

The National Archives Conservation Building at Pierrefitte-sur-Seine and its Air Treatment System
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The National Archives, a Democratic Institution Serving our Collective Memory

A democratic institution preserving France's memory, the National Archives are at a critical period in their history with the opening of a new building at Pierrefitte-sur-Seine, in the Seine-Saint-Denis department.

Created during the French Revolution, the National Archives conserve documents from the different political regimes that have followed one another from the 7th century to the present, as well as private archives and the records of Parisian notaries.

The practice of State secrets that prevailed under the Ancien Régime gave way in 1794 to openness and communication of State archives, basic principles for all democratic regimes.

The Pierrefitte-sur-Seine Project

1. Pierrefitte-sur-Seine Site.

For many years, the National Archive's sites in the Ile-de-France region have been facing major difficulties related to their saturation and/or the difficulty in accessing them, which has raised concerns in the national and international community of researchers and archivists. The decision was therefore taken by the government in 2004 to build a new building for the National Archives at Pierrefitte-sur-Seine.

The project proposed by the architect Massimiliano Fuksas was accepted in May 2005 for the construction of this building whose final project brief was approved in the autumn of 2007; the building permit was issued on 18 June 2008 and the construction contract was notified on 19 May 2009. The building is scheduled to be delivered at the beginning of 2012.

The building designed by Massimiliano Fuksas is in keeping with the programme based on the principles of density, materiality and thermal inertia.

Characteristics of the Programme

Estimate of the staff

± 320 people

Detailed surface areas

Reading room: approximately 1,400m² (variable depending on the position of the separation between the inventory room and the originals room)

Capacity in the originals room: 160 seats

Inventory room: approximately 512m², capacity: 84 seats

Microfilm room: 338m², capacity: 50 seats

Foyer: 363m²

Temporary exhibition room: 400m²

Conference room: 280 seats

Usable surface area of the facilities

62,048m², including 44,000m² of conservation storage space (75%)

Total linear archiving capacity: 320kml

Land

Surface area: 43,960m² or 4.39 hectares

High-rise building

Building with ground+10 floors on an underground service gallery

Dimensions: 47.40m wide, 162.80m long and 38.58m high

SAT buildings

6 Satellite buildings: buildings between ground floor and g+5 on an underground level (car park)

Main functions of the SATs:

SAT A: reception / exhibit room / educational workshops and school groups

SAT B: conference room / foyer

SAT C: mainly offices

SAT D: unloading platform

SAT E: restoration workshop / gilding workshop / preventive conservation

SAT F: treatment rooms

Total surface area

Gross floor area: 108,136m²

Net floor area: 82,505m²

Usable surface area: 62,048m²

A Building with Good Inertia Reducing the Use of Air Conditioning Systems

At the very start of programming for the National Archives centre at Pierrefitte-sur-Seine, special attention was given to the sustainable development question. Emphasis was placed on designing a building with strong thermal inertia in order to reduce the use of technical air treatment systems to ensure environmental stability, with little use of the cooling capacity installed. The programme thus planned ahead for the RT2005 thermal regulations¹ applicable since 1 September 2006, making reduced use of air conditioning a key goal.

The conservation storage building, made of concrete with outside insulation, meets these needs. The satellites, which house most of the office functions, are equipped with a triple solar protection system (glazing with a very weak solar factor, shade screens built into the façade and outside shutters) and vents.

The conservation building's performances place it in the group of the least energy-intensive conservation buildings.

Conservation Building

The conservation building is a parallelepiped measuring approximately 160m long, 50m wide and 40m high.

Its base has a 2,500m² reading room, some offices and some technical rooms. The rest of the block is dedicated to document conservation.

The building comprises concrete walls that are 20 to 30cm thick, providing good thermal inertia and insulation from the outside with a 10-cm layer of rock wool.

The 220 storage rooms, each unit measuring 200m², make up 43,062m² of usable space for an average height of 3.3m.

There are no glazed openings to the outside except in the circulation areas.

Consequences of Thermal Inertia in the Storage Rooms

The goal of using less air conditioning has given rise to a compact building with a large concrete mass and external insulation.

On average, each storage room has 330 metric tonnes of concrete between the 30-cm thick load-bearing walls, 20-cm thick non-load-bearing walls and 40-cm thick pre-stressed concrete floors.

This leads to thermal inertia that can be calculated using the concrete's heat capacity of 880 joules per degree. 73kWh of heat has to be supplied for the temperature of a 330-metric tonne storage room to rise by one degree.

Given the thermal insulation installed on the walls and flat roof, heat losses for all 220 storage rooms amount to approximately 7kW for a one degree difference in temperature between the inside and outside of the building.

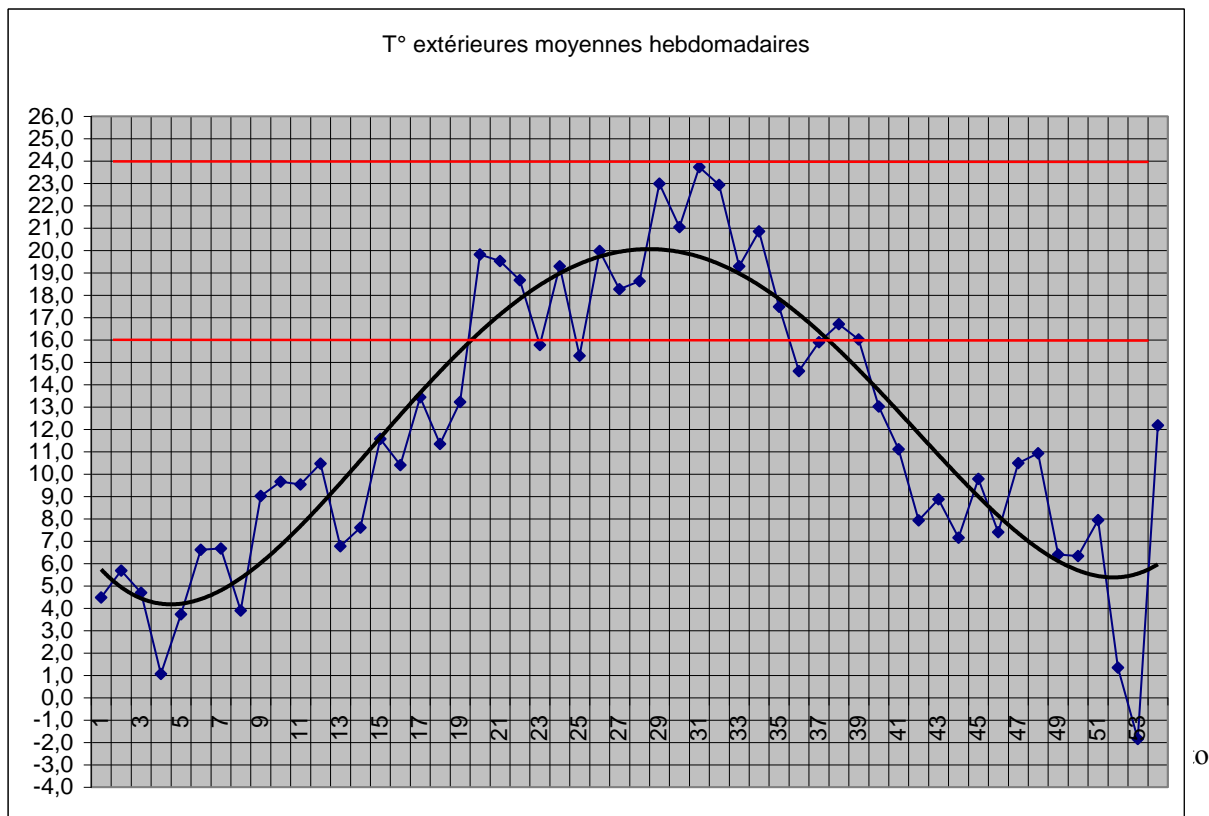
Using these elements, we can evaluate very concretely the consequences of thermal inertia:

In summer: for an outside temperature of 32°C and an inside balance in the storage rooms of 22°C, i.e. a 10°C difference, without air conditioning, it will take 10 days for the building to reach 23°C.

In winter: for an outside temperature of - 4°C and a temperature of 16°C in the storage rooms, i.e. a 20°C difference, it will take 5 days without heating for the building to lose 1°C.

This thermal inertia provides a buffer against variations in the outside temperature, between day and night, but also over the longer term on the scale of one week.

Average Weekly Outside Temperature



The need for air conditioning, excluding humidity treatment and compensation for possible internal contributions, can therefore be sharply reduced if we accept that the inside conditions are close to the 23/24°C zone.

In winter, on the other hand, the same approach cannot be used and only an underground building could go without heating, excluding air renewal.

Climatic Conditions for Conservation at the Pierrefitte Site

The desire to seek out energy savings in the part of the building to be used for conservation led to discussions on the set points to be adopted for temperature and humidity.

The former recommendations from the Direction des Archives de France (DAF) were 18°C +/- 1°C and 55% RH +/- 5%

If these strict conditions are complied with, they lead to high energy consumption. Widening the ranges of acceptable values naturally leads to reductions in heating and air conditioning.

Setting up a working group with the operation's programmer, himself having a strong awareness of energy issues, and several curators, led to a change in the set points.

Excluding the photo storage rooms, the following new conditions and thresholds are considered acceptable:

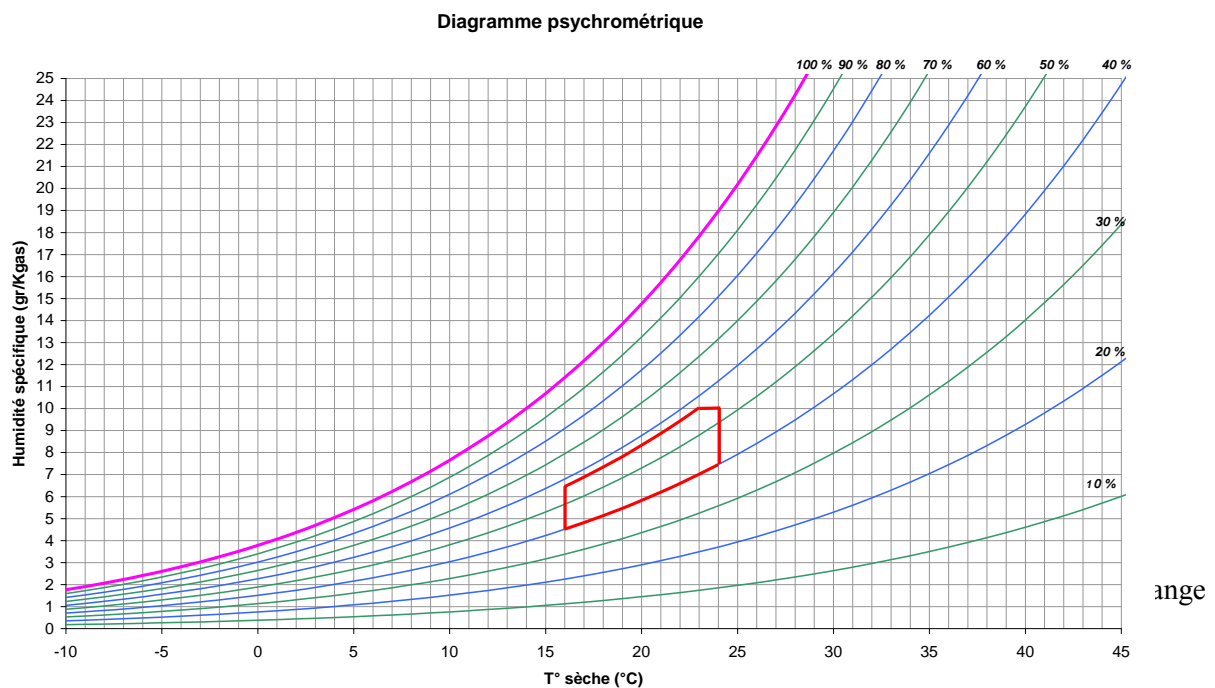
Temperature: [16 to 24°C]
Humidity: [40 to 57% RH]

Relative humidity close to 70% is highly favourable to mould growth. The 57% value chosen leaves room for possible contingencies affecting the controls.

The 24°C and 57% RH pair nonetheless remains a threshold zone and the decision was made not to go beyond 10g of water per kg of dry air, thinking here in terms of absolute humidity rather than relative humidity. Absolute humidity eliminates the notion of temperature linked to relative humidity.

The moist air psychrometric chart below graphically represents the desired zone for inside conservation conditions.

Psychrometric Chart



Maximum humidity variations: 1% per day and 5% per week

This is theoretical and nearly impossible to obtain, but we still consider it to be the target.

Below we will further discuss the methods implemented to reach this target.

The basic idea was that, except for values outside the thresholds, it is more important to ensure very small variations than the absolute values themselves. Repeated variations in temperature and humidity lead to the destruction of materials through modifications to their physical dimensions.

These small variations over time are considered to ensure good conservation, close to the natural conditions that have proven their effectiveness in some cases.

The lower temperature threshold value, 16°C, is not related to a notion of conservation, but rather to a demand for comfort for the personnel in charge of archive movements in the reading room. There are no workstations in the storage rooms, just an occasional short-term human presence.

Extending the set points for temperature and humidity will provide a 30% energy savings on heating and air conditioning.

One-third of these savings are on temperatures and two-thirds are on humidity. These values are the result of an annual simulation with hour-by-hour calculations.

Ventilation Conditions

Ventilation includes two independent parameters:

The rate of fresh air needed to ensure the renewal of inside air;

The rate of air circulation, which firstly ensures the distribution of heating and air conditioning and secondly provides air movement so that no zones are deprived in terms of temperature and humidity.

Here again, the targeted energy savings have led to a large reduction in the volumes involved.

1. Fresh airflow rate: 0.1 volume/hour, full storage room

Equivalent to 0.07 V/h, empty storage room.

The usual DAF-recommended values are 0.3 to 0.5 V/h.

The value used at the BnF (Bibliothèque nationale de France) is also 0.3 V/h.

Reducing the fresh airflow rate by two-thirds is decisive for consumption and energy savings amount to 61% in cumulative values with the changes in the set points for temperature and humidity.

Fresh airflow under the former temperature and humidity conditions, with a renewal rate of 0.3 volumes per hour, is responsible for 70% of energy consumption. This becomes very important in relative values for a well-insulated building for which other sources of losses (walls and roofs) have been reduced.

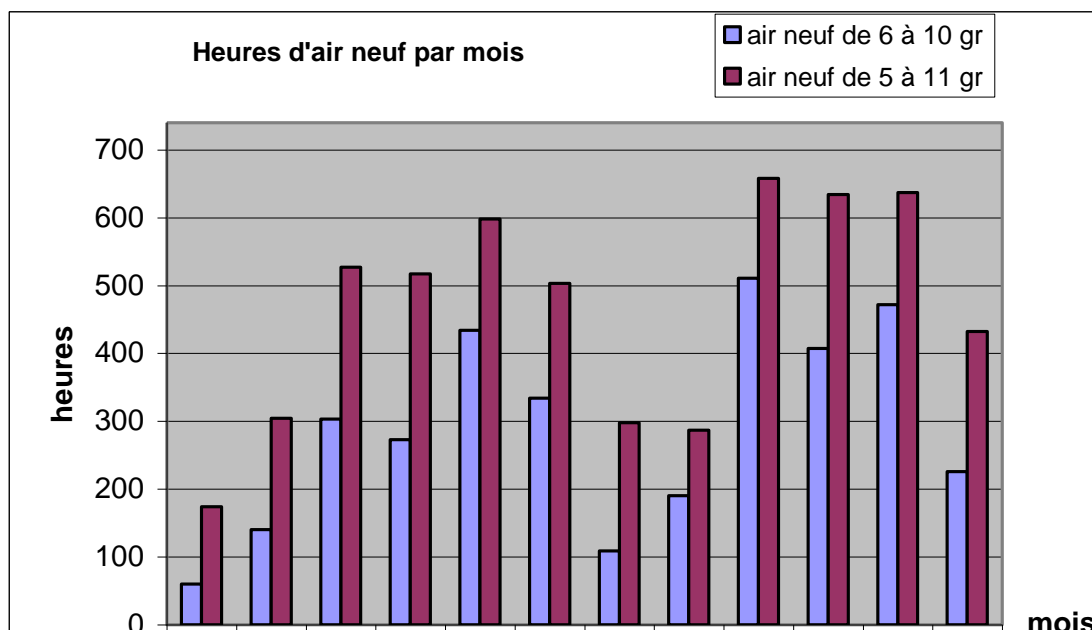
This is still a very important item in the heat balance, especially since humidity is controlled. Humidity is responsible for 44% of consumption related to fresh airflows.

The importance of consumption for fresh airflow gave rise to the following decision.

2. Total shutdown of the fresh airflow under unfavourable outside conditions

The fresh airflow supply is halted if the absolute humidity outside exceeds 11 grams of water per kg of dry air in the summer and if it is lower than 5 grams in the winter.

This avoids having to treat the fresh air under highly unfavourable outside conditions.



The graph above shows that the choice of the external conditions for shutting down the fresh airflow has serious consequences on the number of hours of ventilation.

For the coldest winter months (January and February) and for the hottest summer months (July and August), a variation of 1 gram of water per kg of dry air can lead to the doubling of the number of hours of fresh air supply. This 1-g value is the equivalent of 6 to 7% relative humidity.

The choice of 5g in winter and 11g in summer was made to avoid overly long consecutive periods without fresh airflow.

Furthermore, applying these strict conditions will nonetheless lead to a high rate of fresh airflow for the months of March, April, May, June, September, October and November for which there will be between 500 and 600 hours of fresh air per month. That is why the fresh airflow will be halted between 8 pm and 8 am during this period.

Application of all the restrictions leads to a selective fresh air intake for approximately 300 hours per month uniformly distributed throughout the year.

Additional savings on thermal energy are produced and the total reaches 70% compared with the initial conditions.

3. Rate of air circulation / ventilation

Rate of air circulation initially planned: 3 volumes/hour (usual value recommended by the DAF and also applied at the BnF).

Rate of air circulation adopted in the end: 1.5 volumes/hour (good circulation test carried out on scale 1 using an air distribution process with very high induction).

Special ventilation ducts are used to obtain the same desired air movement effect with half the usual flow rate.



This special air distribution process is sometimes used in the automobile and aeronautical industries when a high level of homogeneity in climatic conditions is desired for large volumes. The air supply duct has perforations calculated to obtain very high induction, ensuring that the ambient air moves with a lower blown airflow rate.

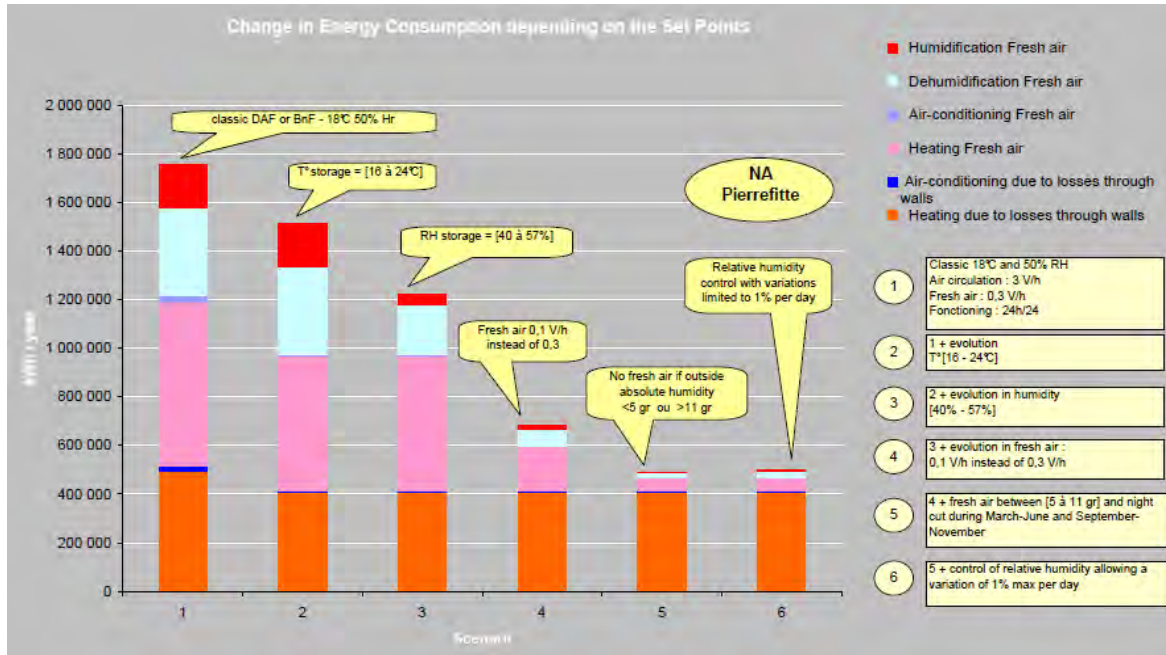
This point provides savings of approximately 50% on electricity consumption in the treatment units for air to be circulated.

These changes to the initial project are very important as this electricity consumption is equal to all thermal energy consumption for treating air for the storage rooms.

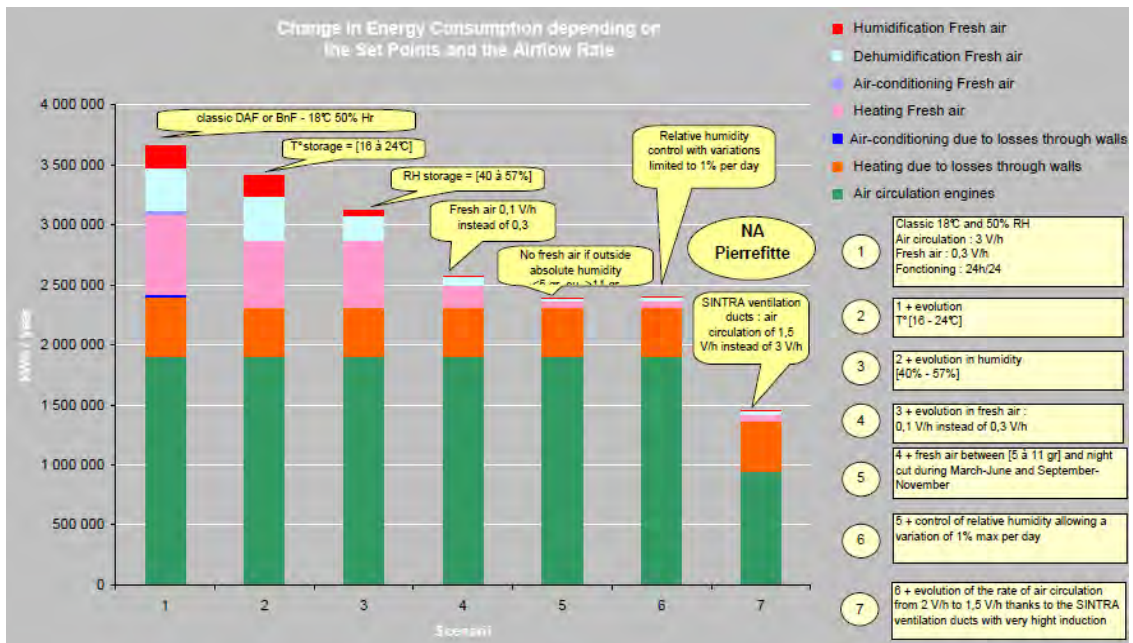
The **following** two graphs represent the changes in energy consumption per item, depending on the set points chosen. The first only concerns the thermal part and the second introduces electricity consumption for the circulation fans.

Change in Energy Consumption depending on the Set Points

Climatic Conditions for Conservation at the Pierrefitte Site



Climatic Conditions for Conservation at the Pierrefitte Site



Complying With the Speeds of Variations in Temperature and Humidity

Temperature

The stability target is 0.5°C per day and 2°C per week.

The building's inertia is such that its natural temperature variations are much lower than the target. We saw earlier that these variations will be approximately 1°C in 10 days for the summer period and 1°C in 5 for the coldest periods.

It would be enough not to disturb the building's natural tendencies with a poorly controlled fresh air intake.

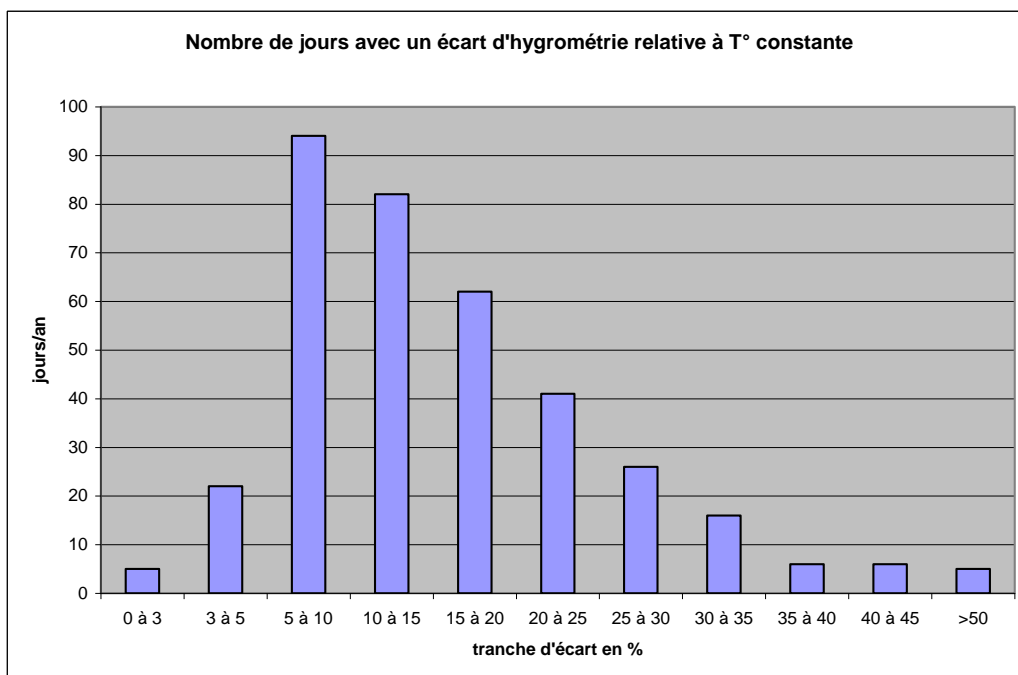
It has never been hard to control a temperature to within a half a degree. All that needs to be done is to blow in fresh air at the ambient temperature of the storage rooms and the entire building will slowly shift in relation to the outside temperature.

Humidity

This aspect of the project is of utmost importance and is very difficult. The stability target is 1% relative humidity per day and 5% per week.

A study of the humidity conditions of outside air in the Paris region gives an idea of the problem.

If we want to continue to think in terms of relative humidity, we have to correct the outside air to a constant temperature in the calculations. The notions then become comparable to working with absolute humidity. Furthermore, this is what is done in practice: the temperature of the outside air is adjusted before being brought into the building.



The table above represents the number of days per year for which the variations in relative humidity are included in a given bracket.

For example, there are 94 days with a humidity difference between 5 and 10%. There are 82 days with a difference between 10 and 15%. There is not a single day with a difference less than or equal to 1%, which is our target. Variations in the humidity of outside air are therefore very strong and unrelated to our target.

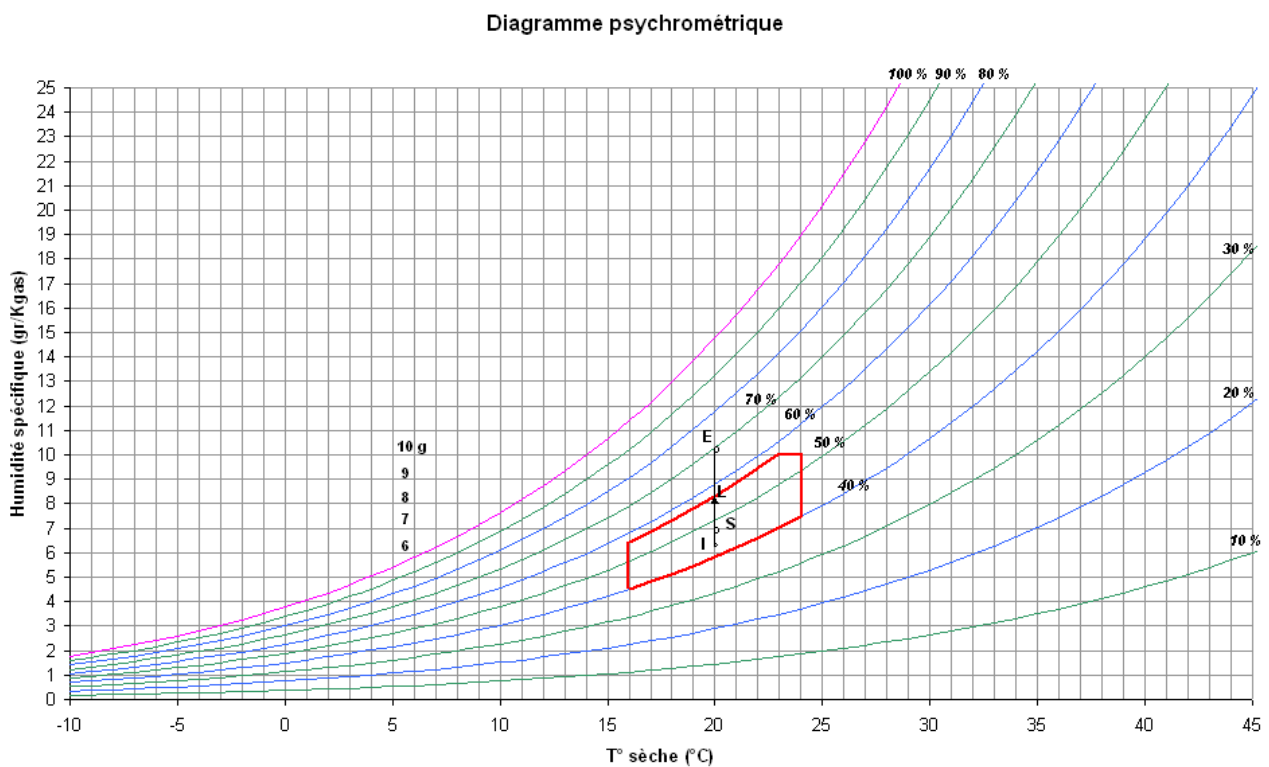
The air renewal rate of 0.1 Volume/hour means that all the air in the storage rooms is replaced with fresh air every 10 hours.

We cannot count much on paper to dissipate variations in humidity. Tests have been carried out by the National Archives conservation department. They showed that a block of 20kg of archives, under real storage conditions, takes 4 months to go from 70% humidity to 50%. A “Bottin” (big French phone book) does not react to variations in humidity in the same way as a sheet of paper in a laboratory.

For our studies, we took the most unfavourable case and we considered that nothing would naturally compensate for variations in the humidity of the outside fresh airflow.

If we seek to achieve the target for the stability of humidity, fresh air must be treated with the greatest precision possible.

The following graph demonstrates the principle of humidity control.



In order to make it easier to understand these phenomena, the entire presentation is given for a constant temperature of 20°C inside the storage rooms, but also for the outside fresh airflow.

Point “E” is representative of the outside air, i.e. 20°C and 70% RH, for the example.

Point “I” is the air inside the storage rooms: 20°C and a little more than 40% RH.

Point “L” is the upper admissible limit in the humidity range: still 20°C, but 57% humidity.

Point “L” is interesting because it is the point to be reached for energy consumption to be as low as possible, since it is the point closest to the outside air conditions. It is therefore the point that will need the least correction possible for fresh air: in our example, it is a question of dehumidification.

Point “S” represents the conditions for blowing in fresh air: 20°C and a little less than 50% on the moist air chart.

By mixing the inside air, “I”, with the fresh air treated at “S”, i.e. dehumidified, point “I” progressively shifts toward point “L”.

The speed of variation of point “I” is conditioned by the [IS] difference. The greater the difference, the faster the speed of change to “I”.

Point “S” is therefore a set point for adjusting the humidity of fresh air. It is a set point that constantly changes. This is not common in controls.

The [IS] difference must be controlled in order to control the speed of variation and to reach the target of 1% per day.

This difference, which is constant, sets a speed of variation. The main difficulty in applying this theory, which is simple, lies in the [IS] difference, which must be very small: approximately 1% RH.

The precision of a humidity sensor is approximately 2% relative humidity.

The simulations that we performed on the humidity control parameters for the fresh air blown in did not take this lack of precision into account and we cannot put a laboratory sensor in each storage room. We therefore do not know how this control will react or what level of precision will be achieved.

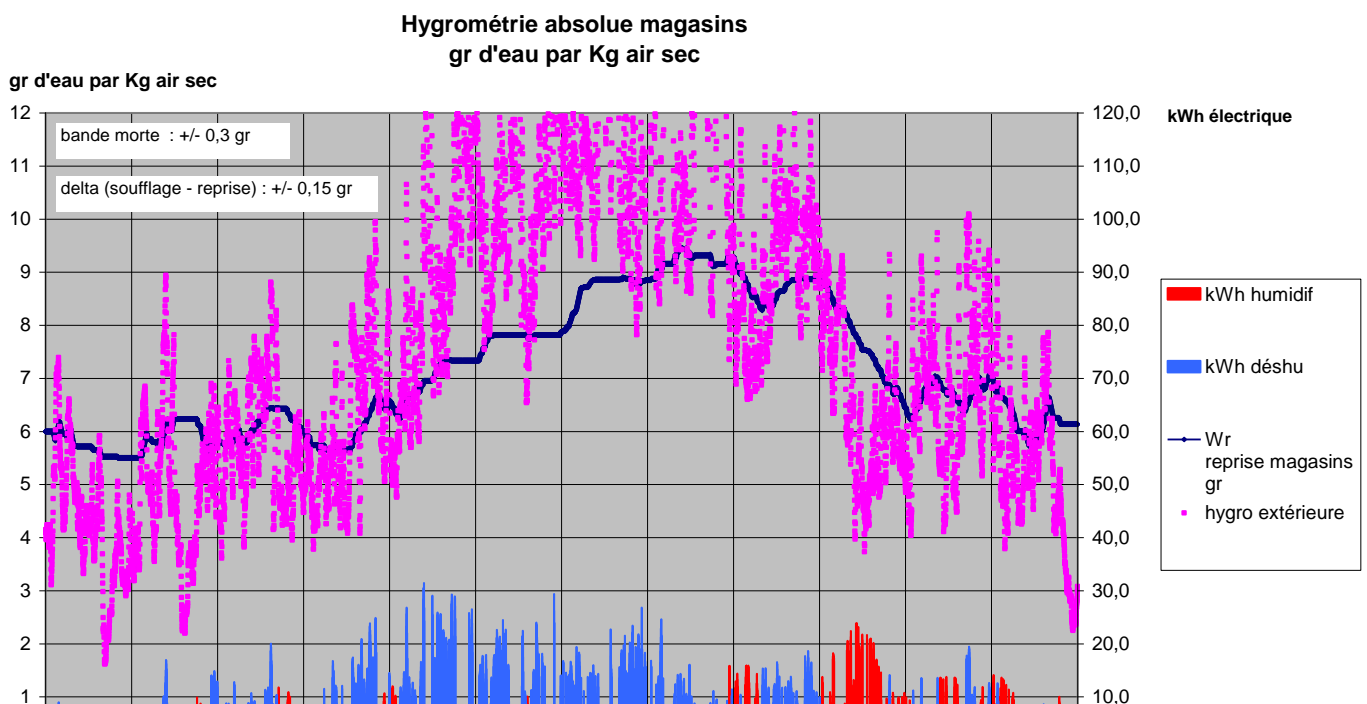
The graph below represents the hour-by-hour annual changes in the absolute humidity of the outside air and the absolute humidity of the air in the storage rooms obtained through theoretical simulations of the controls. We can clearly see the wide variations in the outside fresh air and the inside air, which tends to shift toward the outside conditions, while complying with the demands of the set points.

The main control parameters are:

- The dead band (+/- 0.3g on the graph): this is the stability of the control. It is what keeps us from excessively and pointlessly alternating between the two humidity control functions, humidification and dehumidification.
- Delta (Blowing – Recovery) +/- 0.15g: this is the [IS] difference that sets the speed of variation. The lower this value, the more the inside humidity curve is smoothed and the more it is stable. But energy consumption increases because the inside/outside difference is reduced slowly. In any case, we are limited by the precision of the sensors.

The choice of these parameters is the result of a compromise between energy consumption, the stability of the control and technical impossibilities due to the humidity sensors.

These parameters can, of course, be changed during operations in relation to the real behaviour of the equipment. The planned values today are indeed those indicated on the graph. Theoretically, they should make it possible to reach the target of 1% per day for 86% of the time, and for the remaining 14%, the variations in humidity will be approximately 2% per day.



We should not let the lack of precision in humidity sensors reduce our optimism because we are not so much interested in the absolute value measured by the sensor as in its stability, i.e. its resolution and its repeatability in comparisons. The measurement will be off but it may be very stable.

Another problem lies in the fact that the calculation for [IS] is the result of several humidity sensors that do not necessarily have the same measurement error or the same behaviour over time.

We will be able to observe these wonderful operating contingencies as soon as the building is commissioned, scheduled for the beginning of 2012.

If the realities in the field turn out to be unfavourable and the required precision of 0.15g absolute humidity is unstable or impossible to obtain, we are still far from having failed.

The goal is indeed to comply with a maximum variation of 1% over 24 hours. If we take our reasoning to the extreme, we can increase the 0.15g value up to a value that is compatible with the precision of the sensors (0.3g, for example) and obtain a change in humidity of 1% over 12 hours, then stop all fresh air intake, ensuring that the conditions reached are maintained. This may be brutal, but the goal is met in value, although not necessarily in its philosophy.

The idea should not be rejected; it is a first step toward chrono-proportional controls. When you cannot adjust power between zero and 100%, for example in certain cases of electric heating, you work with the equipment's operating time. The case of 12 hours on and 12 hours off is symbolic. In reality, this may mean one hour on and fifteen minutes off depending on the parameters adopted and the needs. Stopping the fresh air intake during shutdowns can be offset by a larger flow rate during periods of operation.

This is a layer of control that could be applied with the first one and will be explored if the situation in the field so requires.

Bruno Bonandrini, July 2012

Notes:

1. The text of the RT2005 is available in French at: <http://www.rt-batiment.fr/batiments-neufs/reglementation-thermique-2005/textes-de-reference.html> (Accessed November 2011.)