor Application Scheme	68818	270,949
			312 814
	Estimated ~~Surplus~~ Deficiency as regards Creditors* being difference between:	£	
	Gross Assets brought from preceding page d........	209,808	
	and		
	Gross Liabilities as per column e........	522 622	
£522 622		312,814	

Issued and Called up Capital £

– preference shares of – each

– called up –

2,000,000 ordinary shares of 5 Pence each

2,000,000 called up @ 5 Pence Per Share 100,000

Estimated ~~Surplus~~/Deficiency as regards Members* (as per List "F") £ 412,814

Please do not write in this binding margin

Please complete legibly, preferably in black type, or bold block lettering

**Please refer to note 1 overleaf before completing this form*

page 3

No company accounts were filed by the Receiver for the year 1985/6. Instead the Receiver filed the following abstract of transactions

Form No. 57

G THE COMPANIES ACTS 1948 TO 1981 **57**

Receiver or manager's abstract of receipts and payments

Pursuant to sections 372(2) and 374(1) of the Companies Act 1948

Please do not write in this binding margin

Please complete legibly, preferably in black type, or bold block lettering

To the Registrar of Companies

For official use | Company number: 1697521

Name of company

DUTOM MEDITECH Limited*

*delete if inappropriate

†delete as appropriate

[I] [We]† ROY EWART ADKINS AND GEOFFREY HARRISON

of KENNEDY TOWER, ST. CHADS QUEENSWAY, BIRMINGHAM, B4 6EL

‡Enter description and date of instrument containing the powers under which receiver or manager is appointed

appointed [receiver] [manager]† of the above-named company under the powers contained in‡

A DEBENTURE IN FAVOUR OF BARCLAYS BANK PLC GIVING A FIXED AND FLOATING CHARGE OVER THE UNDERTAKINGS AND ALL PROPERTY AND ASSETS OF THE COMPANY

dated 5TH JULY 19 83

present overleaf [my] [our]† abstract of receipts and payments for the period from 16TH APRIL 1985 to 15TH APRIL 1986

number of continuation sheets (if any) attached

Signed G. Harrison

Date 6 May 1986

Presentor's name, address and reference (if any):
GRANT THORNTON
KENNEDY TOWER
ST. CHADS QUEENSWAY
BIRMINGHAM
B4 6EL

D4276

For official use
Liquidation section | Post room

Page 1

ABSTRACT

Receipts

16TH APRIL 1985 TO 15TH APRIL 1986	£	p
Brought forward		
Rent Received	1,816	66
Book Debts	7,773	9?
Receiver's Trading Receipts	10,745	28
Sale of Stock	15,000	00
Sale of Plant & Machinery	20,501	10
Sale of Motor Vehicles	800	00
Sale of Freehold Property	105,000	00
Bank Deposit Interest Received	77	56
V.A.T.	11,229	64
Thorn EMI - Sale of Intellectual Property	25,000	00
Post Office - Refund on Franking Machine	19	72
PTS Consultancy - Service Charge re Rented Property	2,053	48
Advanced Protein Products - Sub Tenant Service Charge	4,013	12
Carried forward	204,030	53

Payments

16TH APRIL 1985 TO 15TH APRIL 1986	£	p
Brought forward		
Insurance	2,818	00
Rates	252	95
Heat Light & Power	2,122	24
Telephone	1,451	22
Materials	3,474	32
Gross Wages	11,683	27
Overheads	1,854	20
Agents Costs	3,935	67
Book Debt Collection Costs	18	28
Solicitor's Fees	3,501	95
Receiver's Remmeration	12,500	00
Receiver's Disbursements	632	22
Statement of Affairs Fee	300	00
Payments to Statutory Undertakings	1,104	53
HP/Lease Companies	5,473	50
Debenture Holder	88,000	00
Employees - Preferential	1,894	92
VAT Payment - Post Appointment	6,997	31
Carried forward	148,014	58

Please do not write in this binding margin

Please complete legibly, preferably in black type, or bold block lettering

Note

The receipts and payments must severally be added up at the foot of each sheet and the totals carried forward from one abstract to another without any intermediate balance so that the gross totals shall represent the total amounts received and paid by the receiver or manager since the date of appointment

Page 2

Please do not write in this binding margin

Please complete legibly, preferably in black type, or bold block lettering

Payments	£	p
Brought forward	148,014	58
Redirection of Mail	13	00
Bank Charges 6 Commission	81	37
Wragge & Co. Payment re vacation of Dutton property	10,400	00
Service Charge lost i. vacation by PTS Consultancy	1,708	26
VAT	4,558	30
Refuge Disposal	34	71
Carried forward	164,810	22

Page 3

APPENDIX D

KEY PERSONNEL AT DUTOM

Key Personnel at Dutom

Mr J Dutton, aged 32 in 1981, had qualified as a Management Accountant with the Thorn Electronics group, where he had become the Management Accountant of a subsidiary company. From 1970 to 1973 he was a Consultant/Lecturer at Aston University specializing in small business research. From there he joined the BL Group and worked in management training and financial management positions finishing up as Financial Controller of the group's African subsidiaries.

He left BL in 1980, after being appointed as Director of a Finance Company and related Property company Kinrade Finance Ltd and Kinrade Property Ltd. He became a director or Dutom in June 1980 at the time of the company's formation.

Dr J Thompson, aged 39 in 1981, gained a degree in Chemistry from Birmingham University in 1964, and remained at the University to complete his PhD, in analytical chemistry applied to herbicides in soil. After his PhD he worked for a year in Sweden, before returning to Birmingham University as a lecturer in Physiology and later Anaesthetics. He lectured in a range of subjects at the medical/chemical interface, and undertook research in drug behaviour and air pollution monitoring of anaesthetics.

At the time of formation of the company, Professor R Belcher, acted as non-executive chairman. He was Professor of Analytical Chemistry at Birmingham University, and widely respected. Unfortunately he died in 1982 soon after the company had begun its operation, thus leaving Mr Dutton and Dr Thompson as the only Board Members.

The first employee of the company was Dr R Sithamparanadarajah, (Dr Rajan), he joined the company in 1981, aged 30. He held an HND in Applied Chemistry and had recently completed his PhD at Birmingham University under the supervision of Dr Thompson. They had worked on the monitoring of operating theatre air and had invented the Adsorba monitor for this. He was appointed as the Manager of analytical chemistry work.

Dr D Henry had gained a BSc in Electrical and Electronic Engineering, and then he joined the Department of Anaesthetics at Birmingham University to complete a PhD on a computer model of gas movement in the lungs. He later worked as a Computer Officer at Birmingham University Computer Centre and also engaged in computer systems and programming consultancy. He was appointed to Dutom staff in April 1981 to run the computer systems side of the company.

Dr M Shakespeare, joined Dutom in July 1981 aged 30, with a degree in Biochemistry from London University, and a PhD from Lanchester Polytechnic. He had experience of immunology and protein purification, he was employed as Manager of Biotechnology aspects of the company's business.

Mr H W Bryan, joined the company in July 1981, from the Space Research Department at Birmingham University, where he was Chief Technician. He had been responsible for the design of electronics for various rocket and satellite experiments. He was to be in charge of analogue electronic circuit design.

Mr G Clark, joined the company in July 1981, aged 34, he had been a colleague of Mr Dutton at BL and was appointed as General Manager.

Dr E Hartmann, a graduate of the American University in Cairo, joined Dutom in October 1981, from Birmingham University where he had just completed a PhD in environmental chemistry. His research was on interactions of metals with soils, and initially he was appointed as an Analytical Chemist.

Mr T May joined Dutom in May 1982, aged 34. He held a HNC in Chemistry and had been employed as a salesman, product manager and marketing manager by laboratory equipment manufacturers. Prior to joining Dutom he had worked with Millipore (UK) Ltd and with Gelman Sciences (UK) Ltd particularly marketing filtration equipment. He was appointed as Sales Manager, a title later changed to Sales and Marketing Manager.

The company raised a public share issue over the summer of 1983 renaming and recapitalizing the company as Dutom Meditech plc. In line with this recapitalization, a number of appointments were made.

Mr C Robson, took shares in the company during Spring 1983. He was trained as an engineer and held Chartered Engineer status. Prior to joining Dutom he had worked with Century Oils Ltd where he had attained the position of Marketing Director. He was aged 51 in June 1983 when he became a non-executive Director of Dutom, he also was a Director of Baxefoxe Ltd, an engineering company.

Mr A Bridgewood, the brother-in-law of Dr Thompson formally joined Dutom in June 1983 aged 43. He held a HNC in Chemistry and had worked for ten years in management positions of various industrial chemical companies. Immediately prior to joining Dutom he was Marketing Manager for Parket-Hannifin (UK) Ltd. Initially he was engaged on commission by Dutom as a salesman, but this proved unsuccessful and he was engaged as the General Manager of the OEH division of Dutom's business, as the company looked to expand in line with its share issue.

Mr P Linder was a graduate in economics, and had been a colleague of Mr Dutton at BL where he had qualified as a Management Accountant. He had been Finance Director of one of BL's overseas subsidiaries. Aged 31, he was appointed Company Secretary in June 1983 with the purpose of him becoming Finance Controller after the share issue was completed.

Two prominent figures were appointed to the Dutom board on completion of the Dutom share issue as non-executive Directors. The Rt Hon Sir Neil Marten, ex-MP for Banbury and ex-Minister for Overseas Development, became Dutom Chairman. Professor R Perry, aged 43, a PhD contempory of Dr Thompson's at Birmingham University, and then the Professor and Head of Public Health and Water Resource Engineering at Imperial College, became a Director.

In addition to the staff appointments made to coincide with the share issue Dutom also appointed two panels of advisors. These were published in the prospectus for the share issue and make impressive scientific reading. The brief and membership of these two panels as reported in the prospectus are reproduced in the following Table.

Table 1 The Dutom Scientific Advisory Panel and Consultants.

Scientific Advisory Panel

The Panel will assist the Company in the formulation of medium and long term research and development objectives. It will also be involved in reviewing current research and development activities of the Company.

PROFESSOR OWEN LYNDON WADE, CBE, MA, MD, BChir (Cantab), FRCP, FRCPI, Dean of the Faculty of Medicine and Dentistry and Professor and Head of the Department of Therapeutics and Clinical Pharmacology, University of Birmingham.

PROFESSOR J MALCOLM HARRINGTON, BSc, MB, MRSC, MSc, MD, FRCP, FFOM, Professor of Occupational Health at the University of Birmingham and Director of the Institute of Occupational Health which is based at the University.

PROFESSOR S ALAN BARKER, BSc, PhD, DSc, CChem, FRSC, Professor of Carbohydrate Chemistry, University of Birmingham.

PROFESSOR JOHN MANN, BE, PhD, FBIM, Professor of Chemical Engineering, University of Technology, Loughborough.

PROFESSOR RICHARD T BOOTH, DIC, PhD, CEng, FIME, MIISO, Professor and Head of the Department of Environmental and Occupational Health, University of Aston in Birmingham.

DR RODNEY STEWART BARRATT BSc, PhD, CChem, FRSC, Lecturer in Environmental Health University of Aston in Birmingham.

Consultants

A panel of consultants is being established to assist and advise in specific technical and commercial areas of interest to the Company. Members of the panel are:-

DR EDMUND ROY CLARK, BSc, PhD, CChem, FRSC, MIWES, Lecturer in Analytical Chemistry, University of Aston in Birmingham.

DR SPYRIDON D COMIS, BSc, PhD, MIBiol, Lecturer in Physiology, University of Birmingham.

FRANK S GILL, BSc, MSc, CEng, MIMinE, MIOH, Dip Occ Hyg, Senior Lecturer in Occupational Hygiene, University of Birmingham.

DR PETER HUTTON, BSc, PhD, MB, ChB, FFARCS, Lecturer in Anaesthesia, University of Bristol.

DR DAVID A SCRIMSHIRE, BSc, PhD, CEng, MIProdE, AFIMA, Lecturer in Production Engineering, University of Aston in Birmingham and a Director of Techno-Economic Consultants Limited (Trading under the name of Dewtec).

DR WILLIAM I STEPHEN, JP, BSc, PhD, DSc, CChem, FRSC, Reader in Analytical Chemistry, University of Birmingham.

APPENDIX E

THE DEVELOPMENT OF A SYSTEM TO EVALUATE THE ADSORBA MONITOR

1.0 Theory

In order to exploit the Adsorba/Desorba system commercially it was imperative that a broad data base was established, such that the advantages and limitations of the system were known. With this information Dutom would be in a position to answer customer enquires, predict sampling strategies and develop collection methods for further chemicals.

Published data on the performance of the Adsorba system was limited, and little work had been done to fully characterize the adsorption of typical pollutants on the porous polymers employed in the Adsorba. Of the studies made,*(1-3)* Brown and Purnell did derive breakthrough and safe sampling volumes for a range of chemicals. However, these studies were difficult to relate to the performance of the Adsorba, and the assumptions and empirical definitions made in the calculations mean this data could only be used as a crude guide. A method was therefore required which enabled measurements of the performance of the Adsorba to be made.

1.1 Gas Chromatography

Gas chromatography (gc) was first used to measure distribution isotherms in 1946.*(4)* The frontal analysis technique was introduced by James and Phillips*(5)* to study adsorption and gas-solid isotherms were first studied using a chromatographic technique by Gregg and Stock.*(6)* The treatments defined in these early papers were progressively refined during the 1960s and have been extensively used to investigate adsorption equilibria.

The gc methods are quicker than the static methods for obtaining data, and can be used at low surface coverages. A particular advantage for this study was that experiments by the frontal analysis gc technique mimic the use of the Adsorba in the field. Frontal analysis was the gc method selected because:

1. it may be used on diffuse and self sharpening boundaries, i.e. the adsorption and desorption process may be studied.

2. It is experimentally applicable to short columns so the Adsorba itself may be used as the column.

3. It mimics the field use of the Adsorba.

1.2 Basic theory of frontal analysis

A stream of pure carrier gas is equilibrated with a gc column and then suddenly replaced with a continuous stream of carrier mixed with solute at a constant concentration. This produces two regions of differing concentration separated by a sharp boundary. The boundary migrates through the chromatographic column, but breakthrough is delayed by solute being abstracted from the gaseous phase by the column. The total number of moles on the column is then given by:

$$n = ctrF$$

where c = concentration of solute breaking through the column
tr = retention time at that concentration
F = flow rate

Therefore: $n = AF$
where A = area behind the front

The number of moles adsorbed on the stationary phase is then determined by subtracting the number of moles in the gas phase ng, which is given by the retention time of a non adsorbed front.

Thus: $q = (n-ng)/m$
where q = moles adsorded per unit mass
m = mass of adsorbent

An isotherm can then be plotted by operating at a fixed temperature and measuring the area (A) behind the frontal boundary as the concentration varies.

1.3 The front profile

The front is introduced as a sharp boundary. The solute concentration examined at the oulet of the column is initially zero and rises to the inlet concentration as the front breaks through and the column reaches equilibrium. Hence the detected front is S shaped. The slope of the curve however is dependent upon the nature of the isotherm and isotherms typical of the adsorption of organics on a porous polymer exhibit a self sharpened adsorption boundary and a diffuse desorption boundary.

The shape of the front is also affected by changes in the flow rate as the front migrates along the column and by features arising from deviations from ideality in the system. In order to take account of these, refinements to the mathematical treatment have been made. The two most important effects arise from the pressure gradient and the sorption effect.

Pressure gradient

The variation of pressure along the column has two effects.

a) The flow rate along the column length varies as the gas expands and this must be accounted for in the calculation of the actual flow rate as measured at the outlet pressure.

b) As the gas expands the mole fraction of solute in the carrier will vary. Thus the mole fraction at the outlet should be used.

By using a short column i.e. the Adsorba, the pressure gradient is kept to a minimum thereby reducing these pressure effects.

Sorption Effect

The sorption effect occurs because as sorption takes place the flow rate across the column is affected. This has consequences for the flow rate and the frontal shape.

Comprehensive works have been written(7-13) describing the gc techniques in detail, the derivation of the equations including correction factors refining the earlier treatments, and the application of the techniques to physicochemical measurement. Thus it is sufficient here to quote the equation used for these studied and refer readers to Conder for its derivation.(14)

$$q = \frac{jPoF}{RTm}\frac{A'y}{h}$$

where Po = outlet pressure F = flow rate
y = mole fraction of solute at outlet R = gas constant
m = mass of stationary phase T = temperature in K
j = correction factor for the pressure gradient
A' = area behind the curve corrected for dead volume
h = height of trace above baseline at outlet concentration

1.4 Physical Data obtainable from the Experiments

Number of Theoretical Plates

Two equations have been proposed to calculate the number of theoretical plates, N, (which is a measure of the efficiency of the column at resolving components) in the column from frontal data. These are as follows:

$$N = 2\pi\left(\frac{SVg}{c}\right)^2 \qquad \text{ref.}(2)$$

where c = inlet concentration:
Vg = retention volume at 50% inlet concentration
S = slope of the front at 50% inlet concentration

or

$$N = \frac{V'Vg}{(Vg-V')^2} \qquad \text{ref.}(15)$$

where V' = retention volume at 15.87% inlet concentration

Retention volumes and isosteric heats

Gc has been widely used to obtain thermodynamic data since Greene and Pust(16) showed heats of adsorption could be determined. Working from the Clapyron-Clausius equation and assuming ideal gas behaviour gives:

$$\ln Vg = \frac{\Delta H}{RT} + \text{constant}$$

where H = differential molar isosteric heat of adsorption

Assuming H is independent of temperature many workers(1-3),(17-19) have derived H from the slopes of these plots. Conder(20) argues that the plot should be ln Vg/T versus 1/T giving values larger by RT but the difference is usually sufficiently small to not affect the linearity of the plots.

By extrapolating the straight line of the above equation the retention volume may be determined at any temperature, which enables information on the performance of the Adsorda at room temperature and at desorption temperatures to be obtained.

Differential Molar Entropy

Having obtained a value for ΔH, then ΔS may be derived using the classical equation.

$$\Delta G = \Delta H - T\Delta S$$

However, care must be exercised as to which standard state is referred to. Various workers have used different standard states.(5),(21),(22)

Breakthrough

Breakthrough is an important measurement in the performance of a pollutant monitor but breakthrough volumes have been arbitrarily defined. Some authors have used the detection of 1% of the input concentration in the effluent(1),(23),(24) others an arbitrary fraction of the retention volume.(25) Because these studies fail to take account of the number of theoretical plates in the column and are dependent upon the inlet concentration selected the breakthrough is defined at a variable collection efficiency.

Senum(26) proposed that breakthrough volumes for any desired collection efficiency can be determined irrespective of the input concentration. His method defined breakthrough at a fraction of the total collected adsorbate, rather than as the fraction of the input concentration not collected. He derived a family of curves to give breakthrough volumes at any chosen efficiency which could be used by substituting the values obtained for the number of theoretical plates and the retention volume.

Adsorption isotherms

Adsorption isotherms may be constructed from the chromatographic experiments.(5),(18),(21),(27),(28) All five types of BET classification have been observed and comparisons made are in good agreement with static results.(6),(27),(28) This is despite most of these studies being made by the earlier unrefined methods.

Surface areas

The isotherms obtained may be replotted according to the appropriate BET model. Once a linear plot is obtained i.e. the data has been fitted to an adsorption model, the surface area covered by the adsorbate may be derived from the slope and intercept of the plot, and an estimate of the molecular area of the adsorbed species. Agreed values for molecular areas are difficult to find, but some estimates have been made.(29)

Correlation of Data

Frontal analysis has the potential to provide data on the interaction occurring between the sorbent and the adsorbed pollutant within the Adsorba. It was the intention to attempt to correlate this interaction with other physical data to enable these studies to have a predictive value of how the Adsorba may perform with an untried pollutant as well as providing empirical data on the species tested. Correlations have been suggested with length of hydrocarbon chain,*(17)* polarizability,*(2)*,*(13)*,*(17)* heats of liquefaction,*(17)* boiling point,*(1)*,*(30)* and molecular orientation.*(5)* By deriving data from suitable families of chemicals it was hoped to demonstrate which of these correlations were valid.

2.0 Experimental

2.1 Apparatus

A stream of nitrogen containing the pollutant at a fixed known concentration was created by passing the nitrogen through a diffusion cell. This apparatus is fully described by Thompson and Barratt*(31)* but briefly it consisted of a capillary, containing the contaminant as a liquid, which protruded into a chamber through which the nitrogen flowed. The capillary tube was of known diameter and the distance of the meniscus from the orifice in the mixing chamber could be measured. The environment of the capillary was thermostatically controlled and by measuring the rate of fall of the meniscus the diffusion rate of the contaminant into the nitrogen stream could be determined and the equipment calibrated.

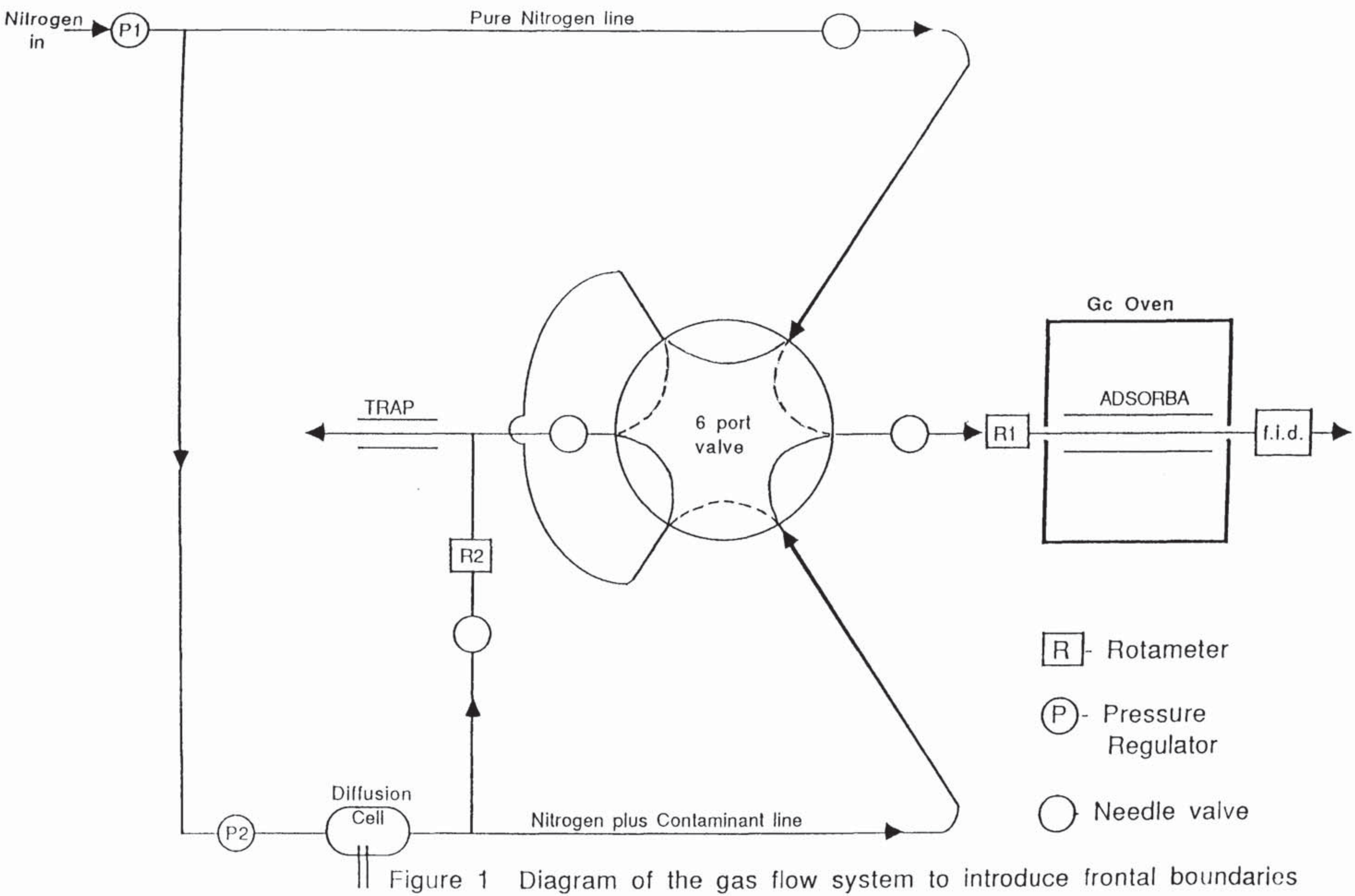


Figure 1 Diagram of the gas flow system to introduce frontal boundaries

A Pye 208 gas chromatograph was fitted with twin carrier gas supply lines as illustrated in Figure 1. These balanced pure and contaminated supplies flowed to a six port gas sampling valve which routed either supply into the gc. Hence turning the valve produced a sharp frontal boundary. Within the gc oven the column had been replaced by an Adsorba tube. The detector was a flame ionization detector (f.i.d.) which measured the pollutant concentration at the Adsorba outlet, and the electrical output from this was amplified so as to be in the range 0-5V and read every 0.5s by a BBC B microcomputer through its analogue/digital converter.

2.2 Method

Adsorba tubes were packed with a known weight (0.220 ± 0.001g) of freshly conditioned Tenax GC and the pressure drop across each tube at a gas flow of 20 ml/min was measured. The flow rates of the twin carrier supplies were measured through the Adsorba and set as nearly as possible to 20 ml/min. The gc oven was brought to the selected temperature then the six port valve was turned, which switched to the contaminated carrier supply thus introducing the front to the Adsorba, and simultaneously the BBC began to examine the signal from the f.i.d.

Because of adsorption of the contaminant on the Adsorba the initial signal was equivalent to that with the pure carrier but as the front migrated through the Adsorba the concentration of contaminant detected at the outlet of the Adsorba rose until it reached the inlet concentration. At this point rate of adsorption and desorption of the contaminant on the Adsorba had reached the equilibrium under those temperature conditions.

The BBC running the Collection of Digital Signal program, Program 1, recorded the f.i.d. output every 0.5s and every 64s examined the data to determine which position on the S shaped curve had been reached. Until the rise in outlet concentration was detected the BBC acted simply as a timer but once the rise was detected the computer stored every data point. Once the equilibrium position had been reached the BBC terminated data collection. Thus the time and shape of the front as it emerged from the Adsorba was recorded.

The experiment was then run in reverse by switching to the pure carrier supply and examining the desorption process. Depending on the contaminant and the temperature each experiment could take from several seconds to several hours to run.

For each contaminant the variables of temperature and concentration were varied independently in order to plot the natural logarithm of retention volume versus reciprocal temperature, and the isotherm.

The data recorded by the BBC was then examined using a second program, Program 2. This "WHALLOP" program performed three functions.

1. It scaled the collected data from 0-100% of the inlet concentration and adjusted for the blank readings.

2. It calculated the area behind the front using Simpson's rule and thus determined the weight of contaminant adsorbed.

3. It calculated the number of theoretical plates.

Program 1 Collection of Digital Signal Program

```
10HIMEM=&7A00
20REM COLLECTION OF DIGITAL SIGNAL
30REM BY A. PICKARD
40CLS
50PRINT "**************************************"
60PRINT
70PRINT "COLLECTION OF DIGITAL SIGNAL"
80 PRINT " BY A. PICKARD"
90PRINT "BBC VERSION 3 DECEMBER 1984"
95PRINT "LAST UPDATE 25/03/85"
100PRINT:PRINT "**************************************"
110CLEAR
120DIM A%(4608)
130 C=0:G=0:H=0:F=0:B=0:EXIT=0
140*FX13,3
150*FX13,5
160REM Q= SLOPE FACTOR
170Q=0.3
180PRINT "PLACE DATA COLLECTION DISK IN DRIVE"
190INPUT "INPUT COMPOUND ";C$
200INPUT "INPUT TEMPERATURE IN DEG C ";T$
210INPUT "INPUT CONC. MG/M3 ";D$
220INPUT "INPUT DATE ";B$
230PRINT "FOR ADSORPTION TYPE A"
240PRINT "FOR DESORPTION TYPE D"
250INPUT "A OR D ";G$
260INPUT "INPUT FLOW ML/MIN ";FW
270*CAT
280INPUT "NAME THE STORAGE FILE ";N$
290PRINT "PROG ADDS A OR D FOR ADS AND DES"
300N$ = N$ + G$
310PRINT "CAUTION! ENSURE THIS NAME IS NEW"
320INPUT "TYPE Y OR N";E$
330IF LEFT$(E$,1) <>"Y" THEN GOTO 280
340GOSUB1570
350INPUT "HIT RETURN AT START OF RUN ";E$
360REM -------
370REM DATA COLLECTION
380*FX 14,5
390 REM SET TIMER
400 CALL SET
410 PRINT "INIT OK"
420 REM ENABLE A/D
430REM ENABLE A/D EVENT
440*FX16,1
450REM SET EVENT VECTOR
460 PRINT "OK HERE"
470 PRINT "********** COLLECTING DATA ***********"
480REM -------
490 REM PEEK STATUS LOOP
500 X=?STATUS
510 IF X<>8 THEN GOTO 550
520 BUFF=122
530 PROCBUFF
540 CALL CLR1: REM CLEAR BUFF1
550 IF X<>128 THEN GOTO 590
560 BUFF=123
570 PROCBUFF
580 CALL CLR2: REM CLEAR BUFF2
590 GOTO 490
600REM PROG NOW LOOPS TILL SUBPROCS
610REM ALLOW EXIT
620REM -------
630REM CALL STOP
640 PROCSTOP
650PRINT "**********STOPPED INTERUPTS************"
660PRINT "END OF DATA ALLOCATION"
670PRINT "SORTING AND FILING DATA IN PROGRESS"
680PROCFINDBASE
690PRINT "FOUND EB"
700EE=EE/128
710X=OPENOUT(N$)
720PRINT£X,G$:PRINT£X,C$:PRINT£X,T$
730PRINT£X,D$:PRINT£X,B$
740PRINT£X,FW:PRINT£X,ND%:PRINT£X,B
750PRINT£X,EB:PRINT£X,EE
760 FOR I = 1 TO ND%
770 PRINT£X,A%(I)
780NEXT I
790CLOSE£X
800PRINTADVAL(1)
810PRINT "RUN ENDED"
820SOUND2,-15,53,40
830END
840REM -------
850DEF PROCBUFF
860REM HANDLING DATA IN FULL BUFFER
870Z0=0:Z1=0:Z2=0:Z3=0
880L1%=128:ND%=ND%+128
890REM LINEAR REG TO FIND SLOPE
900 FOR I = 0 TO 255 STEP 2
910 J=I/2
920 XL=?(BUFF*256+I)
930 XH=?(BUFF*256+I+1)
940 X=XL+XH*256
950 X=X/16
960Z0=Z0+J
970Z1=Z1+J^2
980Z2=Z2+X
990Z3=Z3+J*X
1000 NEXT I
1010REM END OF LINEAR REG
1020Z2=Z2*Z0/L1%
1030Z0=(Z0^2)/L1%
1040QM=2*(Z3-Z2)/(Z1-Z0)
1050PRINT "*",QM
1060REM IF EXIT SET SAVES 3 BUFFERS
1070REM REGARDLESS OF SLOPE THEN EXIT
1080IF EXIT > 0.5 THEN GOTO 1120
1090IF QM > -Q AND QM < Q THEN GOTO 1290
1100REM IF HERE NOT BASELINE
1110IF G = 0 AND H = 0 THEN C=-1
1120C=C+1
1130H=1: REM FLAG SAYS BEEN HERE ONCE
1140REM DATA TO A%(I)
1150 REM FIRST POINT AT TIME = 0.5S
1160 REM IS A%(1)
1170 FOR I = 0 TO 255 STEP 2
1180 J=I/2+1
1190 XL=?(BUFF*256+I)
1200 XH=?(BUFF*256+I+1)
1210 X=XL+XH*256
1220 X=X/16
1230A%(J+128*C)=X
1240 IF EXIT = 3 THEN EE=EE+X
1250NEXT I
1260IF EXIT > 0.5 THEN EXIT = EXIT + 1
1270 IF EXIT = 4 THEN GOTO 630
1280ENDPROC
1290REM -------
1300REM BRANCH FROM PROCBUFF
1310REM TESTS FOR BASE VS END
1320PRINT "BASELINE ROUTINE ENTERED"
1330REM OUT TEST INSERTED TO STOP END
1340REM DUE TO BASELINE NOISE OR BIG SPIKE
1350REM WILL NEVER END UNLESS ADVAL
1360REM OVER 32000 (ADS) UNDER 32000 (DES)
1370IF G$="A" THEN OUT=A%(ND%-128)> 2000
1380IF G$="D" THEN OUT=A%(ND%-128)<2000
1390IF OUT THEN EXIT = 1
1395IF OUT THEN PRINT"...........EXIT ROUTINE...........
1400REM EXIT FLAG SET
1410REM IF EXIT SET IT SAVES 3 BUFFERS
1420REM THEN EXITS TO 740
1430IF EXIT > 0.5 THEN GOTO 1120
1440IF G=1 OR H=1 THEN PROCOVER
1450G=1: REM FLAG SAYS BEEN HERE
1460GOTO 1170 :REM BACK TO PROCBUFF
1470 REM -------
1480DEF PROCOVER
1490REM SET C BACK TO 0
1500C=0
1510REM B = NO TIMES OVERWRITTEN
1520B=B+(ND%-128)/128
1530REM C= 0 SO SET ND% = 128
1540ND% = 128
1550ENDPROC
1560 REM -------
1570 REM INITIALIZE SUB
1580 REM ADDRESSES OF LABELS
1590SMPL=&0CF6:SMPH=&0CF7
1600BUFL=&0CF8:BUFH=&0CF9
1610 BUFFER =&0CFA
1620STATUS=&0CFB
1630 REM CLOCK ADDR
1640 ?&0CF0=&CE
1650 ?&0CF1=&FF:?&0CF2=&FF:?&0CF3=&FF
1660?&0CF4=&FF
1670 OSBYTE =&FFF4
1680 OSWORD=&FFF1
```

```
1690 REM -------
1700 REM SET VECTOR TO START A/D
1710 REM POINT TO A/D READ FIRST
1720 ?&0220=4
1730 ?&0221=&0C
1740 FOR PASS=0 TO 2 STEP 2
1750P%=&0C00
1760 [ OPT PASS
1770.SET SEI
1780JMP INIT
1790.START
1800PHP
1810PHA
1820TYA
1830PHA
1840TXA
1850PHA
1860LDA£&11
1870LDX £01
1880JSR OSBYTE
1890LDY £&0C
1900LDX £&F0
1910LDA £4
1920JSR OSWORD
1930LDA £&39
1940STA &0220
1950LDA £&0C
1960STA &0221
1970LDA£13
1980LDX£5
1990JSR OSBYTE
2000LDA£&E
2010LDX£3
2020JSR OSBYTE
2030PLA
2040TAX
2050PLA
2060TAY
2070PLA
2080PLP
2090RTS
2100.TAKE
2110PHA
2120TXA
2130PHA
2140TYA
2150PHA
2160 LDA£&80
2170LDX£01
2180JSR OSBYTE
2190STY SMPH
2200STX SMPL
2210LDA£13
2220LDX£3
2230JSR OSBYTE
2240LDA £4
2250STA &0220
2260LDA £&0C
2270STA &0221
2280 LDA £00
2290 STA &70
2300 LDA BUFH
2310 STA &71
2320 LDY BUFL
2330 LDA SMPL
2340 STA (&70),Y
2350 INC BUFL
2360 LDY BUFL
2370 LDA SMPH
2380 STA (&70),Y
2390 INC BUFL
2400BNE RESET
2410LDA BUFFER
2420CMP BUFH
2430BEQ BUF2
2440.BUF1 STA BUFH
2450LDA STATUS
2460ORA£&80
2470STA STATUS
2480JMP RESET
2490.BUF2 INC BUFH
2500LDA STATUS
2510ORA £08
2520STA STATUS
2530.RESET
2540LDA£&E
2550LDX£5
2560JSR OSBYTE
2570PLA
2580TAY
2590PLA
2600TAX
2610PLA
2620CLI
2630 RTS
2640.CLR1 LDA STATUS
2650AND£&80
2660 STA STATUS
2670RTS
2680.CLR2 LDA STATUS
2690AND£08
2700STA STATUS
2710RTS
2720 .INIT
2730 PHA
2740 TXA
2750 PHA
2760 TYA
2770PHA
2780LDY £&0C
2790LDX £&F0
2800LDA £4
2810JSR OSWORD
2820LDA £&7A
2830STA BUFFER
2840 LDA BUFFER
2850 STA BUFH
2860 LDA £00
2870 STA BUFL
2880LDA£00
2890STA STATUS
2900PLA
2910TAY
2920PLA
2930TAX
2940PLA
2950CLI
2960 RTS
2970 ]
2980 NEXT PASS
2990 PRINT "COMPILED"
3000RETURN
3010 DEF PROCSTOP
3020 REM RESTORE NORMAL EVENTS
3030*FX13,3
3040*FX13,5
3050 REM CLEAR EVENT VECTOR
3060 ?&0220=00:?&0221=00
3070 ENDPROC
3080 REM -------
3090DEF PROCFINDBASE
3100REM SUB TO FIND MEAN BASELINE
3110FOR I = 0 TO 15
3120Z0=0:Z1=0:Z2=0:Z3=0
3130FOR J=1 TO 8
3140X=A%(8*I+J)
3150Z0=Z0+J
3160Z1=Z1+J^2
3170Z2=Z2+X
3180Z3=Z3+J*X
3190NEXT J
3200Z2=Z2*Z0/8
3210Z0=(Z0^2)/8
3220QM=2*(Z3-Z2)/(Z1-Z0)
3230IF QM <-Q OR QM >Q THEN GOTO 3280
3240 FOR J =1 TO 8
3250EB=EB+A%(8*I+J)
3260NEXT J
3270F=F+1
3280NEXT I
3290 IF F=0 THEN GOTO 3320
3300 EB=EB/(8*F)
3310 GOTO 3400
3320REM FAILSAFE IF NONE OF SECTORS
3330REM ARE IN THE LIMIT
3340EB=0
3350 FOR I =4 TO 8
3360EB=EB+A%(I)
3370NEXT I
3380PRINT" EB FOUND FOR SECS 2-4 ONLY"
3390EB=EB/5
3400 ENDPROC
```

Program 2 Analysis of Data Program "Whallop"

```
4000 REM ANALYSIS PROGRAM A.WHALLOP
4010PRINT "***************************************"
4020PRINT:PRINT "ANALYSIS OF DATA "
4030PRINT "BY WHALLOP PROGRAM"
4040PRINT"LAST UPDATE 20/03/85":PRINT
4050PRINT "***************************************"
4060CLEAR
4070DIM XX%(1200):DIM Y(1200)
4080DIM R(1200):DIM W(400)
4090F$="I"
4100C=0:Z=0:FLAG2=0:IVD=0
4110 REM RES = VALUE FOR RESIDUAL SLOPE
4120 RES = 0.01
4130PRINT "IS THIS A BLANK? Y OR N"
4140PRINT "IF N WILL ASK FOR BLANK DATA"
4150INPUT "TYPE Y OR N  " E$
4160IF LEFT$(E$,1)="Y" THEN GOTO 4220
4170PROCMANBLK
4180V=45:W=55
4190INPUT "TYPE Y IF V. SHARP RISE "E$
4200IF E$="Y" THEN GOTO 4230
4210GOTO 4240
4220A0=0:V0=0:VV0=0
4230V=35:W=65
4240PRINT "PLACE THE DISK CONTAINING THE DATA"
4250PRINT "IN THE DRIVE"
4260INPUT "THEN PRESS RETURN : " E$
4270*CAT
4280PRINT "INPUT THE NAME OF THE FILE"
4290INPUT "FOR ANALYSIS " N$
4300CH=OPENIN(N$)
4310INPUT£CH,G$,C$,T$,D$,B$
4320INPUT£CH,FW,N,B,EB,EE
4330FOR I = 1 TO 134
4340INPUT£CH,W(I)
4350NEXT I
4360CLOSE£CH
4370FOR I = 1 TO 7
4380TEST=TEST+W(I)
4390 IF TEST <> 0 THEN GOTO 4420
4400FOR I = 1 TO 7
4410W(I)=W(8):NEXT I
4420REM ABOVE SECTION INSERTED FOR BAD DATA
4430E$=INKEY$(200)
4440PROCVIEW
4450CH=OPENIN(N$)
4460INPUT£CH,E$,E$,E$,E$,E$
4470INPUT£CH,ZZ,ZZ,ZZ,ZZ,ZZ
4480REM COMMENCING INTEGRATION
4490REM BY SIMPSONS RULE
4500IF TEST<>0 THEN GOTO 4540
4510INPUT£CH,X
4520X=W(1)
4530GOTO 4550
4540INPUT£CH,X
4550AA=(X-EB)*100/(EE-EB)
4560FOR J = 2 TO (N-2) STEP 2
4570INPUT£CH,X1,X2
4580IF TEST <> 0 OR J > 7 THEN GOTO 4600
4590X1=W(J):X2=W(J+1):REM OVERWRITES ZERO DATA
4600X1=(X1-EB)*100/(EE-EB)
4610X2=(X2-EB)*100/(EE-EB)
4620AA=AA+4*X1+2*X2
4630IF J<20 THEN GOTO 4720
4640IF FLAG2 = 1 THEN GOTO 4690
4650T1=X1>10:T2=X1<22
4660T3=X2>10:T4=X2<22
4670IF X1 AND X2 >=35 THEN PROCVVOL
4680IF FLAG2 = 0 THEN GOTO 4710
4690T1=X1>V:T2=X1<W
4700T3=X2>V:T4=X2<W
4710IF T1 AND  T2 AND T3 AND T4 THEN PROCMID
4720NEXT J
4730INPUT£CH,X
4740CLOSE£CH
4750AA=AA+(X-EB)*100/(EE-EB)
4760AA=AA*FW/(2*3*60)
4770REM AREA IN %ML UNITS
4780REM AREA OF RECTANGLE GIVEN BY
4790Y=100*FW*(B*128+N)/(2*60)
4800REM AREA BEHIND CURVE GIVEN BY
4810AA=Y-AA
4820REM -------
4830PROCSLOPE
4840REM RETN VOL
4850X50=(50-D)/S
4860RT=(128*B+X50)/120
4870VG=RT*FW
4880IF IVD = 1 THEN PROCIVD
4890REM FINDS NTP FROM UNCORRECTED VOL
4900 NTP = (VG*VV)/((VG-VV)^2)
4910 AA=AA-A0:VG=VG-V0:VV=VV-VV0
4920E$="+"
4930E$=E$+D$
4940WT=VAL(E$)
4950CLS
4960VDU2
4970PRINT N$
4980PRINT C$," ",T$;" DEG C"
4990PRINT D$;" MG/M3 ",B$
5000 PRINT N;"  SAMPLES"
5010PRINT"AREA = ";AA;"  %ML UNITS"
5020 PRINT "RETN VOL = "VG;" ML"
5030PRINT "RETN VOL V(15.87%) = ";VV;" ML"
5040IF IVD = 1 THEN PRINT "VVOL FROM 50% SLOPE"
5050 PRINT "NO. THEORETICAL PLATES = ";NTP
5060IF WT = 0 THEN GOTO 5130
5070 WT = WT * AA/100000
5080PRINT "WT. ADSORBED = ";WT;" MG"
5090PRINT:PRINT
5100PRINT"---------------------------------------"
5110PRINT:PRINT:PRINT
5120VDU3
5130REM -------
5140PRINT "PUT DISK FOR ANALYSED DATA IN DRIVE"
5150INPUT "THEN HIT RETURN " E$
5160M$=N$+F$
5170CH2=OPENOUT(M$)
5180PRINT£CH2, G$,C$,T$,D$,B$
5190PRINT£CH2, N,AA,VG,VV,NTP,WT
5200CLOSE£CH2
5210PRINT:PRINT"********** PROGRAM ENDED *************"
5220END
5230 DEF PROCVIEW
5240PRINT G$
5250PRINT C$;TAB(20);T$" DEG C"
5260PRINT "CONC = "D$;TAB(20);B$
5270PRINT "FLOW = "FW,"SAMPLES = ";N
5280PRINT "EB = "EB,"EE = "EE
5290 INPUT "DO YOU WISH TO CHANGE CONC",E$
5300IF LEFT$(E$,1)<>"Y" THEN GOTO 5320
5310INPUT "INPUT NEW CONC IN MG/M3 "D$
5320INPUT "DO YOU WISH TO CHANGE FLOW",E$
5330IF LEFT$(E$,1)<>"Y" THEN GOTO 5350
5340INPUT "INPUT FLOW IN ML/MIN "FW
5350 PRINT "EB = ",EB
5360 FOR I = (1+Z) TO (51+Z) STEP 3
5370 PRINT W(I),W(I+1),W(I+2)
5380 NEXT I
5390 IF Z > 79 THEN GOTO 5460
5400INPUT "DO YOU WANT TO SEE MORE EB",E$
5410IF E$<>"Y"THEN GOTO 5460
5420PRINT EB
5430 Z=Z+40
5440 GOTO 5350
5450NEXT I
5460INPUT "DO YOU WISH TO CHANGE EB",E$
5470IF LEFT$(E$,1)<>"Y" THEN GOTO 5490
5480INPUT "INPUT EB "EB
5490ENDPROC
5500DEF PROCMANBLK
5510PRINT "INPUT BLANK DATA "
5520INPUT "A0 = ",A0
5530INPUT "V0 = ",V0
5540INPUT "VV0 = ",VV0
5550ENDPROC
5560DEF PROCMID
5570XX%(C+1)=J:XX%(C+2)=J+1
5580Y(C+1)=X1:Y(C+2)=X2
5590C=C+2
5600ENDPROC
5610DEF PROCSLOPE
5620REM -------
5630REM SLOPE BY RESISTANT LINE
5640OVER = C MOD 3
5650 IF OVER<>0 THEN 5670
5660H1 = C/3:H2=2*C/3
5670 IF OVER <>1THEN 5690
5680 H1=C DIV 3:H2=2*INT(C/3)+1
5690 IF OVER <> 2 THEN 5710
```

```
5700 H1 =INT(C/3)+1:H2=2*INT(C/3)+1
5710ODD1= H1 MOD 2
5720ODD2=(H2-H1) MOD 2
5730REM -------
5740REM SENDS Y TO W RETURNS  MEDIANS
5750REM FIRST THIRD
5760LAST=H1
5770 HALF=H1 DIV 2
5780FOR I = 1 TO H1
5790 W(I) = Y(I)
5800NEXT I
5810PROCSORT
5820IF ODD1<>1 THEN GOTO 5850
5830YL=W(HALF+1):XL=XX%(HALF+1)
5840GOTO 5870
5850YL=(W(HALF)+W(HALF+1))/2
5860 XL=(XX%(HALF)+XX%(HALF+1))/2
5870REM LAST THIRD
5880 FOR I = 1 TO H1
5890 W(I)=Y(H2+I)
5900NEXT I
5910PROCSORT
5920 IF ODD1<>1 THEN GOTO 5950
5930YR=W(HALF+1):XR=XX%(H2+HALF+1)
5940 GOTO 5970
5950YR=(W(HALF)+W(HALF+1))/2
5960XR=(XX%(H2+HALF)+XX%(H2+HALF+1))/2
5970REM MIDDLE THIRD
5980LAST=H2-H1
5990 HALM = (H2-H1) DIV 2
6000FOR I = H1+1 TO H2
6010W(I-H1)=Y(I)
6020NEXT I
6030PROCSORT
6040IF ODD2<>1 THEN GOTO 6070
6050YM=W(HALM+1):XM=XX%(H1+HALM+1)
6060 GOTO 6090
6070YM=(W(HALM)+W(HALM+1))/2
6080XM=(XX%(H1+HALM)+XX%(H1+HALM+1))/2
6090REM -------
6100REM FIRST ESTIMATE OF SLOPE
6110S=(YR-YL)/(XR-XL)
6120D=(YR+YM+YL-S*(XR+XM+XL))/3
6130S1=0
6140REM -------
6150REM CALCULATE RESIDUALS
6160FOR I = 1 TO C
6170R(I)=Y(I)-(D+S*XX%(I))
6180NEXT I
6190REM FIRST AND LAST THIRDS TO W
6200LAST=H1
6210FOR I=1 TO H1
6220W(I)=R(I)
6230NEXT I
6240PROCSORT
6250 IF ODD1<>1 THEN 6270
6260RL=W(HALF+1):GOTO 6280
6270RL=(W(HALF)+W(HALF+1))/2
6280FOR I=1 TO H1
6290W(I)=R(H2+I)
6300NEXT I
6310PROCSORT
6320IF ODD1<>1 THEN 6340
6330RR=W(HALF+1):GOTO 6350
6340RR=(W(HALF)+W(HALF+1))/2
6350REM FINDS RESIDUAL SLOPE
6360S2=(RR-RL)/(XR-XL)
6370 IF ABS(S2) <= RES THEN GOTO 6430
6380 IF S1 = 0 THEN GOTO 6410
6390IF SGN(S1)<>SGN(S2)THEN S=S-S2(S1/(S2-S1))
6400 S1=S2:GOTO 6420
6410S=S+S2
6420 GOTO 6150
6430REM -------
6440REM RESIDUAL SLOPE ZERO
6450REM FIND MIDDLE SUMMARY POINT
6460LAST=H2-H1
6470FOR I = H1+1 TO H2
6480W(I-H1)=R(I)
6490NEXT I
6500PROCSORT
6510IF ODD2 <>1 THEN GOTO6530
6520RM=W(HALM+1):GOTO 6540
6530RM=(W(HALM)+W(HALM+1))/2
6540D=D+(RR+RM+RL)/3
6550ENDPROC
6560DEF PROCSORT
6570REPEAT FLAG=0
6580FOR I=1 TO LAST
6590IF W(I)>W(I+1) THEN PROCCHANGE
6600NEXT I
6610UNTIL FLAG = 0
6620ENDPROC
6630DEF PROCCHANGE
6640CHAN=W(I+1):W(I+1)=W(I)
6650W(I)=CHAN:FLAG=1
6660ENDPROC
6670DEF PROCVVOL
6680FLAG2 = 1
6690IF C > 10 THEN GOTO6720
6700IVD = 1:REM HELP FLAG SET
6710GOTO6760
6720PROCSLOPE
6730REM FIND V AT 15.87%
6740XV=(15.87-D)/S
6750VV=FW*(128*B+XV)/120
6760C=0:D=0:S=0
6770ENDPROC
6780DEF PROCIVD
6790REM SENT HERE BY FLAG IVD
6800REM INSUFFICIENT V DATA
6810REM SO CALCULATES ON 50% SLOPE
6820XV=(15.87-D)/S
6830VV=FW*(128*B+XV)/120
6840ENDPROC
```

3.0 Results and discussion

Nitrogen atmospheres contaminated with three aromatic organic solvents (benzene, toluene, p-xylene) were generated using the diffusion cell. The intent was to generate atmospheres at a series of concentrations up to and including the threshold limit value (TLV) in order to investigate the adsorption isotherms and the performance of the Adsorba at typical working conditions. Calibration of the diffusion cell proved an awkward and time consuming exercise but diffusion constants under the experimental conditions were derived and concentrations of the right order generated.

The carrier gas containing the contaminant was passed through the Adsorba and the inlet concentration and temperature were varied independently. A series of curves was recorded at the Adsorba outlet which exhibited a self sharpened front boundary and diffuse rear boundary. The fronts were analysed by the "WHALLOP" program to yield the data of Tables 1-3.

The adsorption and desorption results of this data are in good agreement despite the marked difference in the shape of the fronts. Adsorption isotherms were plotted for the three chemicals and they exhibited a slight Langmuir curvature typical of such gas-solid interactions and in agreement with the observed frontal profiles.

Retention volumes and isosteric heat

The logarithm plots all showed excellent correlation with a straight line. Hence, the adsorption and desorption performance of the Adsorba could be evaluated.

Table 1

Toluene Data TLV = 375 mg/m^3

		ADSORPTION			DESORPTION		
Concentration mg/m^3	Temp ^oC	Ret^{n}vol ml	NTP	Adsorbed wt mg	Ret^{n}vol ml	NTP	Adsorbed wt mg
688	100	154	390	105	144	20	102
448	90	281	520	125	-	-	-
447	100	169	240	75.0	158	27	71.9
447	110	100	130	44.6	94.8	39	42.9
446	125	-	-	-	44.8	50	20.9
445	140	23.9	67	10.4	21.7	40	10.5
444	160	-	-	-	9.51	27	4.94
434	90	288	490	125	261	19	117
433	100	171	220	73.2	158 160	27 28	69.7 70.7
431	110	100	120	42.9	95.2	38	41.6
431	125	45.4	83	19.1	-	-	-
430	140	22.7	61	9.59	21.7	47	9.65
429	160	9.67	29	4.35	9.33	28	4.69
418	100	170	210	70.7	158	26	67.5
310	100	175	170	53.8	167	31	52.6
225	100	186	130	42.0	-	-	-
89.5	100	194	94	17.2	187	50	16.9
57.7	100	196	81	11.3	190	49	11.0
27.9	100	193	64	5.34	188	54	5.27
27.9	100	195	68	5.39	188	52	5.25
27.9	100	-	-	-	188	53	5.25
6.57	100	198	56	1.29	191	58	1.25
6.57	100	200	69	1.31	191	54	1.26
5.79	90	379	65	2.18	363	53	2.10
5.79	100	199	51	1.15	189	65	1.10
5.79	110	111	53	0.631	105	60	0.601
5.79	125	48.4	56	0.279	45.7	52	0.262
5.79	140	22.8	53	0.124	22.2	66	0.152
5.79	160	9.97	27	0.063	9.59	13	0.063

Table 2

Benzene Data TLV = 30 mg/m^3

		ADSORPTION			DESORPTION		
Concentration mg/m^3	Temp °C	Ret^{n}vol ml	NTP	Adsorbed wt mg	Ret^{n}vol ml	NTP	Adsorbed wt mg
90.4	80	196	77	17.7	189	40	17.2
48.3	80	200	67	9.64	192	43	9.34
34.2	60	745	95	25.5	713	36	24.5
34.2	60	-	-	-	716	35	24.6
33.9	70	380	73	12.9	372	42	12.7
33.8	80	201	63	6.78	198	48	6.71
33.8	100	63.9	68	2.14	61.8	55	2.08
33.8	120	23.2	78	0.778	22.3	88	0.742
26.6	70	391	65	10.4	375	43	10.1
26.6	80	206	60	5.47	-	-	-
26.6	90	112	63	2.97	108	57	2.87
26.6	100	63.9	65	1.70	61.6	63	1.63
26.6	120	23.2	94	0.605	22.3	81	0.595
26.6	130	14.7	91	0.397	14.2	90	0.375
12.8	80	206	58	2.63	198	51	2.55
12.8	80	208	58	2.66	-	-	-
6.23	80	207	58	1.29	199	54	1.24
3.32	80	210	60	0.702	201	48	0.671
3.32	80	-	-	-	202	49	0.677
1.76	80	200	79	0.348	201	41	0.354

Table 3

p - XYLENE DATA TLV 425 mg/m^3

		ADSORPTION			DESORPTION		
Concentration mg/m^3	Temp ^oC	Ret^{n}vol ml	NTP	Adsorbed wt mg	Ret^{n}vol ml	NTP	Adsorbed wt mg
415	100	373	860	154	-	-	-
414	100	379	870	156	328	14	144
415	110	225	310	92.6	202	21	86.5
415	130	78.1	66	34.9	72.0	28	31.3
415	150	27.8	26	13.0	25.6	25	11.7
415	170	10.8	12	5.69	10.4	5.2	6.00
370	70	1540	5700	569	-	-	-
370	90	614	1900	225	531	11	210
370	100	381	710	139	335	16	129
370	110	224	270	81.4	205	23	77.1
370	130	74.4	74	27.0	70.3	34	26.4
370	150	25.1	32	8.67	24.1	26	9.20
370	170	9.15	8	3.44	8.97	7	3.99
290	100	394	530	114	361	16	110
178	100	446	330	78.6	403	20	74.2
155	100	435	270	66.4	404	23	63.3
136	100	456	230	61.6	429	23	59.7
71.4	100	489	140	34.5	470	31	33.7
28.3	100	555	94	15.1	504	45	14.2
15.7	100	539	79	8.38	523	47	8.18
15.7	100	536	69	8.32	-	-	-
8.31	100	549	78	4.54	539	51	4.48
8.29	90	1100	100	8.98	939	49	8.91
8.29	100	558	69	4.59	542	48	4.50
8.29	110	283	61	2.31	272	54	2.25
8.29	130	81.5	49	0.643	78.5	44	0.649
8.29	150	26.4	23	0.218	25.6	30	0.217
8.29	170	10.2	4	0.0893	9.46	14	0.0954

Regarding retention volume the performance of the Adsorba is of most significance when monitoring at the TLV concentration. The retention volume (Rv), at 20^{o}C and near the TLV, was therefore derived from the adsorption results since this is a measure of how the Adsorba will perform when monitoring that chemical in the field. For desorption I assumed single stage desorption without a cold trap, as was practised at Dutom. The adsorbed contaminant needs to be flushed rapidly onto the gc if good resolution is to be achieved. Hence, a 50% desorption retention volume of 0.5ml was assumed to derive the required desorption temperature (Dt).

Finally values were derived for the differential isosteric molar heat of adsorption ΔH. This result is concentration dependent and so the value used in order to compare data is the value as the concentration tends to zero. The values derived here are all at concentrations of less than 10ppm and are typical of the heats of adsorption of good gas-solid physisorption. Better values could be derived by obtaining the H values at a series of concentrations and extrapolation to zero, however this would require several more days of experiments per chemical.

Table 4. Data of the performance of the Adsorba

	Benzene	Toluene	p-Xylene
Dt ^{o}C	217	247	257
Rv litres	16.1	46	184
ΔH kJ/mol	63	68	79

Breakthrough

The method for deriving breakthrough proposed by Senum*(26)* is dependent upon evaluating the number of theoretical plates. However, the profile of the fronts was found to be temperature and concentration dependent and the values obtained for the number of theoretical plates varied in a manner which were unsuitable for extrapolation. Furthermore the paper upon which Senum based his mathematics describes the frontal boundary only as idealised functions and does not allow for the self sharpened and diffuse boundaries observed.

Breakthrough values must therefore be derived as a percentage of the inlet concentration. This treatment could be applied to these measurements if the retention volume at the selected percentage concentration could be shown to be compatible with a logarithmic plot. This certainly would be preferable to Brown and Purnell's method*(1)* of arbitrarily deriving a safe sampling volume by dividing the retention volume by two.

4.0 Summary

The system has been shown to provide useful empirical data which measures the performance of the Adsorba. It could be improved if the calibration and flow measurement of the twin carrier lines were made easier, possibly by incorporating a mass flow meter into the lines. Such a device would considerably reduce time required in the calibration and enable concentrations to be changed much more readily. However, it is important that any such device should not have a "memory effect" of the previous concentration or affect the sharp frontal boundary.

Given the limited number of chemicals the system has tested and the lack of further interest in data specific to the Adsorba no attempt has been made to use this information obtained as a means of predicting the

Adsorba performance with other chemicals. Nevertheless the system has the potential for this given further work.

REFERENCES

1 Brown R. H. and Purnell C. J., *Journal of Chromatography*, 178, 79, 1979

2 Clarke A. I., McIntyre A. E., Lester J. N. and Perry R., *Ibid.*, 252, 147, 1982

3 Tanaka T., *Ibid.*, 153, 7, 1978

4 Glueckauf E., *Journal of the Chemical Society*, 1302, 1947

5 James D. H. and Phillips C. S. G., *Ibid.*, 1066, 1954

6 Gregg S. J. and Stock R., in Desty D. H. (Ed.), *Gas chromatography*, Butterworths, London, 90, 1958

7 Conder J. R. and Young C. L., *Physicochemical measurement by gas chromatography*, Wiley Interscience, 1979

8 Bosanquet C. H. and Morgan G. O., in Desty D. H. (Ed.), *Vapour phase chromatography*, Butterworths, London, 35, 1957

9 Conder J. R. and Purnell J. H., *Transactions Faraday Society*, 64, 3100, 1968

10 Conder J. R. and Purnell J. H., *Ibid.*, 65, 824, 1969

11 Conder J. R., *Chromatographia*, 7, 387, 1974

12 Conder J. R. and Purnell J. H., *Transactions Faraday Society*, 64, 1505, 1968

13 Kislev A. V. and Yashin Y. I., trans. Bradley J. E. S., *Gas Adsorption Chromatography*, Plenum Press, London, 1969

14 Conder J. R. and Young C. L., *op. cit.*, 383, 1979

15 Purnell J. H., *Gas chromatography*, Wiley, 99, 1962

16 Greene S. A. and Pust A., *Journal of Physical Chemistry*, 62, 55, 1958

17 Dominigo-Garcia M., Ferdinandez-Morales I., Lopez-Garzon F. J. and Moreno-Castilla C., *Journal of Chromatography*, 294, 41, 1984

18 Beebe R. A., Evans P. L., Keinstuber T. C. W. and Richards L. W., *Journal of Physical Chemistry*, 70, 1009, 1966

19 Gale R. L. and Beebe R. A., *Ibid.*, 68, 555, 1964

20 Conder J. R. and Young C. L., *op. cit.*, 436, 1979

21 Nicolescu A., Udrea M. and Popa G., *Revue Roumaine de Chimie*, 23, 361, 1978

22 Hayward D. O. and Trapnell B. M. W., *Chemisorption* 2nd ed., Butterworths, London, 296, 1964

23 Guenier J. P. and Muller J., *Annuls of Occupational Hygiene*, 28, 61, 1984

24 Russell J. W., *Environmental Science and Technology*, 9, 1175, 1975

25 Reilley C. N., Hildebrand G. P. and Ashley J. W., *Analytical Chemistry*, 34, 1198, 1962

26 Senum G. L., *Environmental Science and Technology*, 15, 1073, 1981

27 Ebberley P., *Journal of Physical Chemistry*, 65, 1261, 1966

28 Perrett R. H. and Purnell J. H., *Journal of Chromatography*, 7, 455, 1962

29 McClellan A. L. and Harnsberger H. F., *Journal of Colloid Interface Science*, 23, 577, 1967

30 Conder J. R., in Purnell J. H. (Ed.), *Advances in analytical chemistry and instrumentation: Progress in Gas Chromatography*, Wiley Interscience, 6, 209, 1968

31 Barratt R. S., Jones J. L. and Thompson J. M., *British Journal of Anaesthesia*, 47, 1177, 1975

APPENDIX F

EXPERIMENTAL STUDIES OF POTENTIAL REACTIONS FOR A FORMALDEHYDE MONITOR

This report briefly describes some of the investigations of potential reactions from which a formaldehyde monitor may have been derived.

Xylene reaction

Some cursory observations of colour changes of xylene in the presence of formaldehyde and sulphuric acid had been made by the Dutom Technical Director and Research Manager, from which they proposed a thermally desorbable formaldehyde monitor may be derived.

Xylene exists in three isomers, and the different isomers have different substitution patterns. For the purposes of experiment p-xylene was chosen since this has all ring substitution sites equivalent. The reaction with formaldehyde was then investigated.

a) In solution.

p-Xylene was dissolved in ether at a concentration of 4 mg/ml. A gaseous formaldehyde atmosphere was generated by passing N2 through an aqueous formaldehyde solution, and this was then passed through the ether solution. Gc analysis of the solution showed no peaks other than those attributable to ether and xylene.

b) As a liquid trap.

p-Xylene was placed in an impinger, formaldehyde vapour generated as above was pased through the xylene. Analysis of the resulting solution by gc showed no peaks attributable to a formaldehyde-xylene complex.

c) On a solid support.

Silica gel 60-80 mesh was washed with conc. sulphuric acid and then in water and dried. The acid washed silica was added to p-xylene, shaken, filtered and dried to a free flowing solid. This xylene coated silica was then exposed to formaldehyde and the resulting species subjected to gc analysis.

The addition of conc. sulphuric acid to the xylene coated silica gave results described in Table 1.

Table 1 Results of xylene coated on a solid sorbent and exposed to formaldehyde.

Xylene coated silica.	- The silica became off-white and one or two faint brown patches appeared.
Xylene coated silica exposed to formaldehyde.	- An intense red colour formed immediately upon addition of acid. A red deposit was also noted on the pipette tip suggesting that the reagent(s) reacting with the acid are volatile. The colour darkened on standing.
Xylene coated silica exposed to formaldehyde and themally desorbed.	- A red colour formed but this was markedly less intense than for the desorbed silica.

d) Thermal desorption.

The samples of the exposed xylene coated silica were thermally desorbed at 240^{o}C with the gc column at two operating temperatures 220^{o}C and 150^{o}C.

At 220^{o}C no peaks were noted after the broad xylene peak.

At 150^{o}C a set of peaks were noted before the broad xylene peak.

Characterisation of the xylene reaction.

The observations are due to the following reaction and mechanism taking place.

Formaldehyde is known to react with p-xylene in the presence of a Lewis acid to yield 1,1'-methylenebis[2,5-dimethylbenzene] (2,5-dixylylmethane)*(1)* see Figure 1. This is a white solid which has been well characterised by n.m.r.*(2)* but little i.r. or u.v. data is available. It may also be prepared by the reaction of alkyl halide with p-xylene.*(3)*

The reaction mechanism for formaldehyde may be represented as in Figure 2, although the second step may involve a radical as opposed to a carbonium ion.

2,5-dixylymethane has been reported to have the following physical properties.

Ref.	mp^{o}C	bp. ^{o}C @ 1mm Hg	bp. ^{o}C @ 760mm Hg
(1)	60-60.5	-	313-16
(3)	61-62	125-126	327-29

A red coloured solution is reported when using aluminium chloride as a catalyst in the reaction.*(3)* Dark coloured reaction products are reported from condensing formaldehyde with petroleum aromatics using sulphuric acid, phosphoric acid and iron (III) chloride as catalysts.*(4)* Lighter coloured products result from the use of the Lewis acids, zinc chloride and acetic acid.

Now the 2,5-dixylymethane has a more reactive aromatic ring system than p-xylene. The formation of a sigma complex with the Lewis acid leads to a conjugated double bond system Figure 3. This is the coloured species. The reaction has been investigated in more detail recently.*(5)*

Given these reaction mechanisms and paths the experimental results are accounted for as follows. In the experiment formaldehyde is passed over xylene on silica. In the absence of an acid catalyst no reaction occurs, instead formaldehyde is dissolved in the xylene. The addition of conc. sulphuric acid to this solution, initiates the reactions above to yield the coloured product. The observation that the colour darkens on standing is due to the function of polymeric species which exhibits a longer conjugated pi system.

Neither 2,5-dixylylmethane nor the Lewis acid complex are suitable species for thermal desorption and gc analysis. This route, therefore, has no potential for the development of a thermally desorbable formaldehyde monitor.

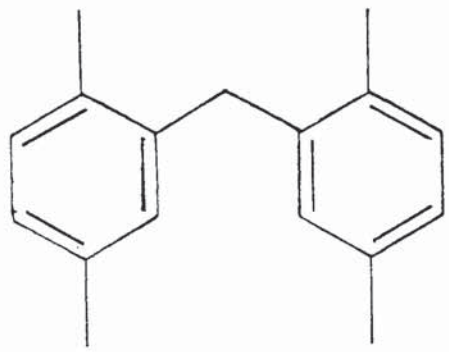


Figure 1 The structure of 1,1'-methylenebis[2,5-dimethylbenzene]

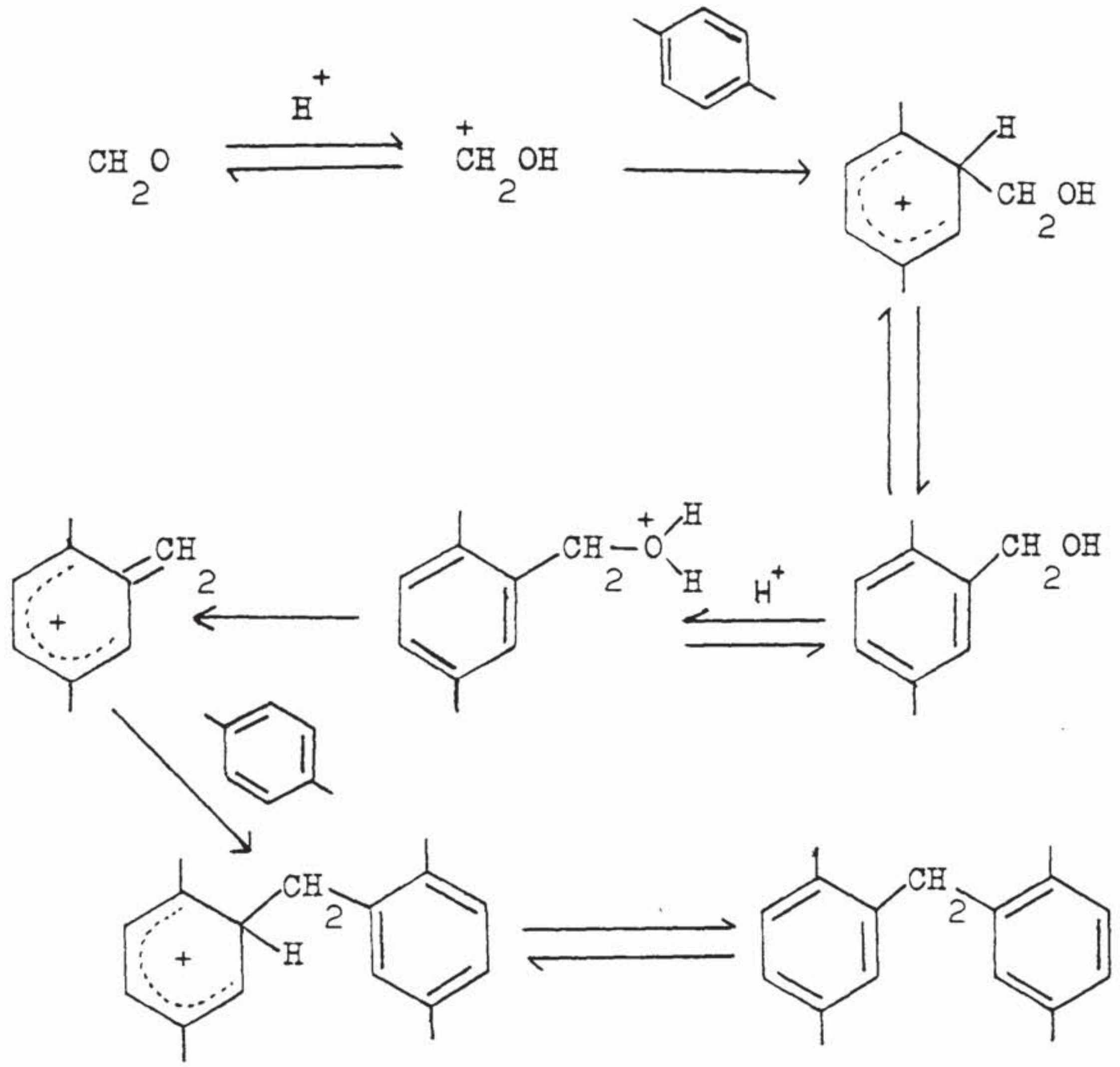


Figure 2 A reaction mechanism for the xylene and formaldehyde reaction

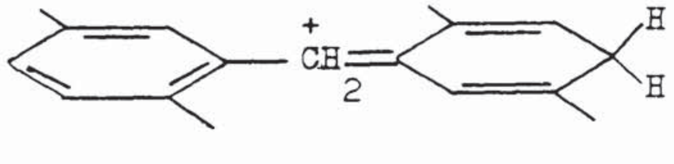


Figure 3 A structure for the coloured complex.

Propane-1,3-dithiol reaction

A study of aldehyde reactions, led to propane-1,3-dithiol being proposed as a potential reagent for trapping formaldehyde. It is well known for its use as a protecting agent for carbonyl groups,*(6)* or following treatment with Raney nickel as a means of selectively reducing them.

The reaction proceeds to form a cyclic mercaptal (see Figure 4). Mercaptals are stable to alkali and not rapidly hydrolysed by acid. The product contains few functional groups reactive to other species present, and by forming discrete cyclic molecules further reaction is inhibited. The product 1,3-dithiane is sufficiently low boiling to suggest thermal desorption may be possible. Furthermore a flame photometric detector is very sensitive to the product.

The reaction, therefore, exhibited some potential but it remained to be ascertained whether formaldehyde reacted with the reagent to give the cyclic mercaptal, or if the competing polymeric product predominated. The reaction of dithiols with formaldehyde had been variously reported to give good*(7)* and poor*(8)* yields. Reaction at a two phase interface had led to polymer formation,*(9)* but experimental details were not clearly reported for the synthesis until a synthesis of 1,3-dithiane from methylal was reported.*(10)*

Acid washed silica gel was coated with propane-1,3-dithiol by two methods.

a) Injecting a small quantity of the thiol onto the silica and shaking to allow redistribution.

b) Washing the silica in a solution of propane-1,3-dithiol in chloroform and evaporating to dryness.

The coated silica was then exposed to a gaseous formaldehyde atmosphere, generated as above, and from a paraformaldehyde source, by diffusion. The products were examined using both solvent and thermal desorption techniques, followed by gc analysis. The analysis showed the presence of propane-1,3-dithiol but no 1,3-dithiane. i.e. the reaction is not occuring sufficiently readily under the reaction conditions to generate the desired product.

The conclusion to these experiments was that the proposed reaction does not occur under the conditions imposed by a solid state monitor. This reaction is therefore not suitable as the basis for a thermally desorbable monitor.

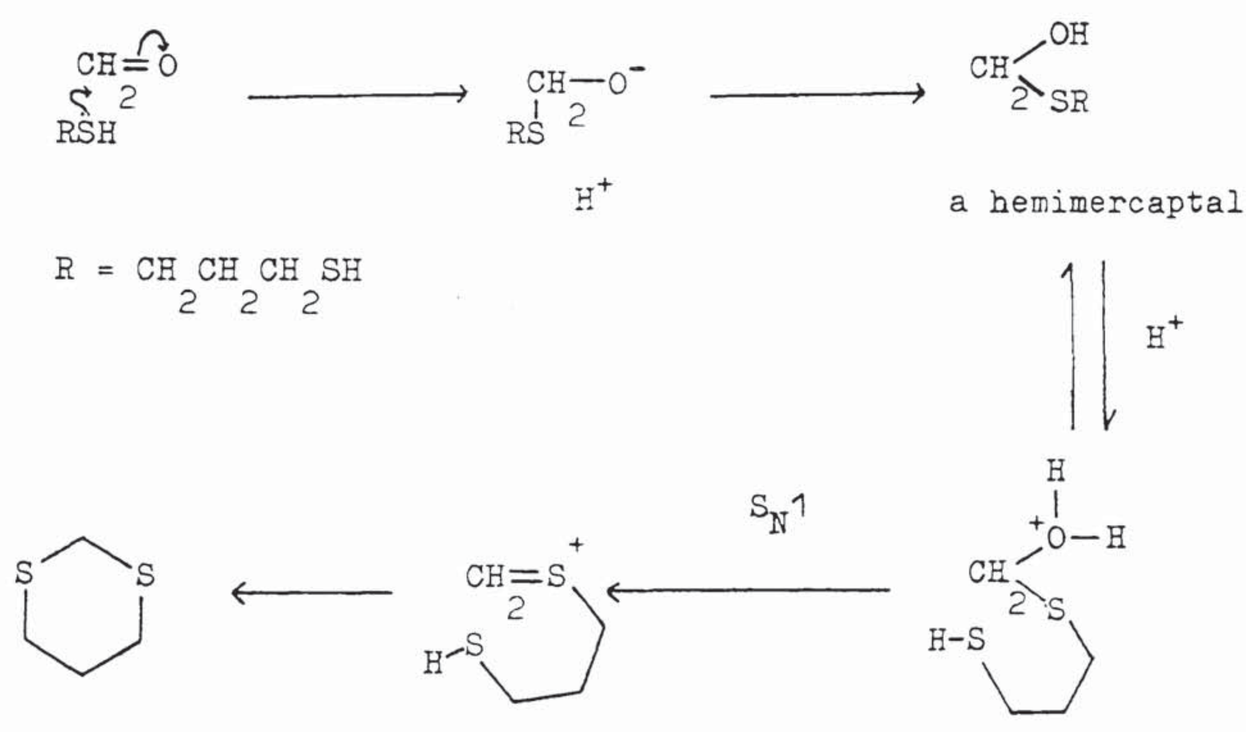


Figure 4 Mechanism by which propane-1,3-dithiol may react with formaldehyde.

1 Huston R. C. and Ewing D. T., "The action of trioxymethylene on p-xylene in the presence of aluminium chloride", *Journal of the American Chemical Society*, 37, 2394, 1915

2 Montaudo G., Finnocchiaro P., Caccamese S. and Bottino F., "Synthesis and nmr data of some variously substituted diphenylmethanes and dibenzylbenzenes", *Journal of Chemistry and Engineering Data*, 16, 249, 1971

3 Schmerling L., US Patent 3 000 985, 1962

4 Fulton S. C. and Gleason A. H., "Production of petroleum resins", *Industrial and Engineering Chemistry*, 32, 304, 1940

5 Moshchinskaya N. K., Kovtun V. P., Tokareva O. N. and Zherebtsova L. P., "Study of o-xylene condensation with formaldehyde in the presence of formaldehyde", *Vopr. Khim. Khim. Technol.*, 71, 112, 1983, abstract in *Chemical Abstracts*, 102, 5781, 1985

6 Hauptmann H. and Campos M. M., "Some mercaptols of simple cyclic ketones", *Journal of the American Chemical Society*, 72, 1405, 1950

7 Oae S., Tagaki W. and Ohno A., "3d-Orbital resonance in divalent sulphides, V", *Tetrahedron*, 20, 427, 1964

8 Coffey S. (Ed.), *Rodd's Chemistry of Carbon Compounds* (2nd ed.), Elsevier, Amsterdam, IV(H), 393, 1978

9 Gibson D. T., "1,3-dithiolan", *Journal of the Chemical Society*, 133, 12, 1930

10 Geisling K. L., Miksch R. R. and Rappaport S. M., "Generation of dry formaldehyde at trace levels by the vapour phase depolymerisation of trioxane", *Analytical Chemistry*, 54, 140, 1982

REFERENCES *CHAPTER 1*

THE RESEARCH ENVIRONMENT

1 van Rest D. J., *I.H.D. Thesis summaries 1970-79*, IHD Publication, Aston University, 1980

2 Swann M., *The flow into employment of scientists, engineers and technologists*, Cmnd 3760, HMSO, 1968

3 Cochran A. J., *Vocational PhDs: Aston's IHD Scheme*, IHD Publication, Aston University, 1981

4 Cochran A. J., *ibid.*, 5

5 Callaghan M. J., *The management of diversification in a industrial company*, PhD thesis, Aston University, 1982

6 Molloy K. J., *A systems and cybernetics approach to complex problem solving*, PhD thesis, Aston University, 1981

7 Menzies D. C., *Product innovation in a medium size mature manufacturing company*, PhD thesis, Aston University, 1986

8 Rapoport R. N., "Three dilemmas in action research", *Human Relations*, 23, 499, 1970

9 Cavity Foam Bureau, *Formaldehyde in perspective*, 9/11, The Hayes, Cardiff, 1982

10 Clark P. A., *Action research and organizational change*, Harper and Row, 17, 1972

11 Checkland P. B., *Systems thinking systems practice*, Wiley, 152-3, 1981

12 Cherns A. D., "Behavioural science engagements: Taxonomy and dynamics", *Human Relations*, 29, 905, 1976

13 Dunn W. N. and Swierczek F. W., "Planned organizational change: Towards grounded theory", *Journal of Applied Behavioral Science*, 13, 135, 1977

REFERENCES *CHAPTER 2*

INNOVATION AND THE NEW TECHNOLOGY BASED FIRM

1 Marx K., *The German ideology*, in *Karl Marx and Frederick Engels, Collected Works*, 5, Lawrence and Wishart, London, 41, 1976

2 Engels F., Letter to J Bloch, 21-22 September 1890, in *Karl Marx and Frederick Engels, Selected Works*, 2, Lawrence and Wishart, London, 443, 1953

3 Schumpeter J. A., *Capitalism socialism and democracy*, George Allen and Unwin Ltd, London, 82-3, 1976

4 Press Notice, *Innovation strategy on target after mid-course correction - Pattie*, Department of Trade and Industry, London, 31 October 1985

5 Morton J. A., *Organising for innovation*, McGraw-Hill, 1971

6 White R., *Consumer product development*, Penguin, 1976

7 Miller D., and Friesen P. H., "Innovation in conservative and entrepreneurial firms: Two models of strategic momentum", *Strategic Management Journal*, 3, I, 1982

8 Mueller R. K., *The innovation ethic*, American Management Association, 3, 1971

9 Heininger S. A., "The paradigm shift: Discontinuities for fun and profit", *Research Management*, 28 Jul/Aug, 6, 1985

10 Schon D. A., *Technological change: The new Heraclitus*, Pergamon Press, London, 44, 1967

11 Booz-Allen and Hamilton Inc., *New product management for 1980's*, 1982

12 Ohmae K., "Managing innovation and new products in key Japanese industries", *Research Management*, 28 Jul/Aug, 11, 1985

13 Robinson R. B. and Pearce J. A., "Research thrusts in small firm strategic planning", *Academy of Management Review*, 9, 128, 1984

14 Cooper A. C., "Strategic management: New ventures and small business", *Long Range Planning*, 14 (5), 39, 1981

15 Scott M., in Watkins D. S., Stanworth M. J. K. and Westrip A. (Eds), *Stimulating small firms*, Gower, 1982

16 Goldman A., "Short product lifecycles. Implications for the marketing activities of small high-technology companies", *R&D Management*, 12(2), 81, 1982

17 *Hansard*, 26-30 November, 1327, co1434W, 1984

18 Potts A. J., *A study of the success and failure rates of small businesses*, PhD thesis, George Washington University, USA, 1977

19 Mayer K. and Goldstein S., *The first two years: Problems of small firm growth and survival*, Small Business Administration, Washington, 1961

20 Rothwell R., "Innovation and firm size a case for dynamic complementarity; or is small really beautiful", *Journal of General Management*, 8 (Spring), 5, 1983

21 Barreyre P., "The management of innovation in small and medium sized industries", *International Studies of Management and Organisation*, 7(2), 76, 1977

22 Confederation of British Industry, *Innovation and competitiveness in smaller companies*, CBI, London, 1979

23 Robinson R. B., "Forecasting and small business: A study of the strategic planning process", *Journal of Small Business Management*, 4(I), 7, 1979

24 Van Hoorn P., "Strategic planning in small and medium sized companies", *Long Range Planning*, 12(2), 84, 1979

25 Bolton J. E. (Chairman), *Report to the committee of inquiry on small firms*, HMSO, London, 1971

26 US Small Business Administration, *SBA facts*, US Printing Office, Washington, 1981

27 Bolton J. E., *op. cit.*, 1971

28 "British small business", *The Economist*, July 23, 66, 1983

29 Bolton J. E., *op. cit.*, 1971

30 Howe G., The Today Programme, BBC Radio 4, 9 October, 1985

31 *Hansard*, IO May, 1309, col 1196, 1984

32 Ganguly P. and Hilton S., "Lifespan analysis of businesses in the UK 1973-82", *British Business*, 11, 12 Aug., 838, 1983

33 Hamilton B., in Lewis J., Stanworth J. and Gibb A. (Eds), *Success and failure in small business*, Gower, 1984

34 Rothwell R. and Zegveld W., *Innovation and the small and medium sized firm*, Frances Pinter, London, 120, 1982

35 Birch D. L., *The job creation process*, M.I.T. Centre for Policy Alternatives, Cambridge, Mass., 1979

36 Orr J. L., *Job creation in the Canadian business sector and the vital role of small scale enterprises*, Canadian Federation of Independant Business, Tech-Novation Consultants, 380 Roxborough Ave, Ottawa, Canada, 1980

37 Storey D., *Job creation and small firms policy in Britain*, Centre for Environmental Studies, London, Research Series 11, 1980

38 Oakey R. P., "Finance and innovation in British small independent firms", *Omega*, 12, 113, 1984

39 Riche R. W., Hecker D. E. and Burgan J. U., *High technology firms today and tomorrow: A small slice of the employment pie*, Monthly Labour Review, US Department of Labour Statistics, Nov., 1983

40 Dun and Bradstreet Ltd, *Patterns for success in managing a business*, New York, 3, 1967

41 Bayliss P., "Small cure for great ills", *The Accountant*, 8 July, 17, 1982

42 Ganguly P. and Hilton S., *op. cit.*, 1983

43 Cooper A. C. and Bruno A. V., "Success among high-technology firms", *Business Horizons*, April, 16, 1977

44 Scott M., *op. cit.*, 1982

45 Hall G. and Lam K., in Watkins D. S., Stanworth M. J. K. and Westrip A. (Eds), *Stimulating small business*, Gower, 1982

46 Galbraith J. K., *American capitalism*, Houghton Mifflin, Boston, 91-2, 1952

47 *The overall level and structure of R&D efforts in member countries*, Organisation for Economic Co-operation and Development, Paris, 1967

48 Freeman C., "The role of small firms in innovation, in the UK, since 1945", Report to Bolton Committee on Small Firms, Research Reports 6, HMSO, London, 1971

49 Shanks M., *The innovators*, Pelican, 214, 1967

50 Rothwell R. and Zegveld W., *op. cit.*, 1982

51 Freeman C., *The economics of industrial innovation*, Penguin, 218, 1974

52 Schumacher E. F., *Small is beautiful: a study of economics as if people mattered*, Blond and Briggs, London, 173, 1973

53 Jewkes J., Sawers D. and Stillerman R., *The sources of invention*, Macmillan, 1958

54 Schmookler J., *Innovation and economic growth*, Harvard Press, 1966

55 Pavitt K. L. R., "R&D, patenting and innovative activities: a statistical exploration", *Research Policy*, 11 (1), 35, 1982

56 Freeman C., *op cit.*, 1971

57 SPRU data bank figures, in Rothwell R. and Zegveld W., *op. cit.*, 63, 1982

58 Freeman C., *op. cit.*, 187, 1974

59 Myers S. and Marquis D. G., *Successful commercial innovations*, NSF 69-17, National Science Foundation, Washington, 1969

60 Mansfield E., *Industrial research and technological innovation*, Norton, New York, 1968

61 Freeman C., *op. cit.*, 217, 1974

62 Bolton J. E., *op. cit.*, 1971

63 Rothwell R., *op. cit.*, 1983

64 Scherer F. M., *Industrial market structure and economic performance*, Rand McNally, New York, 357, 1980

65 Penrose E., *The theory of the growth of the firm*, Blackwell, Oxford, 1959

66 Adams A., "Barriers to innovation in small firms: Policy and implications", *European Small Business Journal*, 1, 67, 1982

67 Hosmer L., Cooper A. and Vesper K., *The entrepreneurial function*, Prentice-Hall Inc., Englewood Cliffs, 1977

68 Rothwell R., "The role of small firms in the emergence of new technologies", *Omega*, 12, 19, 1984

69 A. D. Little Ltd, *New technology based firms in the UK and FGR*, Wilton House Publications, London, 1977

70 Shimshoni D., "The mobile scientist in the American instrument industry", *Minerva*, 8(1), 59, 1970

71 Rothwell R., *op cit.*, 5, 1983

72 Utterback J. M. and Abernathy W. J., "A dynamic model of process and product innovation", *Omega*, 3, 639, 1975

73 Utterback J. M., "Innovation in industry and the diffusion of technology", *Science*, 183, 621, 1974.

74 Pavitt K., in Goldsmith M. (Ed.), *Technological innovation in the economy*, Wiley, 92, 1970

75 Rockwell R. and Particelli M. C., "New product strategy: How the pros do it", *Industrial Marketing*, May, 49, 1982

76 Booz-Allen and Hamilton Inc., *op. cit.*, 1982

77 Merrifield B., "Nurturing the innovator", *Research Management*, 22 (Nov), 12, 1979

78 McCrory R., in Gregory S. (Ed.), *The design method*, Butterworths, 1966

79 Bessant J. R., *A study of inputs and their influence on technological innovative activity*, PhD thesis, Aston University 1978

80 Myers S. and Marquis D. G., *op. cit.*, 4, 1969

81 Schmidt-Tiedeman K. J., "A new model of the innovative process", *Research Management*, 25 (March) 18, 1982.

82 Morton J. A., *op. cit.*, 17, 1971

83 Kline S. J., "Innovation is not a linear process", *Research Management*, 28 (July/Aug), 36, 1985

84 Goldhar J. D., Bragaw L. K. and Schwartz J. J., "Information flows, management styles and technological innovation", *IEEE Transactions on Engineering Management*, EM-23(1), 51, 1976

REFERENCES

CHAPTER 3

STRATEGIES FOR INNOVATION IN A NEW TECHNOLOGY BASED FIRM

1 Buijs J., "Strategic planning and product innovation", *Long Range Planning*, 12, 23, 1979

Sage M. G., *The critical role of strategic management in innovation*, PhD thesis, CNAA, 1980

3 Robinson R. B. and Pearce J. A., "Research thrusts in small firm strategic planning", *Acadamy of Management Review*, 9, 128, 1984

4 Littler D., *Marketing and new product development*, Philip Allan, Oxford, 85, 1984

5 Chandler A. D., *Strategy and structure*, MIT Press, 13, 1962

6 Robinson R. B. and Pearce J. A., *op. cit.*, 1979

7 Aharoni Y., Maimon Z. and Segev E., "Performance and autonomy in organizations: Determining dominant environmental components", *Management Science*, 24(9), 935, 1978

8 Mintzberg H., "Patterns in strategy formation", *Management Science*, 24(9), 915, 1978

9 "Hallmark now stands for a lot more than cards", *Business Week*, 29 May, 54, 1978

10 Glueck W. F. and Jauch L. R., *Strategic management and business policy*, McGraw-Hill, 56, 1984

11 Ansoff H. I., *Corporate strategy*, Pelican, 97, 1965

12 Crawford C. M., "Defining the charter for product innovation", *Sloan Management Review*, Fall, 3, 1980

13 Newman W. H. and Logan J. P., *Strategy, policy and central management*, South-Western Publishing, 1981

14 Thompson J. and McEwen W., "Organizational goals and environment", *American Sociological Review*, 23, 23, 1958

15 Mintzberg H., "Organizational power and goals, a skeletal theory", in Hofer C. and Schendel D. W. (Eds.), *Strategic management*, Little Brown, Boston, 1979

16 Guth W. D. and Taguiri R., "Personal values and corporate strategy", *Harvard Buisness Review*, 43 (Sept/Oct), 124, 1965

17 England G. W., "Managers and their value systems", *Columbia Journal of World Business*, 13(2), 35, 1978

18 Mintzberg H., "Strategy-making in three modes", *California Management Review*, 16(2), 44, 1973

19 Miles R. E. and Snow C. C., *Organizational strategy, structure and process*, McGraw-Hill, New York, 1978

20 Glueck W. E. and Jauch L. R., *op. cit.*, 1985

21 Shirley R. C., Peters M. H. and El-Ansary A. I., *Strategy and policy formation*, Wiley, 1976

22 Ansoff H. I., *op. cit.*, 1965

23 Steiner G. A., *Strategic planning*, Free Press, New York, 134, 1979

24 Kindleberger C. P. and Herrick B., *Economic development*, (3rd ed.), McGraw-Hill, 1977

25 Holland S., *The regional problem*, (2nd ed.), Macmillan, 124, 1976

26 Rothwell R., "Government innovation policy", *Technological Forecasting and Social Change*, 22 (Sept), 3, 1982

27 Ansoff H. I. and Stewart J. M., "Strategies for a technology-based business", *Harvard Business Review*, 45 (Nov/Dec), 71, 1967

28 Freeman C., *The economics of industrial innovation*, (2nd ed.), Frances Pinter, London, 1982

29 Financial Times, 10 August, 16, 1981

30 von Neumann J. and Morganstern O., *Theory of games and economic behaviour*, (2nd ed.), Princeton University Press, 1947

31 Newman W. H. and Logan J. P., *op. cit.*, 53, 1981

32 Ansoff H. I., *op. cit.*, 145, 1965

33 Porter M. E., *Competitive strategy*, Free Press, New York, 34, 1980

34 Porter M. E., *ibid.*, 41, 1980

35 Littler D., *op. cit.*, 1984

36 Freeman C., *op. cit.*, 1982

37 Rickards T., *Stimulating innovation*, Frances Pinter, London, 1985

38 David F. R., "How do we choose among alternative growth strategies", *Managerial Planning*, 33, 14, 1985

39 Glueck W. F. and Jauch L. R., *op. cit.*, 300, 1985

40 Jauch L. R., Osborn R. N. and Glueck W. F., "Short term financial success in large business organisations: The environment-strategy connection", *Strategic Management Journal*, 1, 49, 1980

41 Miles R. E. and Snow C. C., *op. cit.*, 29, 1978

42 Ansoff H. I., *op. cit.*, 176, 1965

43 Porter M. E., *op. cit.*, 215, 1980

44 Chandler A. D., *op. cit.*, 1962

45 Mintzberg H., *op. cit.*, 1978

46 Tavistock R., "Approaching the new product innovation problem", *European Journal of Marketing*, 18(6/7), 30, 1984

47 Carter C. F. and Williams B. R., *Industry and technical progress*, Oxford University Presss, Oxford, 1957

48 Burns T. and Stalker G. M., *The management of innovation*, Tavistock, 1961

49 Nystrom H., *Creativity and innovation*, Wiley, New York, 1979

50 Shanks M., *The innovators*, Pelican, 1965

51 Souder W. E., "Effectiveness of product development methods", *Industrial Marketing Management*, 7, 299, 1978

52 Rothwell R. and Zegveld W., *Innovation and the small and medium sized firm*, Frances Pinter, London, 1982

53 A. D. Little Ltd, *New technology based firms in the UK and FGR*, Wilton House Publications, London, 230, 1977

54 Cooper A. C., "Strategic management: New ventures and small business", *Long Range Planning*, 14 (5), 39, 1981

55 Stanworth M. J. K. and Curran J., *Management motivation in the smaller business*, Gower, 1973

56 McClelland D., *The achieving society*, C. van Noosterand, Princeton, 1961

57 A. D. Little Ltd, *op. cit.*, 230, 1977

58 Schon D. A., *Technology and change: The new Heraclitus*, Pergammon Press, Oxford, 1967

59 Collins O. and Moore D., *The organization makers*, Appleton Century Crafts, New York, 1970

60 Cooper A. C., *op. cit.*, 1981

61 Bruce R., *The entrepreneurs*, Libertarian, Bedford, 1976

62 Nylen D. W., "New product failures: Not just a marketing problem", *Business*, Sept/Oct, 2, 1979

63 Roberts E. B. and Wainer H. A., "Some characteristics of technical entrepreneurs", *IEEE Transactions on Engineering Management*, EM-18, 100, 1971

64 Cooper A. C., "Technical entrepreneurship: What do we know?", *R&D Management*, 3 (2), 59, 1973

65 Liles P., *New business ventures and the entrepreneur*, R. D. Irwin, Homewood, 1974

66 A. D. Little Ltd., *op. cit.*, 1977

67 Cooper A. C., *op. cit.*, 1981

68 Cooper A. C. and Bruno A. V., "Success amongst high-technology firms", *Business Horizons*, April, 16, 1977

69 Rothwell R., "The characteristics of successful innovators and technically progressive firms", *R&D Management*, 7, 191, 1977

70 Schon D. A., "Champions for radical new inventions", *Harvard Business Review*, 41 (Mar/Apr), 77, 1963

71 Chakrabati A. K., "The role of champion in product innovation", *California Management Review*, 17 (2), 58, 1974

72 Madique M. A., "Entrepreneurs, champions and technological innovation", *Sloan Management Review*, Winter, 59, 1980

73 Chakrabati A. K., *op. cit.*, 1974

74 Jervis P., "Innovation and technology transfer - The roles and characteristics of individuals", *IEEE Transactions on Engineering Management*, EM-22, 19, 1975

75 Madique M. A., *op. cit.*, 1980

76 Fischer W. A., Hamilton W., McLauchlin C. P. and Zmud R. W., "The role of the product champion", *R&D Management*, 15, 71, 1985

77 Schon D. A., *op. cit.*, 1973

78 Cohn T. and Lindberg R. A., *Survival and growth: Management strategies for the small firm*, AMACOM, 123, 1974

79 Kennedy R. A., "The adoption and diffusion of new industrial products", *European Journal of Marketing*, 17(3), 31, 1983

80 Stewart W. L. and Friedman N. W., *Problems of small high technology firms*, National Science Foundation, US, NSF 81-305, 1981

81 Brion J. M., *Corporate market planning*, Wiley Marketing Series, New York, 88, 1967

82 Crawford C. M., *op. cit.*, 1980

83 Mason R. S., "Product diversification and the small firm", *Journal of Business Policy*, 3 (3), 28, 1973

84 Penrose E., *The theory of the growth of the firm*, Blackwell, Oxford, 1959

85 Rothwell R., "Innovation and firm size: A case for dynamic complementarity, *Journal of General Management*, 8 (Spring), 6, 1983

86 A. D. Little Ltd, *op. cit.*, 230, 1977

87 Hlavacek J. D., Dovey B. H. and Biondo J. J., "Tie small business technology to marketing power", *Harvard Business Review*, 55 (Jan/Feb), 106, 1977

88 A. D. Little Ltd, *op. cit.*, 40, 1977

89 Rothwell R., "Small firms in the emergence of new technologies", *Omega*, 12, 19, 1984

90 Mason R. S., *op. cit.*, 1973

91 Ansoff H. I. and Stewart J. M., *op. cit.*, 1967

92 Porter M. E., *op. cit.*, 232, 1980

93 Mason R. S., *op. cit.*, 1973

94 Porter M. E., *op. cit.*, 230, 1980

95 Goldman A., "Short product lifecycles: Implications for the marketing activities of small high technology companies", *R&D Management*, 12 (2), 81, 1982

96 Ansoff H. I. and Stewart J. M., *op. cit.*, 1967

97 Robinson R. B., "Importance of outsiders in small firm strategic planning", *Academy of Management Journal*, 25, 80, 1982

98 Potts A. J., *A study of the success and failure rates and the use and non-use of accounting information*, PhD thesis, George Washington University, 1977

99 Rothwell R., "The characteristics of successful innovators and technically progressive firms", *R&D Management*, 7, 191, 1977

100 Hlavacek J. D., Dovey B. H. and Biondo J. J., *op. cit.*, 1977

REFERENCES

MANAGING NEW PRODUCT INNOVATION

1 Cooper R. G., "The myth of the better mousetrap", *Business Quarterly*, Spring, 69, 1981

2 Booz-Allen and Hamilton Inc., *New products management for the 1980's*, 1982

3 Littler D., *Marketing and new product development*, Philip Allan, Oxford, 94, 1984

4 Achilladelis B., Jervis P. and Robertson A., *Project SAPPHO: A study of success and failure in innovation*, Science Policy Research Unit, Sussex University, 1971

5 Jervis P., "Innovation and technology transfer: The roles and characteristics of individuals", *IEEE Transactions on Engineering Management*, EM-22, 19, 1975

6 Rothwell R., "The characteristics of successful innovators and technically progressive firms", *R&D Management*, 7, 191, 1977

7 Nylen D. W., "New product failures: Not just a marketing problem", *Business*, Sept/Oct, 2, 1979

8 Millman A. F., "Understanding barriers to product innovation at the R&D/Marketing interface", *European Journal of Marketing*, 16(5), 22, 1982

9 Adams A., "Barriers to product innovation in small firms", *European Small Business Journal*, 1, 67, 1982

10 Capital Information Planning Ltd, *Information and the small manufacturing firm*, CPI Publications, 66, 1982

11 Adams A. H. and Walbank W. M., *New product introduction in smaller manufacturing firms*, Science Research Council GR/A 71073, Department of Management Sciences, U.M.I.S.T., Manchester, 1981

12 Twiss B., *Managing technological innovation*, Longman, 6, 1974

13 Cooper R. G., *op. cit.*, 1981

14 Cooper R. G., "The performance impact of product innovation strategies", *European Journal of Marketing*, 18(5), 5, 1984

15 Nylen D. W., *op. cit.*, 1979

16 Goulding I., "New product development", *European Journal of Marketing*, 17(3), 3, 1983

17 Cooper R. G., *op. cit.*, 1981

18 Cooper R. G., *op. cit.*, 1984

19 Rothwell R., *op. cit.*, 1977

20 Finkin E. F., "Developing and managing new products", *Journal of Business Strategy*, 3(4), 39, 1983

21 Cooper R. G., *op. cit.*, 1981

22 Cooper R. G., "How to identify new product winners", *Research Management*, 22(5), 9, 1979

23 Goldman A., "Short product lifecycles: implications for the marketing activities of small high technology companies", *R&D Management*, 12(2), 81, 1982

24 Rothwell R. and Zegveld W., *Innovation and the small and medium sized firm*, Frances Pinter, London, 45, 1982

25 Ford D. and Rowley T. P., "Marketing and the small industrial firm", *Management Decision*, 17(2), 144, 1979

26 Twiss B., *op. cit.*, 9, 1974

27 Millman A. F., *op. cit.*, 1982

28 Clarke F., "Three golden rules of contracting", *New Scientist Supplement*, Contract Research Review, 2 May, 1974

29 Adams A., *op. cit.*, 1982

30 Marketing Society, *Marketing and small business: A study group report*, Marketing Society, London, 1967

31 A. D. Little Ltd, *New technology based firms in the UK and FGR*, Wilton House Publications, London, 241, 1977

32 Burns T. and Stalker G. M., *The management of innovation*, Tavistock, 121, 1961

33 Schon D. A., "Champions for radical new inventions", *Harvard Business Review*, 41(Mar), 77, 1963

34 A. D. Little Ltd, *op. cit.*, 240, 1977

35 Wyant R., *The business failure record*, Dun & Bradstreet, New York, 1977

36 Cooper R. G., *op. cit.*, 1984

37 Mayer K. and Goldstein S., *The first two years: Problems of small firm growth and survival*, Small Business Administration, Washington, 1961

38 Robinson R. B. and Pearce J. A., "Research thrusts in small firm strategic planning", *Academy of Management Review*, 9, 128, 1984

39 Cooper A. . and Bruno A. V., "Success amongst high-technology firms", *Business Horizons*, April, 16, 1977

40 Unni V. K., "An analysis of entrepreneurial planning", *Managerial Planning*, 33, 51, 1984

41 Robinson R. B., "The importance of outsiders in small firm stategic planning", *Acadamy of Management Journal*, 25, 80, 1982

42 Adams A., *op. cit.*, 1982

43 Rothwell R., *op. cit.*, 1977

44 Cooper R. G., *op. cit.*, 1981

45 Smiles S. quoted in Burns T. and Stalker G. M., *op. cit.*, 25, 1961

46 Goldman A., "Short product lifecycles: implications for the marketing activities of small high technology companies", *R&D Management*, 12(2), 81, 1982

47 Ansoff H. I. and Stewart J. M., "Strategies for a technology-based business", *Harvard Business Review*, 45 (Nov/Dec), 71, 1967

48 Madique M. A., "Entrepreneurs, champions and technological innovation", *Sloan Management Review*, Winter, 59, 1980

49 Rothwell R., *op. cit.*, 1977

50 Sinclair C., in De Bono E., *Tactics*, Collins, 1985

51 Times, 15 October, 1, 1985

52 Corfield K., *Innovation into profit: The capitalisation of R&D*, Aston University Lecture, 30 October, 1984

REFERENCES *CHAPTER 5*

THE STRATEGY AND STRUCTURE OF THE COMPANY

1 *Dutom Meditech Ltd, Business Plan 1981 - 1985*, April 1981

2 *Ibid.*

3 *Ibid.*

4 *Ibid.*

5 *Ibid.*

6 *Ibid.*

7 Blake S. P., *Managing for research and development*, Freeman, San Francisco, 87, 1978

8 Memo, Sales Manager, *Sales plan*, July 1982

9 *Sales plan, period July - December 1982*, July 1982

10 Special report of Sales and Marketing Manager to Directors, November 1982

11 Memo, *Dutom US marketing strategy*, October 1982

12 Memo, Sales and Marketing Manager to Managing Director, 27 Jan 1983

13 "Business expansion scheme attracts £75m", *British Business*, 15, 478, 1984

14 Johnson S, quoted in *Oxford Dictionary of Quotations*, Oxford University Press, 1979

15 Laing & Cruickshank, *Dutom Meditech plc: Prospectus of offer for subscription of ordinary shares*, July 1983

16 *Ibid.*

17 *Ibid.*

18 *Ibid.*

19 Managing Director's comments on OEH objectives at Board Meeting, 28 July 1983

20 OEH Paper for Board Meeting, 18 October 1983

21 Board Minutes, 13 September 1983

22 *Dutom Meditech plc: US market status report*, Paper for Board Meeting, 16 January 1984

23 Coopers & Lybrand, *Financial Projections*, July 1983

24 R&D Paper for Board Meeting, 13 September 1983

25 OEH Paper for Board Meeting, 18 October 1983

26 Board Minutes, 18 October 1983

27 Board Minutes, 17 April 1984

28 Board Minutes, 15 May 1984

29 *Dutom Meditech plc, Business plan*, prepared Nov 1984 released Jan 1985

30 *Dutom Meditech Ltd, Business Plan 1981 - 1985*, April 1981

31 Dutom Meditech Ltd, publicity release, 1981

32 Coopers & Lybrand, *Financial projections*, July 1983

33 Paper for Board Meeting, 17 April 1984

34 Report, Personal Assistant to Managing Director, May 1982

35 Memo, Sales and Marketing Manager to Managing Director, 27 January 1983

REFERENCES

CHAPTER 6

DUTOM MEDITECH'S PRINCIPAL PRODUCTS

1 Sithamparanadarajah R., *Quantitative adsorptive trapping of atmospheric contaminants in operating theatres*, PhD thesis, Birmingham University, 1980

2 Thompson J. M., Sithamparanadarajah R. and Stephen W. I., UK patent application no. 80/20635, June 1980

3 Thompson J. M., Sithamparanadarajah R. and Stephen W. I., European patent application no. EP 42683, December 1981

4 Coopers & Lybrand, Report to the Directors, 7 November 1984

5 Thompson J. M., Personal communication, 1 March 1985

6 *Dutom disposable NIOSH type tubes: Marketing strategy*, August 1982

7 Coopers & Lybrand, *Financial projections*, 114, July 1983

8 Scientific Advisory Panel Meeting Minutes, 16 December 1983

9 Telex, President Digicolor Inc. to Managing Director Dutom Meditech plc, *Dutom project report: US market for Adsorba/Desorba systems*, 9 July 1984

10 Memo, Biochemistry General Manager to Managing Director, *Transcript of telephone conversation with Digicolor*, 23 July 1984

11 *Dutom Meditech plc: US market status report*, Paper for Board Meeting, 16 January 1984

12 Dosimeter memo, Marketing Manager to Chief Executive, *Desorba and Adsorba status report and technical evaluation*, 3 March 1983

13 *Ibid.*

14 Technical Manager, *Report on US visit 22 - 30 May 1983*, May 1983

15 Dosimeter memo, Product Manager to Marketing Manager, *Desorba and Adsorba updated status report and technical evaluation*, 28 July 1983

16 Boehringer J. R., and Lecky J., US patent no. 4046014, 1977

17 Letter, Marketing Director Dutom Meditech plc to Chief Executive Dosimeter Corporation, 21 September 1983

18 Telex, President Digicolor Inc. to Managing Director Dutom Meditech plc, *Dutom project report: US market for Adsorba/Desorba systems*, 9 July 1984

19 Memo, Biochemistry General Manager to Managing Director, *Transcript of telephone conversation with Digicolor*, 23 July 1984

20 Letter, Managing Director to Dutom's Solicitors, 4 April 1985

21 Directors Meeting Minutes, 22 March 1985

22 Coopers & Lybrand, *Financial projections*, 112, July 1983

23 Brown R. H. and Purnell C. J., "Collection and analysis of trace organic vapour pollutants in ambient atmospheres: The performance of a Tenax GC adsorbent tube", *Journal of Chromatography*, 178, 79, 1979

24 Telex, President Digicolor Inc. to Managing Director Dutom Meditech plc, 21 November 1984

25 Telex, Dutom Meditech Ltd to J & S Sieger Ltd, 10 January 1983

26 Letter, Production Director J & S Sieger Ltd to Technical Director Dutom Meditech plc, 5 October 1983

27 Letter, Production Director J & S Sieger Ltd to OEH General Manager, 17 November 1983

28 Letter, Acting Managing Director Dutom Meditech plc to Managing Director J & S Sieger Ltd, 31 October 1984

29 Coopers & Lybrand, *Auditors report on the cost estimate: Dutom Meditech plc pre production order - Thermal Desorption Oven*, 18 July 1983

30 Letter, Product Line Manager Combustion Engineering Inc. to the Researcher, 17 July 1985

31 Coopers & Lybrand, *Financial projections*, 113, July 1983

32 Dosimeter memo, Marketing Manager to Chief Executive, *Desorba and Adsorba status report and technical evaluation*, 3 March 1983

33 Telex, President Digicolor Inc. to Managing Director Dutom Meditech plc, "Dutom project report: US market of Adsorba/Desorba systems", 9 July 1984

34 Memo, Biochemistry General Manager to Managing Director, *Transcript of telephone conversation with Digicolor*, 23 July 1984

35 Telex, President Digicolor Inc. to Managing Director Dutom Meditech plc, 30 November 1984

36 OEH General Manager, *Visit report to Gelman Spa*, 29 November 1983

37 Coopers & Lybrand, *Financial projections*, 123, July 1983

38 Autoscribe Ltd, *Market development projects*, March 1984

39 Memo, Biochemistry General Manager to Managing Director, *Desorba situation*, 23 July 1984

40 *Product strategy*, Paper for Board Meeting, 17 July 1984

41 *Objectives - OEH*, Paper for Board Meeting, 27 July 1983

42 Board Meeting Minutes, 13 September 1983

REFERENCES

CHAPTER 7

SOME INCOMPLETE PRODUCT INNOVATIONS

1 *Dutom Meditech Ltd, Business plan 1981 - 1985*, April 1981

2 Letter, Sales Manager BASF (UK) Ltd to General Manager Dutom Meditech Ltd, 21 August 1981

3 *Ibid.*

4 Letters, General Manager Dutom Meditech Ltd to Sales Manager BASF (UK) Ltd, 8 September 1981

5 *Ibid.*

6 Letter, Accounts Staff Dutom Meditech Ltd to BASF (UK) Ltd, 6 July 1982

7 Memo, ex-General manager Dutom Meditech Ltd to Accounts Staff Dutom Meditech Ltd, 1 July 1983

8 *Dutom Meditech Ltd, Business plan 1981 - 1985*, April 1981

9 NIOSH, *Current Intelligence Bulletin*, 34, NIOSH, Cincinatti, 1981

10 Fielder R. J., *Toxicity Review 2, Formaldehyde*, HMSO, 1981

11 *The assesment of data on the effect of formaldehyde on humans*, Techncal Report 1, European Chemical Industries Ecology and Toxicology Centre, Brussels, 1982

12 Marsh G. M., "Proportional mortality patterns among chemical plant workers exposed to formaldehyde", *British Journal of Industrial Medicine*, 39, 313, 1982

13 Acheson E. D., Gardner M. J., Pannett B., Barnes H. R., Osmond C., and Taylor C. D., "Formaldehyde in the British chemical industry: an occupational cohort study", *Lancet*, 8377, 611, 1984

14 Matsumura T. and Muramatsu S., "Study of formaldehyde concentration in indoor air", *PPM*, 14, 2, 1983

15 Hawthorne A. R. and Gammage R. B., "Formaldehyde release from simulated wall panels insulated with urea-formaldehyde foam insulation", *Journal of the Air Pollution Control Association*, 32, 1126, 1982

16 Konakahara T., Kawashima M. and Sato K., "Studies on formaldehyde resins, 21.", *Makromol. Chem. Rapid, Commun.*, 6, 65, 1985, abstract in *Chemical Abstracts*, 102, 150184, 1985

17 3M, Patent, Japan Kokai Tokkyo Koho JP 58178257, 1983

18 Lambert J. L., Paulstelis J. V., Liaw Y. L. and Chaing Y. C., "Sensitive solid reagent for formaldehyde and a new formaldehyde generator", *Analytical Letters*, 17(A17), 198, 1984

19 Ahonen I., Priha E. and Aijala M. L, "Specificity of analytical methods used to determine the concentration of formaldehyde in workroom air", *Chemosphere*, 13, 521, 1984

20 Knox S. E. and Hee S. S., "Phenol interference in the mercury free pararosaniline method and chromotropic acid method for formaldehyde", *American Industrial Hygiene Association Journal*, 45, 325, 1984

21 Muller J. and Grunier J. P., "Sampling gaseous polutants", *Cah. Notes Doc.*, 116, 313, 1984, abstract in *Chemical Abstracts*, 101, 136056, 1984

22 Estes E., Grohse P., Gutknecht W. F. and Jayenty R. K. M., EPA-600/4-83-031, Goverment Reports Announcement Index (US), 83, 4889, 1983

23 Patent, Japan Kokai Tokkyo Koho, JP 59128433, 1984

24 Hauptmann H. and Campos M. M., "Some mercaptols of simple cyclic ketones", *Journal of the American Chemical Society*, 72, 1405, 1950

25 Young G., Under Secretary of State for the Environment, ITN News, 11 October 1982

26 Cooper R. G., "The myth of the better mousetrap", *Business Quarterly*, Spring, 69, 1981

27 Kerin R. A., Harvey M. G. and Rothe J. T., "Product cannibalism", *Business Horizons*, Oct., 25, 1978

28 Board Minutes, 18 October 1983

29 *Manpower*, Paper for Board Meeting, 10 July 1984

30 *Project strategy*, Paper for Board Meeting, 10 July 1984

31 *Review of research progress*, Paper for Board Meeting, 10 July 1984

32 Letter, Managing Director Dutom Meditech plc to Commercial Manager Jeol (UK) Ltd, 5 March 1985

33 Letter, Managing Director Dutom Meditech plc to Managing Director Kane-May Ltd, 17 January 1985

34 Letter, Managing Director Dutom Meditech plc to Commercial Manager Jeol (UK) Ltd, 5 March 1985

35 Coopers & Lybrand, *Financial projections*, 127, July 1983

36 Autoscribe Ltd, *Marketing development report*, March 1984

37 Board Minutes, 17 April 1984

38 Coopers & Lybrand, *Financial projections*, 139, July 1983

39 Board Minutes, 17 April 1984

REFERENCES *CHAPTER 8*

A DISCUSSION OF DUTOM'S STRATEGIES AND PRACTICES

1 Freeman C., *The economics of industrial innovation*, Penguin, 218, 1974

2 Rothwell R., "The role of small firms in the emergence of new technologies", *Omega*, 12, 19, 1984

3 A. D. Little Ltd, *New technology based firms in the UK and FGR*, Wilton House Publications, London, 2, 1977

4 Basil D. C. and Cook C. W., *The management of change*, McGraw-Hill, 50, 1974

5 Report of House of Lords Select Committee on Overseas Trade, October 1985

6 Cooper A. C. and Bruno A. V., "Success amongst high-technology firms", *Business Horisons*, April, 16, 1977

7 Twiss B., *Managing technological innovation*, (3rd ed.), Longman, 7, 1986

8 *Dutom Meditech Ltd, Business Plan 1981 - 1985*, April 1981

9 Basil D. C. and Cook C. W., *op. cit.*, 49, 1974

10 Cooper R. G., "The performance impact of product innovation strategies", *European Journal of Marketing*, 18(5), 5, 1984

11 Rothwell R., *op. cit.*, 1984

12 Adams A. H. and Walbank W. M., *New product introduction in smaller manufacturing firms*, Science Research Council GR/A 71073, Dept. of Management Sciences, U.M.I.S.T., Manchester, 1981

13 Utterback J. M. and Abernathy W. J., "A dynamic model of process and product innovation", *Omega*, 3, 639, 1975

14 Porter M. E., *Competitive strategy*, Free Press, New York, 215, 1980

15 Ansoff H. I. and Stewart J. M., "Strategies for a technology-based business", *Harvard Business Review*, 45(Nov/Dec), 71, 1967

16 Rickards T., *Stimulating innovation*, Frances Pinter, London, 1985

17 Freeman C., *op. cit.*, 1974

18 Dosimeter memo, Product Manager to Marketing Manager, *Desorba and Adsorba updated status report and technical evaluation*, 28 July 1983

19 Adams A. H. and Walbank W. M., *op. cit.*, 1981

20 Board Meeting Minutes, 8 August 1984

21 Coopers & Lybrand, Report to the Directors, 7 November 1984

22 Goldman A., "Short product lifecycles: implications for the marketing activities of small high technology companies", *R&D Management*, 12(2), 81, 1982

23 Rothwell R. and Zegveld W., *Innovation and the small and medium sized firm*, Frances Pinter, London, 1982

24 A. D. Little Ltd, *op. cit.*, 1977

25 *Innovation in small and medium sized firms*, Paris, 1982

26 Clarke F., "Three golden rules of contracting", *New Scientist Supplement*, Contract Research Review, 2 May 1974

27 Millman A. F., "Understanding barriers to product innovation at the R&D/Marketing interface", *European Journal of Marketing*, 16(5), 22, 1982

28 Adams A., "Barriers to product innovation in small firms", *European Small Business Journal*, 1, 67, 1982

29 Cohn T. and Linberg R. A., *Survival and growth: Management strategies for the small firm*, AMACOM, New York, 121, 1974

30 Roth H., "Product development has to be planned", in Lynch C. J. (Ed.), *Managing advancing technology*, vol 1, American Management Association, 143, 1972

31 Rothwell R., "The characteristics of successful innovators and technically progressive firms", *R&D Management*, 7, 191, 1977

32 Millman A. F., *op. cit.*, 1982

33 Twiss B., *op. cit.*, 6, 1986

34 Cooper R. G., *op. cit.*, 1984

35 Cannon T., "New product development", *European Journal of Marketing*, 12, 217, 1978

36 Scientific Advisory Panel Meeting Minutes, 16 December 1983

37 Rothwell R., "Innovation and firm size: A case for dynamic complementarity", *Journal of General Management*, 8(Spring), 6, 1983

38 A. D. Little Ltd, *op. cit.*, 230, 1977

39 Cooper R. G., "The myth of the better mousetrap", *Business Quarterly*, Spring, 69, 1981

40 Cooper R. G., "How to identify new product winners", *Research Management*, 22(5), 9, 1979

41 A. D. Little Ltd, *op. cit.*, 241, 1977

42 Porter M. E., *op. cit.*, 35, 1980

43 *Dutom Meditech Ltd, Business Plan 1981 - 1985*, April 1981

44 Porter M. E., *op. cit.*, 41, 1980

45 Porter M. E., *ibid.*, 230, 1980

46 Autoscribe Ltd, *Market development projects*, March 1984

47 Coopers & Lybrand, Report to the Chairman, 21, 6 July 1984

48 Chairman Dutom Meditech plc, Foreward to the company accounts April 1983-4, 21 November 1984

49 Kennedy A. M., "The adoption and diffusion of new industrial products", *European Journal of Marketing*, 17(3), 31, 1983

50 Letter, Company Secretary Dutom Meditech plc to Coopers & Lybrand, March 1985