Pilote project for a special filter- and air conditioning system for smaller archive

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In 1971 the Rotterdam Municipal Archives moved into their new repositories totalling 2800 square metres of floor space and extending over seven storeys. They were built of concrete with very little window surface.
The architect was of the opinion that he had created a building in which the climate was so constant, that no airconditioning would be needed.
I'm sorry to say that he was wrong. In 1975 an airconditioning system had to be installed that was to keep the temperature at 18° Celsius and the relative humidity at 60%.

This airconditioning system never lived up to our expectations. The RH especially was subject to huge fluctuations: values varied from 30 to 70%. This indicates that the system was primarily concerned with monitoring temperature and RH came a poor second. The moment came that the whole system, apart from the heating, was disconnected and the results in general were better than with the system fully operational.

In 1989 we decided to have another go at solving our airconditioning problems.
Information gathered from other archives told us of endless possibilities as well as numerous pitfalls in practice. Everyone was warning against communication problems: Technicians and archivists do not speak the same language and what is self-evident to the one is quite the opposite to the other.
We considered ourselves well-armed with this advice and felt confident that this would not happen to us. You'll hear all about this glaring overestimation of ourselves.

First thing we did was order a constructional survey of the building and a survey of the possibilities for climate control. The construction physicist was told to find a constructional solution to the problem -if at all possible- or -if unavoidable- to choose and install a system that added not too much to our electricity bills.

At the same time new requirements were laid down:

	old	new
1 RH	55 ±5	50 ±2
2 temperature	18	16-24
3 ventilation	0.16	0.01 - 0.1 *
4 recirculation	2	0.5 - 1 *

* times the room's content per hour.

ad 1 the smaller tolerance was chosen because we feel the RH to be the most important parameter in the preservation of archive material. The STEP-research project once again determined the clear relation between RH levels and the degradation of material. Furthermore it was shown that above 50% RH the degradation increases and at 65% it increases strongly.

ad 2 only minimal variation per day was acceptable. By allowing a wider tolerance in temperature the control of climatic conditions will require less intervention.

ad 3 restricting the outside air intake will result in less fluctuation in temperature and RH and will limit the need for air purification .

ad 4 air recirculation requires a lot of energy. Cutting costs in this area is desirable. Decisive factors here are:
1 the maximum speed at which the air is allowed past the filters - at high speed the filters perform unsatisfactorily
2 the constructional state of the repository. If there is a fair chance of the occurence of a micro climate it is wise to adapt the recirculation speed.

All calculations were done with the computer programme BFEP developed by the faculty of Construction Physics of the Technical University at Delft and used for calculating dynamic temperatures in buildings. They showed a need for intervention in climatic conditions in the following periods of the year. (Fig. 1)

The calculations furthermore showed the feasibility of implementing constructional alterations to level out differences between climatic conditions inside and outside the building.
Maximum insulation would -in an average year- result in only 6 days of repository temperatures over 24°.
The same would more or less be true for the RH. Important here is the need for a completely impermeable insulation material. There are two reasons for this:

1 The insulation material installed on the inside will transfer the dew point to the inside of the building. Condensation may occur. By making the insulation vapour tight on the side of the repository and not on the side of the outside wall, we can prevent moisture from penetrating the insulation material and condensing there.

2 When the room is well conditioned, humidification can be kept to a minimum. This is important because keeping a room at the required RH usually involves periods of humidifying, dehumidifying and heating.

As a result of our experiences over the years with advisers of climate control systems we'd developed a healthy distrust of the species. Partly for this reason and partly for financial reasons we decided to start with a pilot project in one of the repositories. We chose a four hundred square metre room situated on the top floor in the least favourable position where climate control was concerned.

Further requirements were developed:

5 filtering of ventilation- and recirculation air.
6 airconditioning controlled by RH
7 RH in the outside air intake ducts must never top 65%

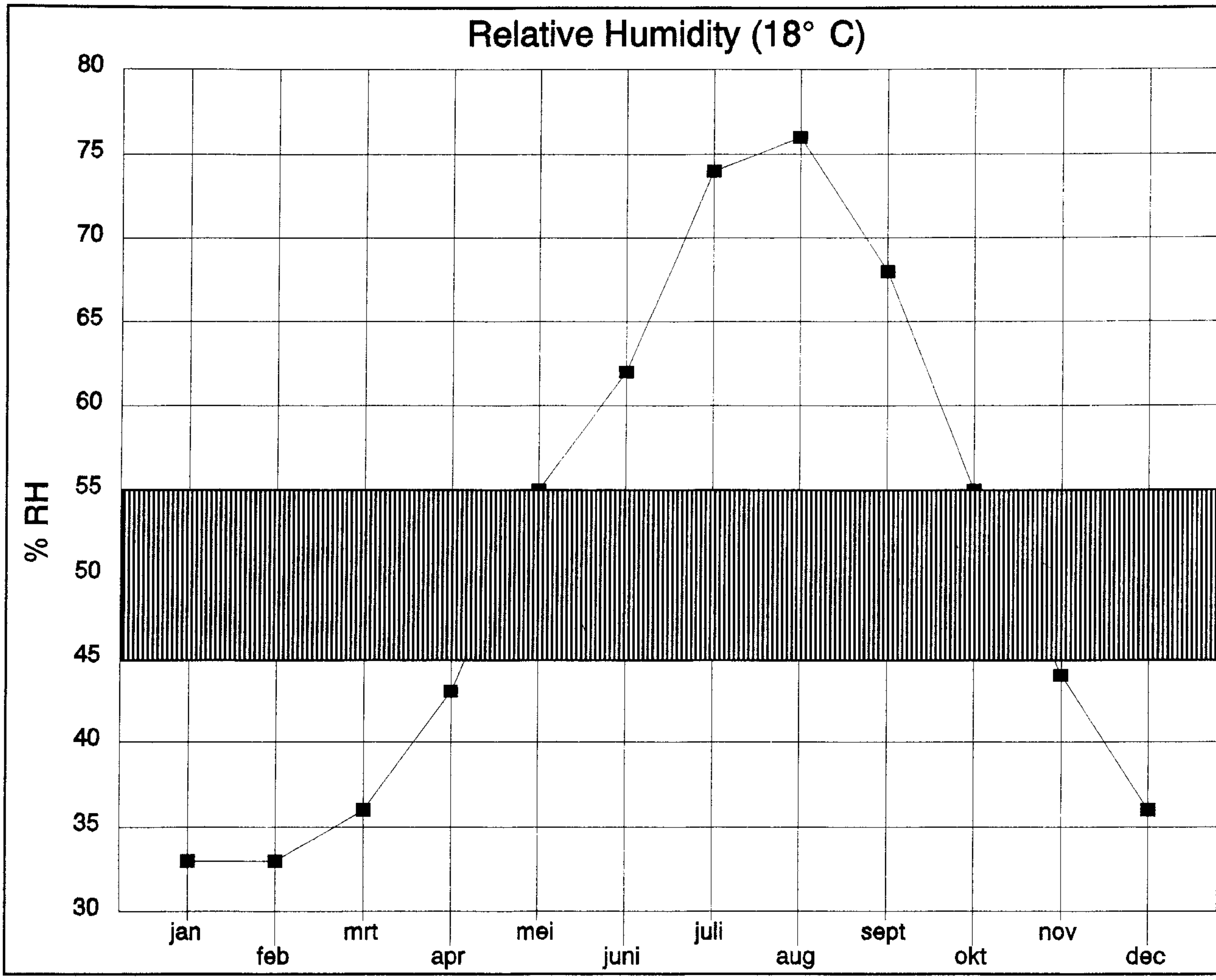


Fig. 1. RH during the year at 18° C. The figure shows that only in the months of April and October the RH is ideal and thus requires no alteration.

8 ventilation fold of 0 (theoretical)
9 homogenous air distribution
10 a separate system for each floor

ad 5 the following filters had to be installed:
- a coarse pre-filter EU4 for filtering out the larger dust particles
- Purafil II, a chemisorbent filter
- Puracarb PP1505
- a smooth endfilter EU 8/9, for filtering out any particles loosened by the other filters as well as particles floating about the room.

NB: Implementing both the purafil and the puracarb filters ensures the best purification of the air. In additon both filters have a known lifespan and their contamination can be checked.
- the speed of the air passing these filters should not exceed 1 metre per second
- the bed depth of the absorbing layer should be more than 28 millimetres.

ad 6 Traditionally there is a close relation between humidifying, heating and cooling in air conditioning systems. By letting the RH steer the system, allowing the temperature a free range between 16 and 24° C and leaving this margin for correction of RH by the unit, we try to avoid this expensive tradition.

This will be best explained by the Mollier diagram. This diagram shows the correlation between different parameters and allows graphic presentation of the calculations. I will limit my explanations to the most important parameters: absolute humidity, air temperature and relative humidity.

- The absolute humidity is presented on the horizontal axis in grams of water per kilogram of dry air.
- The temperature is presented on the vertical axis. These run almost parallell to the horizontal line.
- The curved lines represent the constant relative humidity. The 100% line is the saturation line. It connects the temperatures that allow the existing moisture content to be present in vapour phase. (Fig. 3)

The working of a traditional air conditioning system.

Every air conditioning system works with pre-set temperature and RH. Generally the temperature is set first and then the RH is adapted to the set temperature. I'll give two examples of how an air conditioning unit set for 18° C and 50% RH reacts to any deviation.

Example 1
The temperature in a room is 18° C but the RH has risen to 60%.
The temperature is correct but the RH is too high. The

Media Solutions For Contaminant Gases

Recommended control media	Typical Contaminant Gases										
	Ammonia (NH2)	Chlorine Chlorine Dioxide	Hydrogen Flouride	Hydrogen Sulfide	Nitric Oxide	Nitrogen Dioxide	Nitrogen Oxides	Ozone	Sulfur Dioxide	Sulfur Trioxide	General Hydrocarbons
PURAFIL II Chemisorbant			○	○	○	○	○	○	○	○	
PURACARB PP 1505		○		○					○		

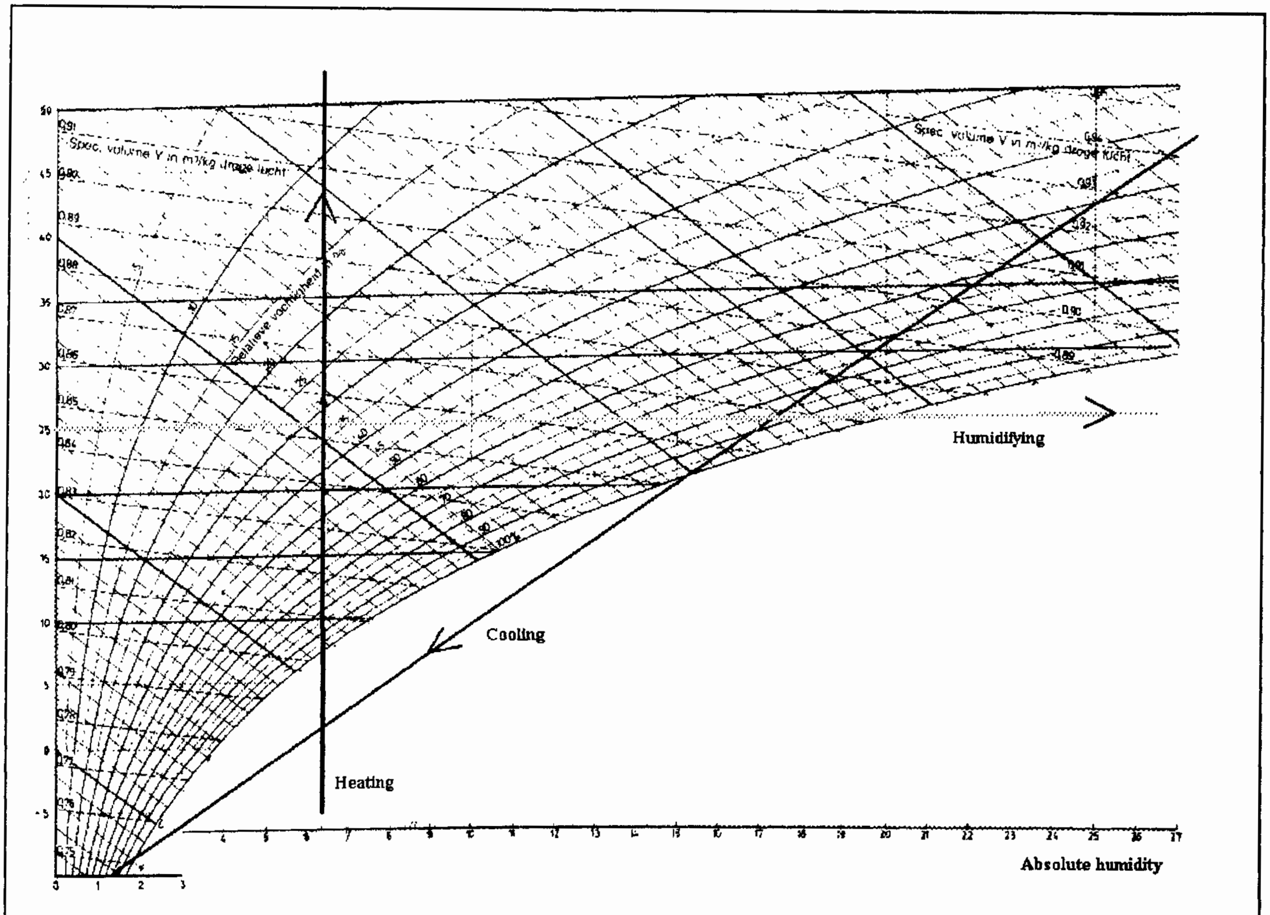


Fig. 3.

air contains 8 grams of moisture per kilogram of dry air. This moisture content should be reduced to 6.4 grams/kg by absorption (onto silicagel) or by condensation (by cooling). In general cooling is used. This results however in a drop in temperature which then calls for extra heating to 18° C.

Action here is cooling - heating. (Fig. 4.)

Example 2
The temperature is 20 ° C and the RH has gone down to 40%.
Two reactions are possible, depending on the given priorities of the air conditioning unit:

1 If RH has priority, then humidification up to 50% will occur, followed by cooling down to 18° C. However, when air is cooled down its RH will rise. If this then results in an RH above the pre-set value, further cooling and then heating will be required.

Action here is humidifying - cooling - heating.
(Fig. 5)

2 If temperature has priority, then the air will be cooled down to 18° C and humidified to 50% RH.

Action here is cooling - humidifying.
(Fig. 6)

To avoid this expensive and continuous process we adapted our requirements accordingly. The air conditioning unit will be ruled by the RH in the room. Any corrections in RH will be achieved by temperature change or humidification alone.

For example 1 this would mean that the temperature would be raised to 21.5° C and in example 2 humidification up to 50% would take place.

ad 7 this maximum RH of 65% should prevent the occurrence of high moisture concentrations locally.

ad 8 a zero-fold ventilation will ensure a more constant climate in the room, because of the major influence of outside conditions on the climate inside. In addition the contamination of the filtration media will be kept to a minimum. A carbon dioxide meter will ensure a good quality air.

NB: Because of 100% of recirculation air we will not be able to create a situation of overpressure in our test room, since this would call for more than 100% of air inside.

ad 9 the importance of good air distribution inside the repository was stressed. Air leakage inward through weak spots in the construction of the building (infiltration), is the only factor left to influence the conditions inside the room negatively.

ad10 though the installation of separate units will raise the costs, this will have the advantage of limiting failures to one unit and one repository only. Furthermore this will create the possibility of storing different materials requiring different conditions in separate repositories. However, no decisions in this matter have yet been made.

After several rewrites of these requirements and their consequences, the order was given to remodel repository 35, situated on the top floor of our building, to serve as a test room for this new air conditioning system. The calcutions were done once more and this time they did show a need for extra cooling capacity.

The following structural provisions have been implemented:

The inside of the outer shell was covered with a 13 centimetres thick layer of FOAM-glass. This insulation material was chosen because of the following characteristics:
- the material is absolutely water and vapour tight.
- it is impervious to moulds and bacteria.
- it will not be eaten by mice, rats etc.
- it has approximately the same coefficient of expansion as concrete.

Because the repository was still being used, a finishing layer of a synthetic material was chosen instead of the preferred plaster, which requires considerable amounts of moisture when it is applied.
The air conditioning system was then installed in the repository. It has the following lay out (Fig. 7):

Air is being blown into the room through eight ducts situated against the ceiling. In these air ducts two nozzles are installed at intervals of 50 centimetres. These ensure an even distribution of air inside the room. The shelving in this repository is mobile and thus very compact, so the nozzles are aimed to give maximum air movement between the bays of shelves. The possibilities of extraction of recirculated air at the bottom of the bays was looked into at this stage, but though structurally it proved to be no problem, the costs were such as to make us drop the idea. The recirculated air is now extracted by the air conditioning unit in two places, and part of the air passes again through the filter bank. Pressure gauges keep check of the degree of contamination of the filters.

Other measurements are taken that are automatically recorded by the computer. They can be printed in tables or diagrams.

Evenly distributed over the repository where placed 8 thermometers and 4 RH meters, set at different heights.

Further monitoring is carried out of:
- start and duration of the running time of the cooler
- start and duration of the running time of the humidifier
- start and duration of the running time of the heater
- frequency of the door opening and the duration of the door being open
- start and duration of the running time of the lighting
- amount of carbondioxide in the air
- temperature of the cooling-water
- energy consumption

The insulation material proved to be insufficiently closed on several places. We immediately pointed this

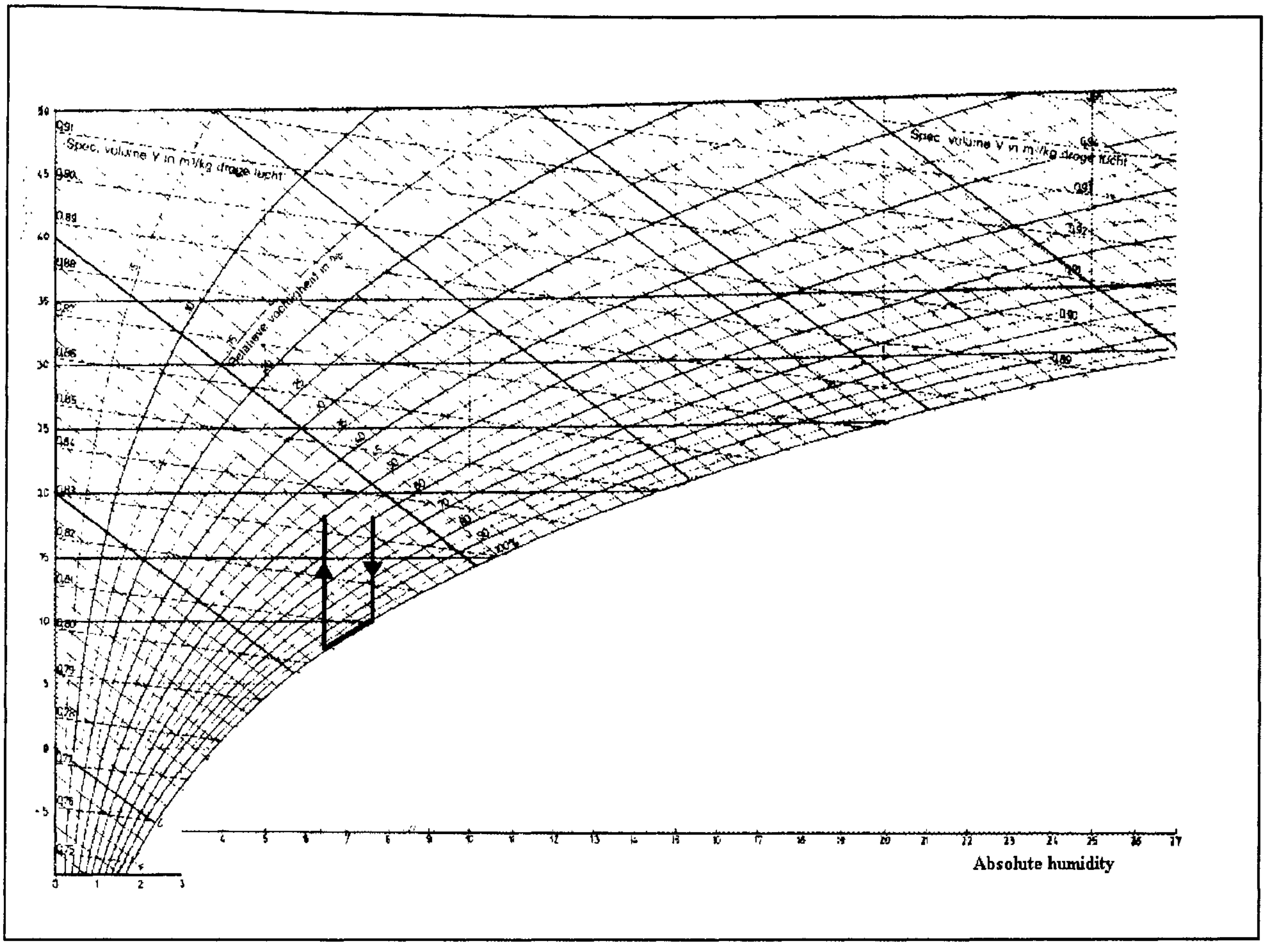

Spec. volume V in m³/kg droge lucht
Absolute humidity

Fig. 4.

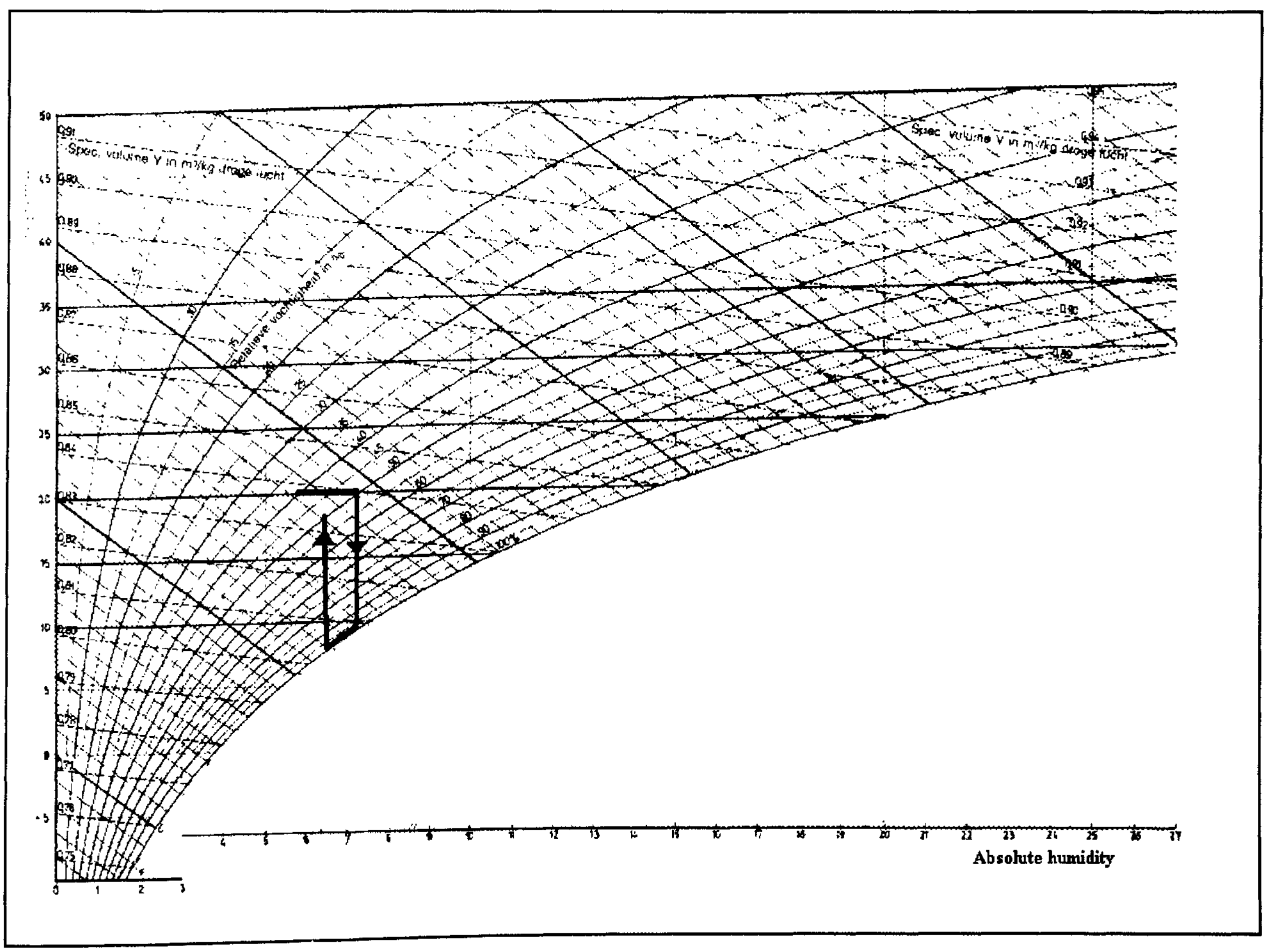

Spec. volume V in m³/kg droge lucht
Absolute humidity

Fig. 5.

out to the installers, for not only did this mean an unnecessary loss of insulating power, but more importantly this resulted -and we didn't immediately realise this- in a complete failure of the so ardently desired vapour tight cage. Through pressure and wind force the badly insulated areas will allow unwanted infiltration of outside air and condensation may occur.

Once the climate in the repository remained within the set limits for much of the time, we turned our attention to the workings of the different components of the airconditioning unit: how was this result achieved?
Quite soon we realised that in spite of the wider tolerance in temperature (16 -22°), the ideal situation in the room required intervention of more than one component of the unit at any one time.

In quite mysterious ways the cooler, humidifier and heater kept influencing one another, though this was precisely what our specific requirements were meant to prevent. After many heated conversations with the Municipal Council's consultant/inspector we discovered that the ac system was not steered by RH but by temperature. The readjustment of the system did not however lead to any noticeable improvement.
After a year and a half of test runs and consultations the situation was still the same: the results were fine but they were achieved by all the components of the system interreacting.
One of the recurring and unanswered questions was: why does the cooler switch on when the room conditions are fine? Later we discovered that the cooler worked to keep the temperature in the buffer drum constant. We then decided to take the cooler off its stand-by position in order to limit its running time to those moments when cooling was directly called for. We also set a cooling temperature. These changes solved a number of problems.
It became quite clear to us that the system was now controlled by the RH but at the same time it was being operated at an average temperature of 18° C.

At the same time we discovered that, contrary to the manufacturer's statements, the pressure gauges on the filters were not recording the contamination of the chemical filters but of the dust filters. We contacted the manufacturer and were told that:

1 the filters we had requested had been replaced by 'comparable' filters,
2 the minimum bed depth could not be guaranteed,
3 instead of the requested fine dustfilter a coarse dust filter had been installed.

ad 1 The absorption speed of comparable filters can be different. The air flow of the air conditioning system has to be adjusted to this absorption speed.
Specifications ordered cannot be changed without prior consultation.

ad 2 The required bed depth at the time was 28 millimetres.
Today the manufacturer advises a depth of 56 millimetres.
The shape of the module is another important factor influencing the overall bed depth. The chemisorbent pellets can settle and this too can cause thin areas in the reactive layer. (Fig. 8)

ad 3 The coarse filters directly influence air resistance and air flow. The more coarse the filter, the lower the air resistance; this then increases the air flow. If the air flow exceeds 1 metre per second the air will not be satisfactorily filtered by the chemical filters.

NB: The right correlation between air flow, recirculation and frontal surface should be maintained. In the initial calculations for an air conditioning system this should be taken into account.

This situation led us to contact a different company. Our requirements and specifications were once again looked at.
The system and the monitoring equipment was inspected and registration was started again. After a few months the system proved not to react as we expected it to. From the resulting talks with the experts we learned that with the controlling equipment installed we would never have our requirements fulfilled. If the RH get too high the system automatically starts cooling: it cannot solve the problem by raising the temperature.
Adjustments would cost *f* 20.000,--

We could however manipulate the system somewhat so that no temperature correction will follow between 16 and 20° C.
In fact however it remains set at 18° C., but leaves a margin of 10% both ways, where previously the unit kept strictly to 18° C.

The final result is a stable climate and the different components making up the unit are less involved in interreacting and so put in fewer hours, though from the point of view of energy saving things could be better.

Conclusion: what did we learn from all this?

- although we assume to understand the engineers of air conditioning units and reckon on them installing everything exactly according to our specifications, each component of the system will have to be checked to detect hiccups in communication in an early stage.
- structural provisions must be given full attention:
  if vapour tight insulation material is used it should be applied in two layers and positioned like roofing tiles to avoid cold bridges and moisture migration.
- daily inspection of the system is necessary: we saw the cooler operating while the room temperature was fine. Later we noticed it was only cooling the buffer drum. The latest in controlling equipment immediately reports any

failure in the system to the computer.

- We would like future systems to have air extraction at floor level evenly distributed over the room.
- the minimal temperature of the air blown into the room should be reduced from 15 to 5° C to avoid unnecessary heating.
- monitoring should not just be done of the system components in operation, but of the results as well.
- the narrower the set tolerances, the more often the system will intervene.
- the monitoring equipment's ability to record minor deviations should be checked.
- air recirculation requires very much energy.

I would like to thank my colleagues of the Rotterdam Municipal Archives for their assistance in writing this article. Furthermore I thank Mrs Elly Pauwels for translating the manuscript in English.

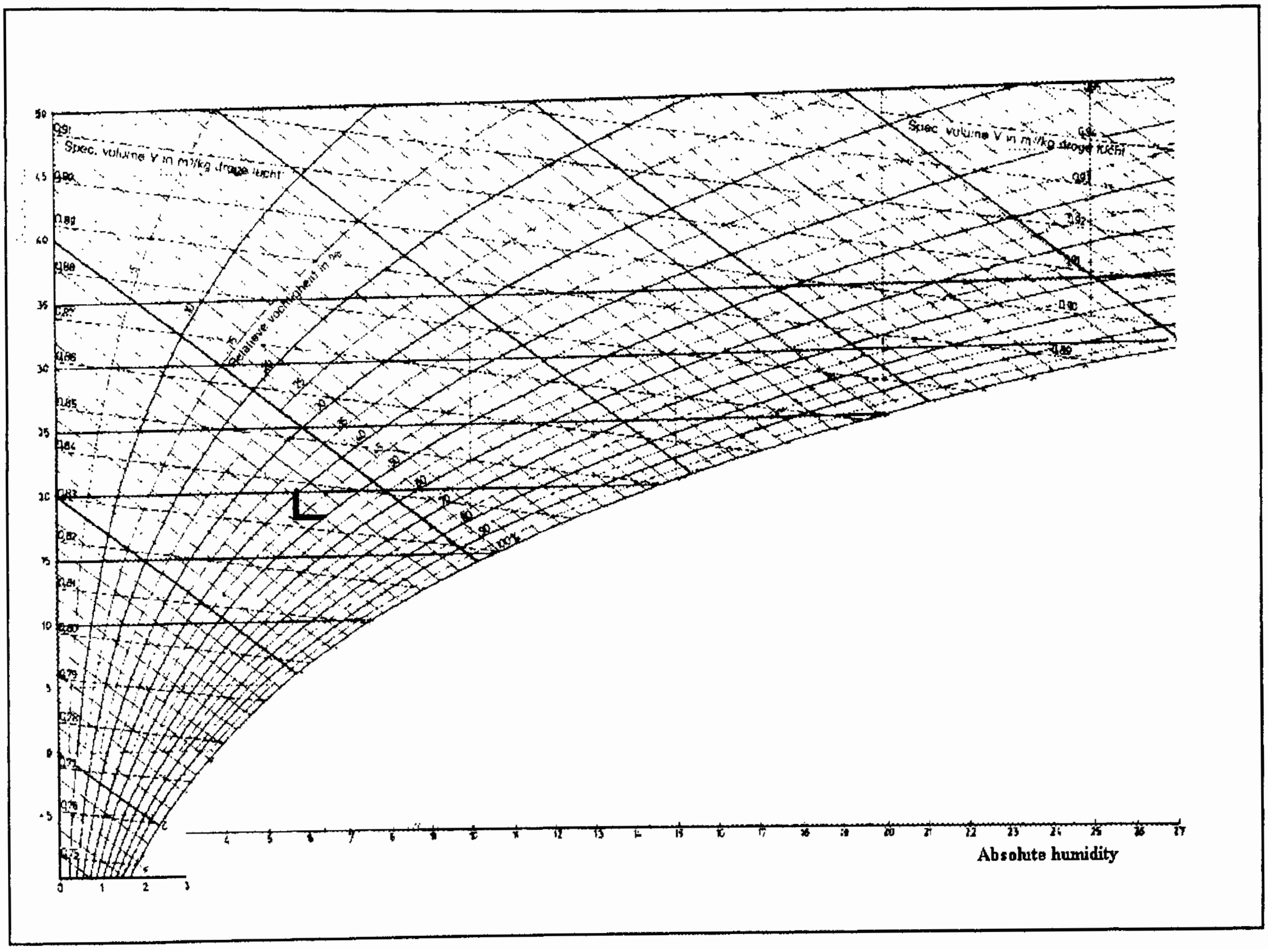
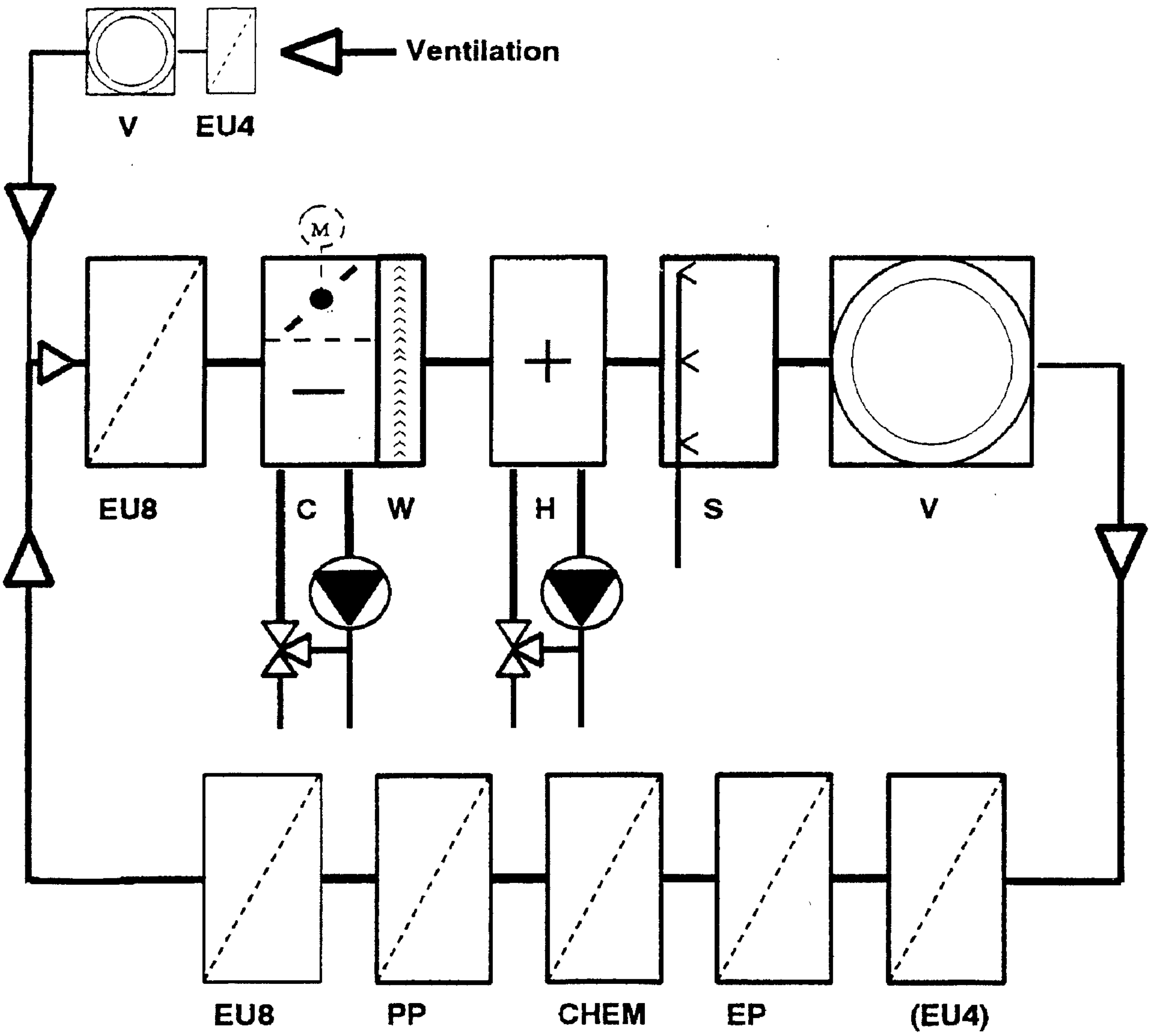


Fig. 6.

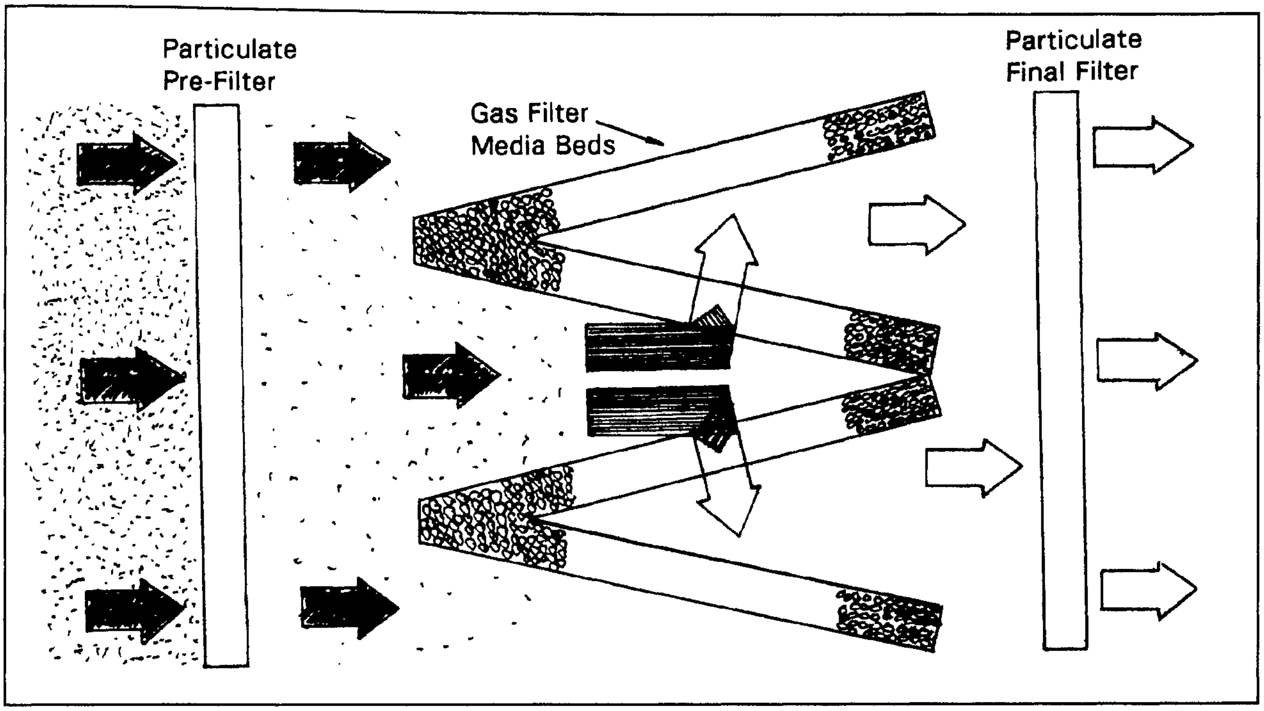
Technical layout air treatment and air purification



Archives/Storagerooms, air circulation approximately 2 air changes

EU..	= dust filter quality ..		
V	= ventilater	CHEM	= chemical air filter
C	= cooler	PP	= carbon air filter
W	= water eleminator		
H	= heater		
S	= steam humidifier		

Fig.7



Particulate
Pre-Filter
Gas Filter
Media Beds
Particulate
Final Filter

Fig. 8.