Preventive Conservation in Historic Houses and Palace Museums: Assessment Methodologies and Applications

SilvanaEditoriale

Preventive Conservation in Historic Houses and Palace Museums: Assessment Methodologies and Applications

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of the Palace of Versailles (EPV),
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and the Research Centre
of the Palace of Versailles (CRCV)

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Assessment of the Risks of Mechanical Degradation of Paintings

Abstract

In this article, we present an assessment method for the mechanical degradation risk of paintings or "risk indicators." It is based on two of painting's fundamental properties, on one hand, the sensitivity to humidity and temperature, represented by the sensitivity diagrams, and on the other hand, the mechanical fatigue endurance limit defined by the minimum tension variation ($V_{mini}t$). This method relies essentially on the relationships that exist between these two properties.

When knowing the work's climatic environment, the mechanical behaviour towards humidity and temperature and the minimum tension variation, we are able to transform the climatic data – humidity or temperature – into mechanical data of force or tension and to assess using the $V_{mini}t$, the tolerance zone which suits each painting.

The risk indicator is an assessment tool which is easy to use, it is constituted of an Excel calculation module and an overview where the results are gathered together.

This risk indicator allows to:

– analyse the mechanical degradation risks of a painting during transport, during a loan for a temporary exhibition.

– to determine the capacity of a room, according to its environmental conditions, prior to an exhibition of painted works of different techniques.

– to determine the climatic tolerance zone of each type of painting.

Keywords

Preventive conservation, risk assessment, humidity-temperature, mechanical fatigue, sensitivity diagram, tolerance zone.

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Introduction

Preventive conservation in museums and in collections has been the subject of numerous books, guides and manuals on risk management. The complexity of managing the risks of heritage and collections' encourages us to evolve in stages to achieve the objectives. The difficulty most often encountered in risk management comes from their assessment. Whatever the method used, risk assessment raises a number of questions. How to get a fair and objective score not diverted by a subjective appreciation? How is it calculated? What are the used parameters?

Our experience has showed us through numerous climatic studies, carried out in the framework of museums, funds, galleries, historic dwellings and exhibition halls, that despite the presence of an air-conditioning system, climate stability is far from being perfect. The humidity and temperature regulation in a building depends on many parameters: exterior climate, the building's sanitary design and state, technical facilities and their functioning state, the attendance and the management of the public's flow, etc.

So the probability that the climate is perfectly stable is very low if not unlikely. It will, in any case, have an impact on the present objects and specially the painted works. Moreover, aware of these limitations, the authors of the various studies that have been conducted to define the best climatic conditions, offer humidity differences that, according to the sources, range from 45 to 55%, from 50 to 60% RH, [Thomson, 1978] or from 40 to 60% [CCI, Note10/4, 1993]. The normative values proposed by the ICOM – RH = 55% ± 5% or 50% ± 5% and T = 20°C ± 2°C – are the most followed instructions by the museums. Knowing that the paintings' sensitivity to humidity and temperature are different from each other, these recommendations are not valid for the whole spectrum of pictorial techniques.

In the context of preventive conservation we have developed an assessment tool that measures the impact of environment climate on the conservation of painted work on canvas or paper. It is a risk indicator. This risk indicator is based on 2 fundamental properties for paintings:

– their sensitivity to humidity and temperature represented by the sensitivity diagrams;

– their endurance limit in mechanical fatigue defined by the minimum tension variation.

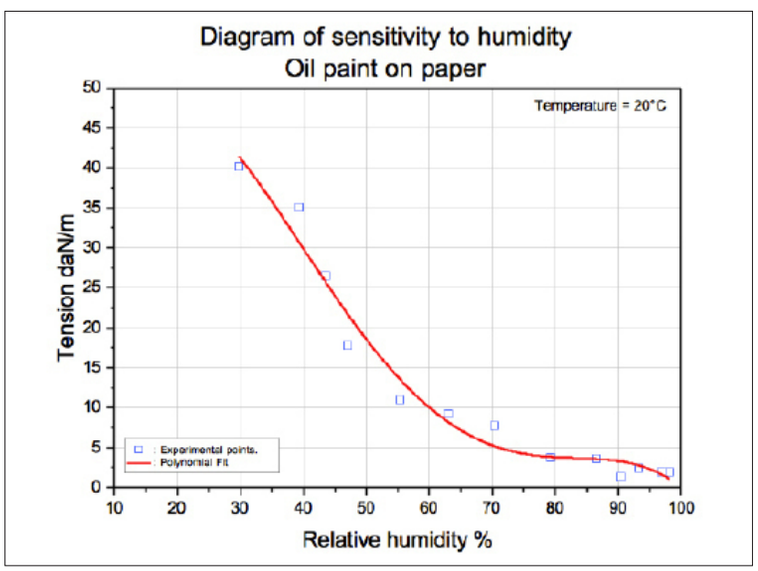


Fig. 1
Experimental construction of a sensitivity diagram.

What is a Temperature and Humidity Sensitivity Diagram?

They are curves specific to each pictorial technique. It is a curve that describes the variation of the tension in a painting according to the humidity or the temperature. They can be built experimentally or theoretically [Roche, 2016].

Experimental Construction: paint samples, mounted on an "Extensiometric Frame" or a "Universal Test Machine (UTM)," enclosed in a climatic chamber, are solicited in humidity or temperature. The experimental measures give a series of points that can be represented by a polynomial degree n. The curve thus obtained

is mathematically described by its polynomial function (fig. 1).

Theoretical construction: the mechanical behaviour of a pictorial technique is obtained according to the law of additivity. By adding the mechanical behaviour of each constituent, it is possible to produce a theoretical diagram of sensitivity to humidity or to temperature (fig. 2).

In all the cases the curves can be mathematically described with a polynomial function of order 4.

$$Y = a + bX + cX^2 + dX^3 + eX^4 \quad (1)$$

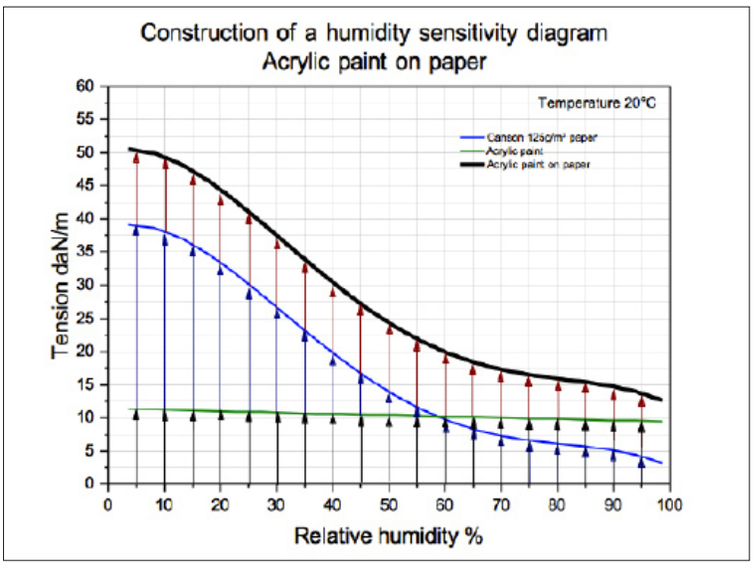


Fig. 2
Theoretical construction of a sensitivity diagram.

The Endurance Limit of a Film of Paint

In mechanical fatigue, it is said that it is the maximum variation of stresses that a film of paint can withstand without breaking, regardless of the number of cycles. If we accept that the endurance limit of a painting is linked to both the breaking stress and to the stress concentration factor *Kt*, we can write that the ratio between σ_{rupt} and *Kt* is equivalent to the endurance limit of a film of paint.
By validating the value of the stress concentration factor at a constant value of *Kt*=100[1] [Roche, 2016], the simplified expression of the endurance limit of a painting is expressed by the following relation:

$$\varsigma Dp = \frac{\sigma_{rupt}}{100} \quad (2)$$

The endurance limit of a film of paint can be expressed through the minimum variation of tension ($V_{mini}t$) which is equal to the product of the endurance limit and the thickness (σDp) of the film of paint (e):

$$V_{mini}t = \frac{\sigma_{rupt}}{100} \times e \quad (3)$$

In any case if:

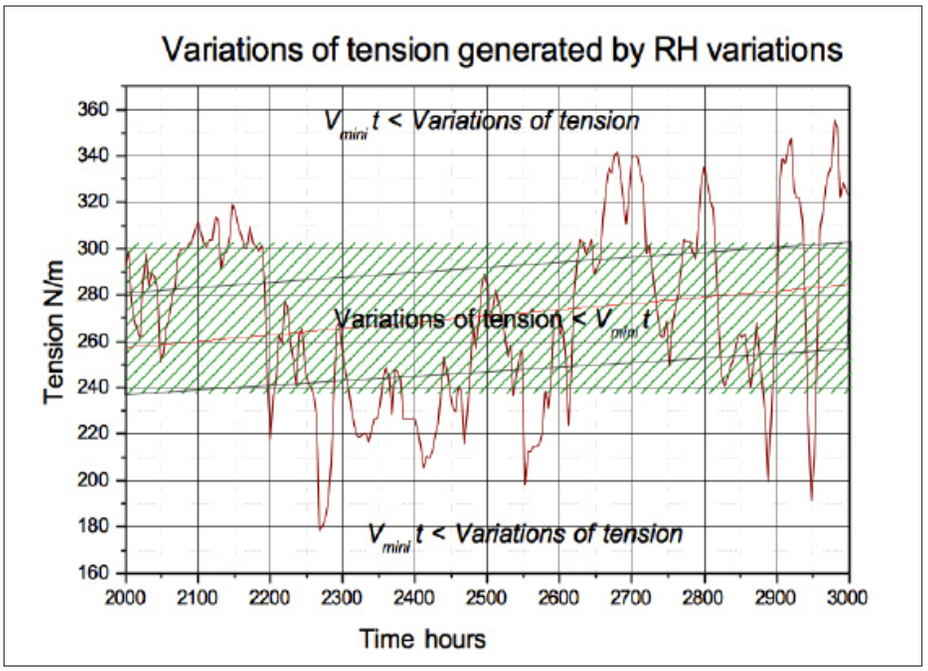
$\sigma Dp > \Delta s_{max}$	ou $V_{mini}t > \Delta t_{max}$	risk of mechanical degradation = 0
$\sigma Dp = \Delta s_{max}$	ou $V_{mini}t = \Delta t_{max}$	risk of mechanical degradation – limited
$\sigma Dp < \Delta s_{max}$	ou $V_{mini}t < \Delta t_{max}$	risk of mechanical degradation – significant

Assessment Principle of the Risk Indicator (RI)

This "risk indicator" tool relies essentially on the relationships that exist between:

– the mechanical properties of paintings vis-a-vis of the environment;
– the mechanical fatigue endurance of the paintings.

Fig. 3
Tracings of the tension curve and the tolerance zone.



By knowing the climatic environment of the artwork, either by placing a mini recorder on the reverse of the artwork or by collecting the climatic data from a recorder close to the artwork, by knowing the mechanical behaviour of the artwork vis-a-vis climatic variations by choosing the appropriate relative humidity and temperature sensitivity diagram and by knowing the minimum tension variation obtained from the thickness of the film of paint and the break stress, one is able to:

– transform the climatic data – humidity or temperature – into mechanical force (N) or tension (daN/m) data;

– compute and plot with the $V_{mini}t$, the upper and lower limits of the tolerance zone appropriate for each painting (fig. 3).

By knowing that the tension values within the zone correspond to tension variations below the endurance limit and that all outside values correspond to variations greater than the endurance limit of the painting, it is possible to calculate the risk index to determine climate impact on the conservation of the artwork. For this we have created a calculation module that converts the climate data into tension in the painting, from one of the 40 polynomial functions and the thickness of the paint.

The risk index can be timed as a time function (duration of exposure or transport) by applying depreciation coefficients.

Presentation of the Risk Indicator (RI)

Calculation Module

The risk indicator on Excel consists of a calculation module in which you enter all the necessary parameters: time/date, relative humidity,

temperature, polynomial function associated to the selected diagram, duration in months. The tension calculation results are displayed in a column as are the values of the upper and lower limits of the tolerance zone. By comparing the obtained tension values with the endurance limit $V_{mini}t$ of the studied painting, the module calculates the risk index noted from 0 to 100%. The results are automatically displayed in the overview of the calculation module.

Overview

The overview contains 2 graphic windows in which will be displayed on the left hand side the curves, the relative humidity and the temperature, framed by the tolerance zone recommended by the ICOM and on the right hand side the tension variation curve framed by the tolerance zone determined by the $V_{mini}t$.

There are also 3 charts displaying on the left hand side statistical climate data, in the centre statistical data of tension values and on the right hand side the paintings' characteristics.

The risk indicator values are presented, in the centre of the overview, by a numerical value in % in a box and a graphic representation in the form of a dial and a moving needle.

Under this part of the overview, there is, on the one hand, a text box allowing the input of comments or the interpretation of the results and on the other hand, the tabs allowing to access the calculation module, the tolerance zone and various humidity and temperature sensitivity diagrams (fig. 4).

The risk indicator dial is divided into 5 zones of appreciation:

– in the "negligible" risk zone (0 to 20%), the formation of a few internal micro-cracks, at the defect level, is likely when the limit value

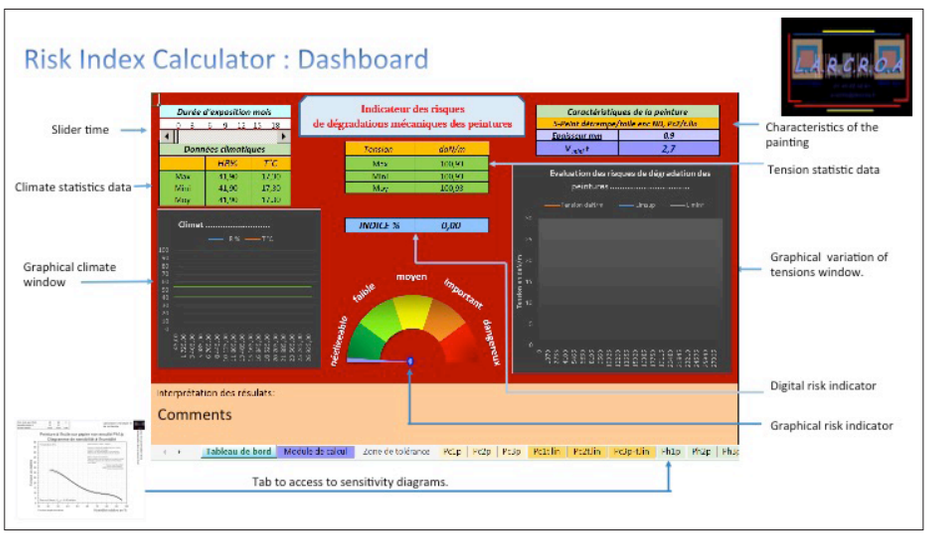


Fig. 4
Presentation of the risk indicator overview.

of 20% is approached. These micro-degradations are not visible on the surface.
– In the "weak" risk zone (20 to 40%), the micro-cracks are going to progress towards the formation of fine cracks, visible on the surface. Their spread increases with the value of the index.
– In the "medium" risk zone (40 to 60%), cracks are intensified with the birth of a network, which will be more or less extended depending on the value of the index.
– In the "significant" risk zone (60 to 80%), the densification of the cracks network intensifies with the emergence of raises in the pictorial material.
– In the "dangerous" zone (80 to 100%), the development of the densification of the cracks network and the raises, jeopardises the integrity of the collection piece.

What are the Applications for this Risk Indicator?

1-6 month loan of an 18th century painting for an exhibition in a museum.

Analysis of the conditions during transport (fig. 5).

If we examine the climatic data during the trip, we can find that the humidity values are completely outside the recommendations. However the calculation of the risk index of 0.2% is very low and the risks are negligible, no degradation of a mechanical nature will appear on this artwork during the trip.

Analysis of the conditions during 6 months of the exhibition (fig. 6).

The humidity conditions during the exhibition period fluctuate. The hygrometry went from a 45% average during the first 2 months to 35% during the last three months. In spite of a certain climate instability, we can see that the tension variations follow the slope of the tolerance zone. The risk index does not exceed 16.45% and stays in the negligible risk zone. During this exhibition period the humidity didn't have a direct impact on the conservation state of this artwork.

Determination of the exhibition hall's capacity to reception, according to its environmental conditions, painted artworks with different techniques.

A library manager has the intention to organise in one of its exhibition halls an exhibition of painted artworks with different techniques:
– oil paint on pasted paper;
– oil paint on paper mounted on canvas;
– painting on unprimed canvas;
– tempera on paper;
– tempera on pasted canvas;
– vinyl paint on pasted paper.

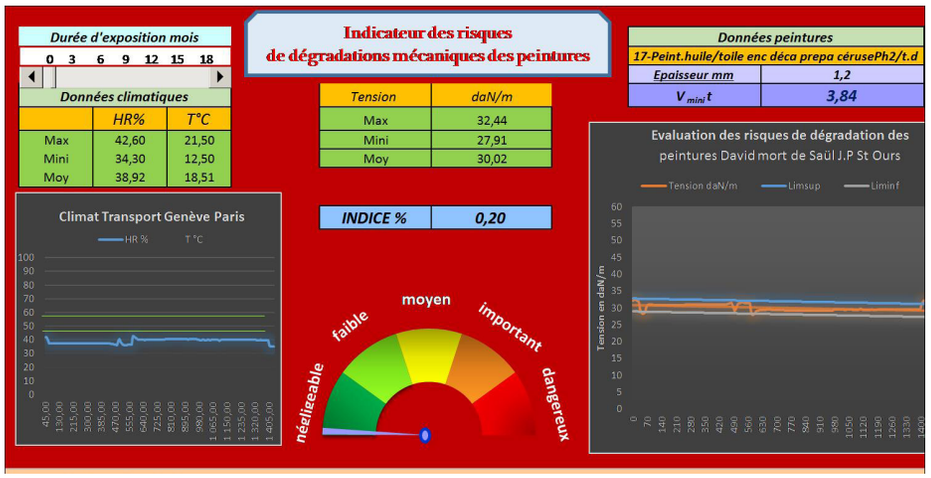


Fig. 5
Analysis of transport conditions of oil painting of Versailles.

Results interpretation:
Risk Index Calculator is 0.2% "insignificant," no degradation is to be expected during transport. If we examine the climatic data during the trip, we can find that the humidity values are completely outside the recommendations. However the calculation of the risk index of 0.2% is very low and the risks are negligible, no degradation of a mechanical nature will appear on this artwork during the trip.

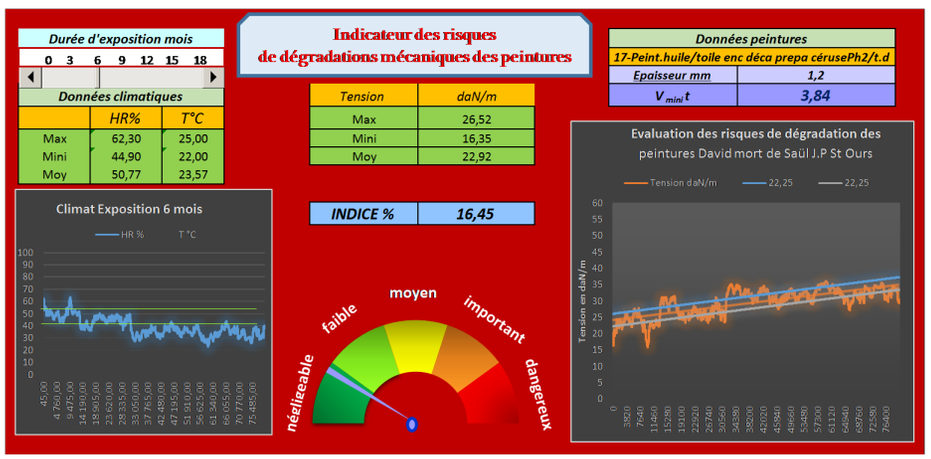
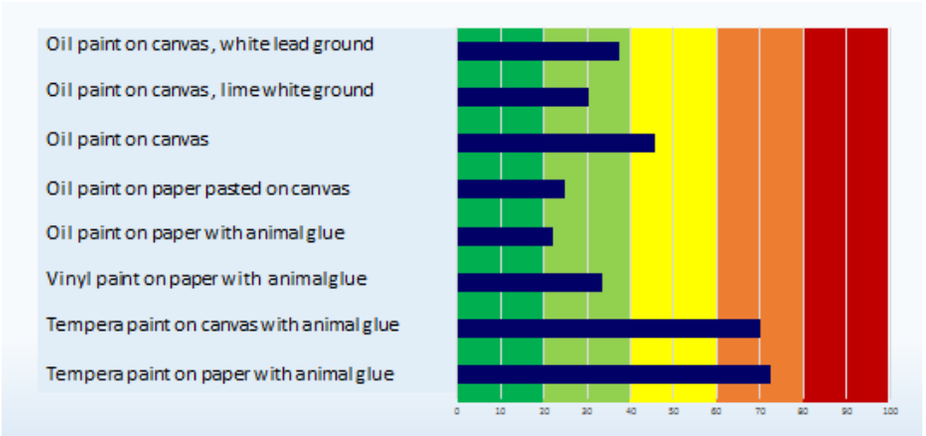


Fig. 6
Analysis of exhibition conditions of oil painting in museum.

Results interpretation:
Risk Index Calculator is 19.84% "between insignificant/weak." Risks of formation and development of internal fissures. Weakness of cohesion. These mechanical degradations are not visible on the painting surface.
The humidity conditions during the exhibition period fluctuate. The hygrometry went from a 45% average during the first 2 months to 35% during the last three months. In spite of a certain climate instability, we can see that the tension variations follow the slope of the tolerance zone. The risk index does not exceed 16.45% and stays in the negligible risk zone. During this exhibition period the humidity didn't have a direct impact on the conservation state of this artwork.

Fig. 7
RI results for the 8 paintings.



Before exhibiting the collection, he wonders if the climatic conditions of the exhibition hall meet the conservation requirements. As a precautionary measure, an evaluation of mechanical deterioration risks for each technique is made from the library exhibition hall's climatic records. The index results obtained are grouped in the following graph (fig. 7).

The results show that tempera paint on paper (IR=72.3%) or on canvas (IR=70.1%) are the most sensitive and vulnerable to the exhibition hall's unstable climate.

Consequently, from the conservation point of view of this kind of painting, it is strongly discouraged to exhibit these artworks in this hall, otherwise the networks of cracks will spread rapidly with the appearance of rises in the pictorial material. Nevertheless, the historical interest of these artworks is such, that they must be exhibited. In order to find a suitable solution, we must look for the optimal conservation of these artworks by determining its zone of climatic tolerance.

Determination of the paintings' climatic tolerance zone in humidity

It is possible to quickly determine the climatic tolerance zone by using the humidity sensitivity diagram and the mechanical fatigue endurance limit $V_{mini}t$ of the painting in question (fig. 8).

For tempera paint on paper, at 55% RH the tension is 16.24 daN/m. Knowing that the $V_{mini}t$ is 1.2 daN/m, adding and subtracting half of the minimum tension variations from the tension value of 55% gives 2 tension values. By projecting their intersection points with the curve, on the X axis, we obtain 2 humidity values. This difference corresponds to the humidity variation that meets the optimal conservation conditions.

The graphic representation shows that the humidity difference must be between 53% and 57% to ensure the best conservation conditions for this painting. In the case that the mechanical degradation

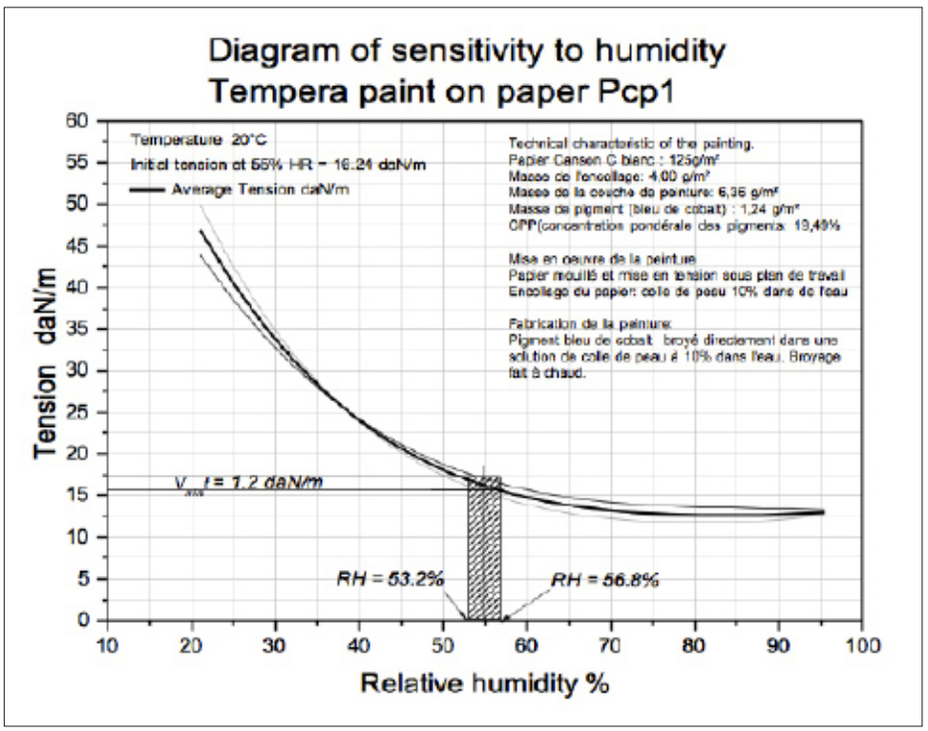


Fig. 8
Search for the tolerance zone on a sensitivity diagram.

risks are null then the two most sensitive paintings can be exhibited. Otherwise there are alternative solutions.

Conclusion

In the field of assessing the degradation risk of painted artworks, we often resort to a subjective assessment of the fragility and the sensitivity of the collection. It is due to a lack of expert tools, essential for this evaluation. It is reflected most of the time by the very different opinions between specialists.

By exploiting, as we have seen, two of the fundamental mechanical properties of the paintings, behaviour towards humidity/temperature and the endurance limit to mechanical fatigue, we are able to obtain a risk value in a specific climatic context which is based on scientific data. This tool gives us a new dimension to this expertise. It will be able to erase any contradiction that may appear in a subjective assessment.

In the context of museums, historic dwellings and funds, climate as a risk factor is very important. Its stability, depending on many parameters, is difficult to manage and master. Ubiquitous, its instability can very quickly lead to a loss in heritage value of the collection.

In addition, cultural policy has for several decades encouraged people to visit museums, historical dwellings and exhibitions. It is responsible for a massive arrival of visitors. This high concentration of people in the permanent and temporary exhibition halls is causing significant

climate disruptions. The impact of the public on the climatic environment can be reduced by improving the management of the flow in the halls or by limiting the access to a smaller number of people. Some institutions have already put in place preventive conservation measures of this kind. In this honourable context of cultural development, to feed the temporary exhibitions in France and abroad, the loaned collections circulate enormously. Transport, handling, climate shocks are all risk factors that must be managed and anticipated. In these conditions we must be vigilant and adapt to changing practices, always bearing in mind that artwork conservation is a priority. We must therefore react accordingly, by giving ourselves the financial and material means to acquire and use the risk assessment tools at our disposal.

Within LARCROA, the quest for humidity and temperature sensitivity diagrams continues. We have developed a new experimental setup with an instrumentation that performs better, to obtain more accurate humidity and temperature sensitivity diagrams. We work on both pictorial techniques that we reproduce from documentation and samples of real paintings from artists. Our goal is to enrich our diagram collection, in order to get closer to reality and to serve the conservation of the collections.

Endnotes

[1] COM-CC Paintings, Preventive Conservation and Documentation Working Groups in association with the Institut National du Patrimoine (INP) and the University of Paris Panthéon-Sorbonne 29 and 30 of September 2016, unpublished. Problématiques physiques dans la conservation des Peintures: Surveiller, documenter et atténuer.

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