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Original Citation:
Francesca, Paluan (2016). *Planning the safeguard of hidden heritage: Standards and compromises for the physical preservation of "minor" archives of Contemporary Architecture.* In: Le Vie dei Mercanti - XIV Forum Internazionale di Studi, Napoli - Capri, 16 - 18 giugno 2016. pp. 589-598

Availability:
This version is available at : http://porto.polito.it/2644438/ since: June 2016

Publisher:
La Scuola di Pitagora editrice

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Le Vie dei Mercanti XIV International Forum
WORLD HERITAGE AND DEGRADATION
Smart Design, Planning and Technologies
Aversa | Naples 16 - Capri 17, 18 June 2016

Planning the safeguard of hidden heritage: Standards and compromises for the physical preservation of "minor" archives of Contemporary Architecture

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Abstract
Contemporary architectural archives are a peculiar kind of "borderline" heritage, oscillating between the collection and the deposit status. This ambivalence raises questions about their protection and enhancement: the architectural drawings exposure and consultation are designed and managed according to Standards relating to the archival sector, in the strict sense; however, such a specific approach will not be sufficient if the documents include design drawings, characterized by different formats, techniques and supports. The balance between external environment, conservation spaces and drawings is maintainable if preventive conservation methodologies are applied to limit the chemical, physical and biological degradation through active and passive systems of environmental control. The protection strategies are explained in Standards and Guidelines, often made accessible by national and international bodies and often taken on, at the institutional level, with different results, since every archive proves to be an organism on its own. This paper proposes the analysis and comparison of the regulations, produced in Italy and abroad, on the preventive conservation and the methodologies of the architectural documents exhibition, highlighting how much the values of environmental parameters are not as important, if they are considered in end of themselves, as the investigation of other factors, ranging from the materials chemistry and physics at the past history of each archive, up to its fruition.

Keywords: architectural archives, standards, preventive conservation, degradation, environmental control

1. Introduction
The contemporary architectural archives constitute a cultural, historic and documentary heritage recently recognized. They are characterized by a heterogeneous stratification of materials, derived by the creator's design practice. The graphic heritage of the architectural archives is considered a privileged tool, many aspects about the "making" architecture could be investigated thanks to, inflecting it depending on the research purposes (historiography, study of technical solutions, restoration, etc.). This approach, which reinforces the importance of the archival drawings such as irreplaceable sources of research [1], however could be symptomatic of a more focused perspective on the centrality of the graphic message delivered by these drawings, at the detriment of their material components, equally relevant in the field of enhancement and safeguard.
The documents constituiting the support and the product of the designers' activities (architects and engineers) can find different locations: the State Archives, the architectural archives/museums, university and research centers and private institutions. This complexity of structures and materials has to be considered at the time that the right microclimate for the storage locations have to be set in order to preserve the documents and drawings from the degradation. This paper would like to investigate the principles of the preventive conservation referring to the legislation in force in the Italian and international territory, focusing on the control of temperature, relative humidity, light and air

quality, highlighting those useful expedients for the preservation and exhibit of design drawings kept in “minor” archives, as the proof of the little-known designers’ work.

2. Architectural documents and degradation

The contemporary architectural archives are different from the most popular and accessible institutions engaged in the safeguard and enhancement of cultural heritage (museums, galleries and libraries), especially in the Italian territory. The archive is placed in fact in the “borderline” position between deposit and museum, inventory and collection of design drawings, due to the multiplicity of informational data constituting it, both for its “designing intention, which almost always tends to project the size of the document in the most heroic of the monument” [2]. It is a peculiar cultural heritage which needs dedicated strategies of conservation and enhancement, not only because of the difficult access to the documentary sources. Architectural archives hold a great historical and cultural potential of complex understanding and communication if the hidden relationships between individual documents, between documents and monuments, between documents and archival funds are not well presumed and enucleated. The architectural drawing may have its own independent artistic nature of course, but it poses often several problems of interpretation related to its own visual document character, being first of all “a document that speaks only when considered as a serial element, that is, part, together with other drawings, of a chain of design solutions” [3].

If the proposals about the architectural documentary heritage enhancement, then focused on the graphic message communication, are developed exploiting more and more the potential offered by the ICT (virtual and augmented reality, web 2.0 for the hypermedia, the sources access and sharing), the protection of the documents requires different physical preservative methods according to the materials, the storage locations and exhibit.

The objects collected in a contemporary architectural archive should be identified and recognized in their material matrix, in their past history and in their current state of conservation, in order to speculate their correct storage and appropriate consultation. The three variables (nature of materials, environment and conservation status) are also the causes of the degradation, which can be pointed out as a “natural, nonlinear and irreversible process of chemical and physical transformation, which necessarily leads to a deterioration of the original features under the conservative profile” [4].

The analysis of the degradation follows a logical path including the causes, mechanisms, effects and actions, different for each type of material, locations of preservation and conservation status.

A contemporary architectural archive could collect drawings on different supports on which graphic techniques and/or reproduction techniques have been applied. These elements, in the conservative phase, are influenced by each other at the single document level: all supports and techniques have indeed a specific physical and chemical nature influenced by each other, conditioned in turn by the environment they are located in.

The execution techniques of architectural drawings are sometimes common to other fields of art; others are typical of the architectural discipline and derived from the need of technical accuracy in the execution and reproducibility, due also to the increase in administrative practices, industrialization and the fragmentation of the works in the contemporary construction sites. In an architectural archive, photographic and audio-visual material, scale models, or painted works can be found, as well as drawings and other paper documents.

The paper materials are made up of cellulose, hemicellulose and lignin in different percentage. In particular the high percentage of cellulose determines the best quality of the support in terms of resistance and insolubility in water; on the contrary the lignin and hemicellulose, called “encrusting substances” and made up of shorter polymer chains, are responsible of the little resistance and yellowing. Other substances are added in the dough or on the surface of the paper: the filling substances are necessary to stuff the paper pores, improving the degree of whiteness, the opacity, the smoothness of the surface and therefore the printability; the adhesives confer resistance to penetration and spreading of the inks and other aqueous solutions; finally, other additives are coloring and bleaching agents [5]. The tracing paper is the most used support in the technical drawing, as it allows the reproduction of drawings and graphics. This kind of support, previously considered of poor quality compared to other types of paper, has only recently become the subject of study in the field of conservation. Its peculiarity lies in the transparency, so that the support presents both sides (front and back) which must always remain readable.

Other kinds of supports have been added to the traditional and tracing paper of various weights and manufacturing, such as plastic films (acetate and polyester) employed to draft the same drawings or for the photographic negatives; also the photographic plates, the magnetic and optical supports for audio and video documents are widespread in contemporary design archives; these components also have different conservation problems, still under investigation by the institutions appointed to the safeguard.

The most commonly chosen graphic techniques are the graphite, pastels, watercolors and various kinds of inks. Such more traditional techniques have been juxtaposed by the airbrush, widely used

since the seventies in place to the watercolor, and later supplanted by the appearance of the Computer-Aided Design, which allows plotting uniformly large fields of color. The collage is another technique, used mainly for expressive purposes. The transferable and the screens are specific materials of the technical drawing, consisting of colored and adhesive letters, lines and symbols, printed on a matrix, which can be transferred with pressure on the back of the drawing.
Drawings can also be represented in the form of copies, realized according to different ways. The reproduction processes, derived from the development and progress of photographic techniques, are differentiated into the cyanotypes, ectography, heliography and xerography, still in use. The preservation of such media is still the subject of study, because the degradation mechanisms and, accordingly, the conservative operations have not been in depth investigated yet [6].

2.1 Causes of degradation

The degradation, originating from more or less visible alterations, is determined, as already stated, by the nature of the documents and by other agents.
Materials differently interact with each other: the cellulosic hygroscopic substances, for example, are subjected to mechanical stress because of the relative humidity, in a different way from the hydrophobic supports, such as some plastic films. In the case in which such materials are assembled, their different hygroscopicity causes tensions and ruptures. In addition to these endogenous factors, linked to the intrinsic nature of the constituent materials, degradation also occurs because of exogenous factors, originating from the storage conditions. This category includes:

- environmental causes, i.e. the values of relative humidity and temperature and their gradients in time, the lighting quality, the air quality (pollutants and dust);
- biological agents, including attacks by animals, insects and micro-organisms;
- human agents, happening as the result of illicit displacements, not suitable manipulation;
- mechanical agents, i.e. vibrations of the building structure, incorrect resting conditions.

Such causes are interconnected: for example, an excessive relative humidity can trigger biological attacks.
Biological agents are responsible for the bio-deterioration. It is originated therefore by cellulolytic organisms, belonging to both bacterial and fungal species, spread by the airborne and the particulate matter. The microorganisms' action on paper is revealed as maculatures and inks discoloration, as well as in perforation and embrittlement processes of the support. The damage produced has different origins: it may be caused by the organism's nutritional activity, which disintegrates the support with its metabolization implemented by the activity of the lytic enzymes, or by the mechanical capacity of the fungal hyphae altering the structure of the support, penetrating in the subtle texture of the cellulose fibers. Even the products of metabolism deposited in the area of infection, such as the production of substances at different pH, or the production of colored pigments that may spread or remain delimited on the support in an indelible way, give origin to a macular damage. The biological attack is determined also by insects and rodents; the first category includes many species of roaches, coleoptera (including woodworms), termites, moths, lice of books and silverfish.
Another cause of the materials alteration is pollution, whose components (atmospheric particles, polluting gases, etc.), combining themselves with the oxygen and water present in the storage spaces, form acidic substances, promoting the degradation reactions of the paper and the fading of inks.
Each material also interacts differently with the microclimate of the storage spaces. Sudden excursions in humidity and temperature, inadequate exposure to light of various nature, cause variations in the paper in its dimensional aspects, corrugations, yellowing and general embrittlement.

2.2 Effects of degradation

The combination of multiple causes, present or past, produces synergistic effects. The degradation is a process involving the number and the intensity of the individual forcing events; it takes place in a progressive manner, with the aging of the material constituting the object and the alteration of its chemical-physical characteristics, accelerated by any environmental perturbations. Therefore, the previous history of each object has to be considered, because the previous environmental conditions have led to a settling of the material, in response to its physical-chemical characteristics and the external environmental sources.
In fact, the ambient conditions, either alone or with other factors, hold a key role in the degradation processes the drawings undergo: the heat and mass exchanges cause processes of internal stress, with irreversible and cumulative effects, reducing the material tolerance limits over time.
Paper undergoes degradation processes due to the impurities and the physical and chemical agents present in the ambient, through the mechanisms of:

- acidic and basic hydrolysis;
- oxidation;
- photo-degradation.

The hydrolysis is a mechanism of chemical degradation, the paper undergoes, due to the high relative humidity. Since the paper is hygroscopic, it tends to absorb or release water molecules according to the degree of the environmental relative humidity. The hydrolysis consists in the breakage of the chemical bonds between the different glucose units forming the cellulose chains, due to the insertion of water molecules. It follows the formation of smaller fragments that lower the polymerization degree of the chain and, consequently, the weakening of the sheet. The cellulose hydrolysis phenomena are catalyzed by the presence of acids (i.e. substances with pH minor than 7) or bases (pH greater than 7). These substances may already be in the paper (such as cellulose bleaching, adhesive substances like alum and rosin, inks), or may come from the external ambient (the anhydrides which easily turn into acids, and the derivatives of ammonia).
The causes and the mechanisms of the cellulose oxidation are more complex to isolate. Oxidation is a chemical reaction that does not change the length of the polymer chain, but involves the transformation of some elements, that become chemically unstable and altered. An obvious discoloration of the paper (yellowing, browning) follows the cellulose oxidation. The presence of heterogeneous compounds on the material (i.e. metals) and/or the exposure to light causes the oxidation of the cellulosic substrate, leading to the formation of acidic substances (carboxyls). In synergy with the hydrolysis, these acidic substances form volatile products of low molecular weight (VOCs, Volatile Organic Compounds), immediately recognizable from the smell found in many archives and library material deposits. The VOCs also does not disperse easily in the environment, remaining largely trapped between the paper fibers within folders closed for years, especially if the ambient is moist. The photo-oxidation is induced by the exposure of paper to the electromagnetic radiation (especially UV) and pollutants, such as ozone and oxidizing chemicals introduced in the support (for example hypochlorite used for bleaching).
The degradation effects are not always immediately recognizable, since they may manifest on the long term and be cumulative.
Light, infrared and ultraviolet rays are for example the largest energy sources and interact both physically and chemically with archival materials (photodegradation). The lighting, both natural and artificial, can:

- accelerate the deterioration, acting as a catalyst in the oxidation reactions;
- facilitate the lowering of the level of the cellulose fragility;
- discolor, fade and stain the paper;
- alter the pigments;
- increase the surface temperature of objects.

The degradation of the architectural drawings on paper is evidently associated, at the chemical level, to the supports acidity, which occurs both as effect of other processes (oxidation and photo-oxidation, the presence of anhydrides derived from pollulants), both as a triggering cause of other types of alteration, occurring especially at the optical and aesthetic level (yellowing).
The polyester (PET), used for the heliography (radex), is stabler than the cellulose and, if properly preserved, has a life expectancy of a few hundred years. The most important way of degradation at the ambient temperature is the hydrolysis, accelerated by temperature, relative humidity, acids, bases and catalysts. The hydrolysis generates carboxylic acids, producing auto-acceleration effects, intrinsic viscosity and tensile strength loss.
The paper could become acidic after the exposure to internal or external polluting agents, in particular sulfur dioxide from the industrial air pollution of the nineteenth and twentieth century. In addition to the Sulfur dioxide (SO_2) there are other substances (the VOCs Volatile Organic Compounds, the carbon monoxide CO, the NO_X nitrogen oxides, the respirable dust PM_{10} and the total suspended dust) related to the air emissions from the antropic activities. The sulfur dioxide, water-soluble, is transformed into sulfur dioxide which causes yellowing and discoloration in contact with paper materials; instead it determines sulfidation and micro spots in contact with photographic materials.

3. The preventive conservation of contemporary architectural archives

A preventive conservation plan has to be identified, after analyzing the state of conservation of the objects and the conditions under which they are kept, in order to limit and prevent those damages that would require a real restoration. The restoration, in addition to being expensive, is sometimes too invasive and potentially destructive; therefore, a good practice is trying to minimize the direct interventions on drawings, investing the economical resources in the implementation of preventive conservation strategies. Briefly:

- the preventive conservation directly affects the causes of degradation;
- the restoration directly acts on the effects of degradation.

The concept of preventive conservation is based on appropriate policies based on the adoption of behaviors and technical precautions, applicable with continuity and aimed to prevent, or slow, the degradation phenomena, reducing them to the lowest intensity.

A preventive conservation plan starts from the analysis of the state of conservation of the drawings and the ambient they are collected in, through the inspection of the site and data collection. This "survey" of the *status quo*, therefore, takes into account:

- the types and nature of the archival material heritage;
- the consistency and importance of the fund;
- the storage conditions;
- the previous history of the archival collection, where the ambient conditions may have led to a specific arrangement of the materials.

The storage conditions are often the result of a compromise choice, especially for the preservation of archives constituted by mixed materials, therefore with different conservation needs, which must be placed in the same spaces for organizational and management issues, with the same environmental conditions.

Another subject to examine in depht is the relationship between drawings and building and the balance established between them, analyzing:

- the general conditions of the building structure (degree of protection with respect to the external climatic conditions), the plant equipment for the ambient control and the structures and systems maintenance procedures;
- the parameters that allow to describe the ambient conditions (temperature, relative humidity, lighting, air quality) to be monitored, in order to identify the critical issues and propose solutions for the improvement;
- the archival spaces designed for the storage, also called ambient of conservation;
- the handling and transport of the drawings.

Many of the problems of conservation are in fact more evident considering that the drawing lives and gradually changes in an ambient it inevitably and continuously interacts with.

Generally an archive, from the spatial and organizational point of view, consists of places having a preservative function, including:

- the storage area, in which the graphic documents are usually kept;
- the consultation reading and exhibition area, in which the graphic documents are consulted and/or temporarily exposed;
- the photocopying and restoration area;
- the access and service area, or other spaces in which the graphic documents can only pass through.

The knowledge of the state of conservation of the artifacts, their location and the relationships between indoor ambient (especially the exhibition rooms and deposits) and exterior rooms, is essential to program the safeguard and enhancement interventions. The preventive conservation measures must be established case by case, based on the real conservation needs of the archival collection in question, with the primary goal of creating safe ambients and optimal storage conditions. Some examples of preventive conservation interventions focus on:

- the preparation of the monitoring systems of the parameters describing the ambient conditions in order to assess the risks for the preservation of documents;
- the interventions on the building elements and systems;
- the identification of the most critical areas to the preservation and development of climate control strategies;
- the identification of improvement solutions with regard to the technologies for the microclimate control and the air quality monitoring;
- the shielding of the transparent portions of the building envelope for the control of natural radiation and choice of suitable artificial lighting systems.

3.1 Conservative format

The Architectural Archives belong, as already mentioned, to a cultural sphere in which the identification of a univocal type of material and object is difficult, so that many factors, very often ignored or not respected necessary from the conservative point of view, have to be analyzed. The balance between the single documents, between documents and archive, between the external environment and archive, are interdependent factors that need to be put in relation to locate the best conditions for preserving the drawings state of conservation.

In order to identify and clarify the various factors contributing to a safe preservation of the archives, a conservative format must be made, aimed at the systematic organization of technical and scientific knowledge relating to the constituent materials, executive procedures and state of preservation of the artifacts. Such organization aspired to the conservation and restoration planning, to the proper management of the manipulation, to the artifacts exhibit and storage. Since the enormous amount of documents in an architectural archive, a condition report for each drawing is difficult to write up: the state of conservation evaluation should be made "taking a sample" of drawings, identifying their

supports and graphic techniques, estimating their consistency in relation of the entire archive, to detect the more common degradation types.

4. International Standards and Guidelines

Architectural archives, as already pointed out, have a very different documentary heritage, both for the great diversity of materials, both for the use of multiple graphic techniques, which can be associated with the contemporary reproduction techniques. For this reason, each type of material needs suitable values of temperature, relative humidity, light and pollulants exposure for conservation, established and recommended by International Standards and guidelines drawn up by the institutions responsible for the safeguard of the architectural archives, identifying diversified conservative strategies for each archival collection, in accordance with its uniqueness condition (documents amount and composition and the building context) and with the availability of resources.

In the Italian background, the technical legislation has sought to address the need to provide Standards for the conservation of the architectural archives materials: paper drawings, heliocopies on paper and synthetic supports (radex), photographs, pastels, watercolors. The reference technical standards are:

- UNI 10586: 1997 Documentation - Climatic conditions for the storage spaces of graphic documents and characteristics of the boxes;
- UNI 10829: 1999 Historical and artistic heritage - Environmental conservation - Measurement and analysis;
- UNI 10969: 2002 Cultural heritage - General principles for the selection and management of microclimate for the conservation;
- UNI EN 15757: 2010 - Specifications concerning the temperature and the relative humidity to limit the mechanical damage caused by the climate to the hygroscopic organic materials.

The D.M. May 10th, 2001 – Guiding Act on the technical and scientific criteria and on standards of operation and development of museums - has also to be mentioned. Despite it is referred specifically to the museum field, it provides, in the VI part, the “Regulations for the conservation and restoration, including the exhibit and handling” of objects, indicating the methodology for conceiving a valid preventive plan, starting from the drafting of the conservation status format and monitoring the environmental parameters.

Other technical standards, internationally recognized, are provided by:

- the British Standards Institution (BSI), with “Recommendation for the Storage and Display of Archival Documents” dating back to the mid-eighties, (BS 5454: 2000, subsequently revised with PD 5454: 2012);
- the NISO (National Information Standards Organization), a nonprofit association accredited by the American National Standards Institute;
- the ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers), among whose rules there is the “Applications 2003 - Museums, Libraries and Archives”;
- the ISO (International Organization for Standardization), with the “ISO 11799: 2015 - Information and documentation - Document storage requirements for archive and library materials”, written in 2015. It specifies the characteristics of deposits, where materials on paper and mixed supports coexist. It does not preclude the establishment of separate areas or compartments within individual deposits, so that the ambient can be controlled to create the right conditions for the needs of specific archival materials. Another standard is the “ISO: 16245: 2009 (revised in 2015) - Information and documentation - Boxes, file covers and other enclosures, made from cellulosic materials, for storage of paper and parchment documents” which specifies the requirements for boxes and covers, made up of cellulose, used for long-term conservation of paper or parchment documents.

Even the establishments dedicated to the enhancement of the architectural archival heritage, along with the conservation and restoration centers, provide their contribution on the rules of drawings maintenance, also reporting the reference values of environmental parameters, as a result of researches about monitoring in archives, museums and libraries collecting documents on paper, photographs, prints, etc.

In Italy, a key role for research on conservation and restoration of archival materials - macro category including, as noted, digital and photographic materials, bindings, drawings on paper, parchment and plastic - is covered by the Istituto Centrale per il Catalogo e la Documentazione (ICCD) and the Istituto Centrale per il Restauro e la Conservazione del Patrimonio Archivistico e Librario (ICRCPAL). Among the most relevant publications by ICCD in the field of preventive conservation, the microclimate monitoring report is of considerable interest, carried out in the same institute archives, by a working group for “the methodological approach in the context of the conservation disciplines in ICCD’s photographic collections”, dating back to September 2013 [7]. This contribution has been taken into account as it provides a recent example of monitoring and control of temperature and humidity parameters in the different spaces of the photographic archive: despite the survey affected only this

particular type of material, it could be considered useful to compare the work methodology applied with the results of similar researches published by other institutions.
At the international level, between the institutions drawing up guidelines on preventive conservation, sometimes made online available, there are:

- in England: The Museums, Libraries and Archives Council (MLA), an English organization absorbed by the International Federation of Arts Councils and Culture Agencies (IFACCA) in 2012; The Preservation Advisory Centre, active in the preservation of library and archival materials, merged into the British Library Collection Care in 2014; the Museaums Galleries Scotland, even if they arefocused on the museum field, provides guidance on the conservation and protection of collections on paper; the Institute of Conservation (ICON), formed in 2005 from the merger of several organizations (The Care of Collections Forum, The Institute of Paper Conservation, The Photographic Materials Conservation Group, The Scottish Society for Conservation and Restoration, and The United Kingdom Institute for Conservation of Historic and Artistic Works), which provides several brief guidelines on the preservation, very active in the field of the communication of research; the National Preservation Office (NPO), which published “Preservation Guidelines for Libraries and Archives Collections” in 2003.
- In France: the Direction des Musées de France, which has published the rules called “MuseoFiches” on preventive conservation.
- In the United States: The Northeast Document Conservation Center (NEDCC), born in 1973 as the first independent laboratory for the conservation of works on paper; the Getty Conservation Institute (GCI) of the Paul Getty Museum, which works to promote conservation practices in the visual arts (artifacts, collections and architectural sites) through scientific research, education, training and the wide dissemination of results; the National Park Service (NPS), with technical bulletins called “Conserve O Gram”; the American group of the International Institution of Conservation (ICC), which has established guidelines since 1964 in the “Murray Pease Repor”, not related to any specific case studies, talking about the responsibilities of the conservation keepers in the maintenance and protection of cultural heritage; an online platform refers to this Institution, called Conservation Online (CoOL).
- In Canada: the Canadian Conservation Institute (CCI), born in 1972, which provides technical bulletins for the thermohygrometric control in archives, for example the “Guidelines for Humidity and Temperature for Canadian Archives” [8]; even the Canadian Council of Archives (CCA) has published a specific guide for archives conservation, dating back to 2003 (Basic Conservation of Archival Materials) [9].
- In Australia: the Australian Institute for the Conservation of Cultural Material (AICCM) which has published “Re-Collections: caring for Colletions across Australia”, six volumes on the conservation, maintenance, exhibition and storage of a wide range of materials, realized by Artlab and Australian Conservators for the Heritage Collections Council.

The technical bulletins and guidelines of these institutions hava been examined in order to make a critical comparison between the Italian and the international situation in the context of monitoring and values to be adopted for the preventive conservation. Other standards, published by international institutions, have also been taken into account, such as:

- UNESCO, with the document, drawn up in 1987 along with the IFLA, ICA and a group of international research, "Preservation and conservation of library and archival documents: a Unesco / IFLA / ICA inquiry into the current state of the world’s patrimony, "which provides not only a survey of archives and libraries conservative state on an international scale, but also recommendations for an appropriate protection strategy [10].
- The International Federation of Library Associations and Institutions (IFLA) is the international body representing the interests of library services, but it also realizes studies within the conservation field since 1984, when the Strategic Programme on Preservation and Conservation (PAC) was created, with the important goal of ensuring that the librarian and archival materials, published and unpublished, in all formats, are preserved in an accessible form for as long as possible. Besides the two guidelines “Principles for the Care and Handling of Library Material” [11] and “Care, Handling and Storage of Photographs” [12], IFLA makes online available international publications on the sector.
- The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM). One of the contributions analyzed is “Standards in Preventive Conservation: meanings and application” [13], in which the use of the standards applied to cultural heritage is told from a historical point of view. Another important essay is “The role of architecture in preventive conservation” [14], in which the impact of a building, defined sustainable, and of environment are examined for the conservation of artefacts in archives and museums.

5. Conclusion: methodologies of environmental control

The light quality and intensity may cause damage to the paper, which is undoubtedly the most widespread support in the archives. The most destructive action for paper is caused by the UV rays,

whose high frequency is able to break the bonds between the cellulose chains, producing fragility on the mechanical and aesthetic level, arising as paper yellowing. In fact anti-UV filters have to be adopted protect the drawings from the sunlight and the artificial lighting systems. The archival documents, whether they are pencil drawings, watercolors, on paper and acetate, or reproductions, are highly light sensitive materials, for which a maximum illuminance is recommend at 50 lx and the annual dose of light at 150000 lx per hour/year [fig. 1].

Artifacts, historic and artistic value	**T_0**	**ΔT_{max}**	**UR_0**	**ΔUR_{max}**	**E_{max}**	**UV_{max}**	**LO_{max}**
Organic Materials							
Artifacts on paper, tracing paper	18-22	1.5	40-55	6	50	75	0.2
Drawings, watercolours, pastels	19-24	1.5	45-60	2	50	75	0.2
Archival documents on paper, parchment, books, manuscripts	13-18	-	50-60	5	150	75	-
Mixed objects							
Film, black and white photographs	0-15	-	30-45	-	150	75	0.2
Film, colour photographies	0-15	-	30-45	-	50	75	0.2
Plastic materials	19-24	-	30-50	-	<300	75	-

Fig. 1: Reference values recommended in stable climat, to the design of air conditioning plant for spaces collecting artifacts on paper (UNI 10829). T_0: temperature (°C); ΔT_{max}: maximum of temperature fluctuations (°C); UR_0: relative humidity(%); ΔUR_{max}: maximum of relative humidity fluctuations (%); E_{max}: maximum illuminance (lx) UV_{max}: maximun quantity of ultraviolet radiation (µW/lm); LO_{max}: maximum of annual light dose (Mlx • h/year)

The direct sunlight is not recommend, while the artificial lighting must be guaranteed only by certain types of lamps, shading and filtering devices of ultraviolet components have to be applied to. The lighting systems should preferably be fluorescence, with filters able to eliminate the radiation with a wavelength minor 400 nm and superior 760 nm. The lighting of the storage rooms must be minor 75 lx as the daytime average, and in any case minor 150 lx during the periods of the access to the storage rooms. In the consultation spaces, however, the lighting system must provide a lighting not superior 150 lx for the reading and not superior 50 lx for the exhibit.
Both the changes in temperature and moisture cause mechanical damage difficult to control. While the inorganic materials (such as metal, stone, painting, and wood) respond to changes in temperature expanding themselves with the heat and contracting with the cold, the hygroscopic organic materials respond to changes in relative humidity, contracting themselves when it decreases and dilating when it increases. If the humidity of equilibrium content and the resulting dimensional change of hygroscopic materials are influenced much more by the relative humidity changes than by temperature changes, the relative humity should be maintained as close as possible to the historical climate levels. The aim of preventive conservation measures is to prevent fluctuations and cycles in the short term and reduce high and/or frequent temperature and relative humidity variations that involve physical damage to drawings. An analysis of data on the external environment conditions should be also carried out in parallel to a regular indoor ambient monitoring, in order to identify the influence that changes in external conditions, due to seasonal and the daytime variations and the extreme weather conditions, could have on the indoor situation. Stable relative humidity values can be obtained through several expedients:

- If the humidity content in the air is constant, the temperature has to be kept as constant as possible;
- If the humidity content in the air is variable, the temperature has to be changed to maintain constant the relative humidity (if the temperature changes do not have a significant impact on drawings);
- If the humidity content in the air is variable, humidity should be added or removed from the air without changing the temperature (if the relative humidity changes do not have a significant impact on drawings);
- If the humidity content in the air is variable, the two previous modes can be combined.

The temperature control in an archive raises questions of human comfort, energy costs, environmental impact and sustainability. In such a moment haracterized by a great concern for the rational use of energy resources, those conditions can not be ignored.
In connection with the thermo-hygrometric parameters, the Standards and Guidelines stipulate that the storage spaces must be constantly maintained at a temperature between 14° and 20° C; the relative humidity must be constantly maintained at a value comprised between 50-60% (its safe-limit value, usually quoted for archival materials to prevent the formation of mold, is 65%). The tolerance ranges

of such values are ± 2° C for temperature and ± 5% for the relative humidity, this in relation to the different points within the rooms and to the possible diurnal and seasonal fluctuations [figg. 2 - 3].

Category of light sensivity	Materials, techniques	Maximum illuminance
Very low	Artifacts relatively insensitive to light: metal, stone materials, ceramics, glass, jewelry and fossils	**>300** lx
Mid	Artifacts moderately sensitive to light: oil paintings, tempera paintings, bone horn, ivory, wood	**150**
High	Artifacts highly sensitive to light: textiles, tapestries, paintings and gouaches not varnished, mixed media, watercolors, markers, prints, books, leather, organic artifacts	**50**
Very high	Artifacts extremely sensitive to light: silk, inks, dyes and pigments such as lacquers	**50**

Fig. 2: Sensivity of light according to materials and techniques of Cultural Heritage. D.M 10 maggio 2001 – "Atto di indirizzo sui criteri tecnico-scientifici e sugli standard di funzionamento e sviluppo dei musei"

In the consultation spaces, the temperature should be between 18° and 23° C and the relative humidity between 50% and 65%. If the difference between the values present in these spaces and in the deposit is superior of 4° C for the temperature and 5% for the relative humidity, the graphic documents must be gradually acclimated. The achievement of the correct environmental conditions must necessarily be obtained by ventilation and air conditioning systems, completely avoiding the opening of doors and windows to make the air changes. The air conditioning and ventilation system should continuously provide from 5 to 7 air recirculation per hour in storage spaces. Because the air movement within an environment can accelerate deposition processes of gas and aerosol present or released into the ambient, the terminal elements of the plant should be placed as far as possible away from the exhibited drawings.
To avoid undisered oscillations of the environmental parameters, both in function of the time and the archival spaces, several remedies can be applied:
- the passive remedies are based on the application of materials or ambient control systems without energy absorption, aimed at reducing the energy flows (heat, light) and/or mass flows (steam, pollutants) between the ambient under control and the external environment.
- the active remedies are based on the application of ambient control systems with energy absorption, aimed at the surface control of energy flows (heat, light) and/or mass flows (steam, pollutants) between the ambient under control and the external environment [15].

UNI 10586	Deposit spaces	Consultation spaces
Temperature [°C]	14 <T< 20 Fluctuation tolerance: ± 2° C	18 <T< 23 Gradual acclimatization if the range in deposit and consultation room is > 4 ° C
Relative Humidity [%]	50 <UR< 60 Fluctuation tolerance: ± 5%	50 <UR< 65 Gradual acclimatization if the hike in deposit and consultation room is > 5%
Illuminance [lx]	Illuminance with fluorescent lamps (UV filters) < 75 lx (one-day average) < 150 lx during the access	For reading: < 150 lx For exhibition: < 50 lx

Fig. 3: Environmental conditions for the preservation of graphic documents (UNI 10586)

Passive remedies should be mainly apply, including the thermal insulation, the use of materials and systems with high thermal and hygrometric inertia, the limitation of the uncontrolled heat and steam exchange, the filtering of the solar radiation, the replacement of the lightning sources. On the contrary,

the active systems must be contained to the minimum necessary and aim to eliminate the daily fluctuations and to reduce further the seasonal ones.
These parameters have to be reevaluated if the architectural drawings are shown at exhibitions, for which some precautions can be identified:

- the use copies instead of the original drawings (if possible);
- the drawings should not be permanently exposed and exhibited;
- the lowest possible levels of light should be maintained;
- the minimization of the exposure to ultraviolet light thanks to appropriate filters;
- closing of windows and the frames should be ensured and they should be made up of materials that do not harm drawings and documents.

Light can be a serious problem for the drawings exhibition because the paper is a highly sensitive support to light, ultraviolet and infrared radiation. The lighting during an exhibition must therefore be well assessed and designed, to ensure the correct visibility even to the moderate levels recommended of light (50 lx). Since every radiation is potentially harmful to the paper and the every damage cumulative, any exposure is detrimental. A limit of 50000 lux for hour has been suggested by the guidelines for high light-sensitive materials. The relative humidity for the ambient exhibit has been fixed to a value between 35 and 50%, with a maximum variation of 5%. The exposure of the environment temperature is fixed at a value not superior than 21º C, with a maximum variation of 3º C. Temperature and relative humidity should be kept as stable as possible during the course of 24 hours, with no perturbations or fluctuations, and as uniform as possible in space.

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