

X-3073

ATMOSPHERIC CONTROL

FOR

INDEPENDENCE GROUP OF BUILDINGS

I N

INDEPENDENCE NATIONAL HISTORICAL PARK

PHILADELPHIA

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NATIONAL PARK SERVICE

PROBLEM

To provide best feasible conditions for the preservation of memorabilia consistent with acceptable discomfort for visitors.

COMFORT

None of the investigators thus far has indicated that the optimum temperature and humidity condition for the preservation of memorabilia need be significantly different from the optimum indoor temperature and humidity for comfort.

The desirable indoor summer temperature for relatively short occupancy is 75° to 77° at 40% to 50% R.H., and for winter between 70° and 74°. The relative humidity in winter has minor effect on the feeling of warmth but relative humidities in excess of 35% are noticeable when entering or leaving conditioned space.

There is no hour by hour relation between the desirable indoor and outdoor temperatures.

PRESERVATION OF MEMORABILIA

Appendix I is a discussion of the effect of temperature, humidity, and atmospheric pollutants, together with recommendations on atmospheric control. (Appendix I, Page v.)

The discussion indicates:

That relative humidity should be substantially constant and should be in the range of 45-55%;

That a dry bulb temperature in the 60° to 85° range is satisfactory;

That sulphurous gases can produce rapid deterioration of many organic materials, paper in particular;

That dust control apparatus efficient in the sub-micron particle size range is highly desirable.

Of the above factors, only that of maintaining the desired relative humidity in winter offers difficulty if condensation on the windows, and to some extent in the construction, is to be avoided in cold winter weather.

Fig. 1 shows the indoor relative humidity at which condensation occurs as a function of outdoor and indoor temperature for single glass, and the relation between outdoor temperature and an indoor temperature of 70° with double glazing.

The curves are theoretical and assume that there would be no leakage between the inside and outside glass.

With double glazing we would recommend a control setting as shown by the broken line when a temperature of 70° was maintained indoors. With single glass and 70° indoors, the relative humidity would have to be dropped below 45% when the outside temperature was below 38°. Alternatively, if the room temperature were permitted to go as low as 60°, condensation would not appear until the outdoor temperature was below 30°.

Because of the use of the East and West Wings, we do not think that the humidity control problem is so important as it is for the three major buildings.

Fig. 1 also shows the number of hours per year that the relative humidity would have to be lowered to prevent condensation as a function of indoor and outdoor temperature. In general, this lowered relative humidity would affect dimensional stability only and, for an extreme cold spell of long duration, there might be deleterious effects on wood but to a considerably

lesser degree than now occurs in a building which does not have good humidity control.

With constant relative humidity even the largest paintings on canvas would not require restretching or other repairs for many years.

With single glazing, damage due to high humidities, atmospheric pollutants and dirt would be largely eliminated. Problems of dimensional stability would be greatly improved but would not be so good as would be possible if the relative humidity could be maintained constant in cold weather.

The air conditioning installation would be essentially the same whether single or double glass were used so, if double glazing is not installed initially, it can be installed at any time during the life of the building if justified by the type of material to be displayed.

DISCUSSION

The complete solution of the problem indicates the use of a full air conditioning system with special attention to accurate control of humidity, means for removing sulphurous and other deleterious atmospheric gases, and filtration efficient in the sub-micron range for the substantial capture of particles such as those comprising a smoke cloud.

If all of the air conditioning installation were made, other than the refrigerant cycle, the system would be generally satisfactory from late fall until early spring but the simultaneous control of humidity and temperature would be lost for the remainder of the year.

In order to have the benefit of controlling atmospheric pollutants and dust, it would be necessary to keep the windows closed. With closed windows the amount of air delivered would be totally inadequate to maintain even reasonable comfort in warm weather, particularly in Independence Hall with its large expanse of south-exposed glass.

In summer, any attempt to control humidity alone without limiting the temperature, as by solid or liquid sorbents, would be open to the same objection of impractically high temperatures in warm weather.

The use of unitary equipment within the various public spaces would not be feasible, even if there were no objection to its appearance and sound level; in part because the number of automatic control systems would be greatly increased and the cost of installation and the cost of maintenance would not be proportional to the size of the area which it served.

Obsolescence

Obsolescence may be separated into means and results.

The objectives of comfort air conditioning, which is closely allied to conditions required for the preservation of memorabilia, have not changed in 100 years. The most significant improvement in result has been in the ability to control dust and other atmospheric impurities, a product of the last thirty years.

If a proper air conditioning system is installed in these buildings, there is no reason to believe that it will become obsolete as regards the results obtained. There is, of

course, the possibility that more efficient fans or more efficient pumps or more efficient refrigeration may be developed but this would have a minor effect on operating cost and would not affect the duct installation and means of air distribution.

RECOMMENDED INSTALLATION

It is recommended that each of the five buildings be provided with its own air conditioning apparatus, other than for the refrigerant cycle which could either be by individual plants or by one central plant. Suggested methods of conditioning are shown as follows:

Plot Plan	-	Drawing No.	NHP-IND 3146,	Sheet 1	
Old City Hall	-	"	"	"	" 2, 3, 4, 5
East Wing	-	"	"	"	" 6 & 7
Independence Hall	-	"	"	"	" 8, 9, 10, 11
West Wing	-	"	"	"	" 12 & 13
Congress Hall	-	"	"	"	" 14 & 15
Cooling Tower and Refrigeration Vault-	-	"	"	"	" 16

DESIGN

The design is predicated on:

Maximum occupancy:

Old City Hall	150
East Wing	95
Independence Hall	280
West Wing	75
Congress Hall	150

Lighting coincident with sunlight not exceeding 1 watt/sq.ft.

Maintaining an indoor temperature of 75° and 45% R.H. in summer and 70° and 45% R.H. when feasible in cold weather.

CENTRAL APPARATUS

For Old City Hall first floor, Independence Hall, and for the first floor of Congress Hall, air treating apparatus would consist of a fresh air intake, return air intake, a coarse filter - preferably of the roll type requiring the least at-

tention, a diffusion type filter for the removal of fine particles such as those comprising visible smoke, an activated cocoanut charcoal filter for the sorption of acid gases and hydrocarbons, an all-copper sprayed coil dehumidifier, an external bypass with a reheater and pocket type medium efficiency filter to permit the recirculating of air between the fan and the cooling coil. There will be a water heater in the spray system for winter humidification.

If the charcoal filter is eliminated, it would be necessary to maintain reasonably close control over the alkalinity of the water in the spray washer in order to remove the sulphurous gases. The charcoal filter offers additional advantages in that it would remove other gaseous atmospheric pollutants such as those generated by the interaction of sunlight and the unsaturated hydrocarbons and the odors associated with large numbers of people.

In Congress Hall and Old City Hall it is proposed to install conditioning apparatus in the attic.

The apparatus for the East Wing and West Wing is relatively small and unitary equipment could be used. We do not consider that it is necessary to provide means for controlling atmospheric pollutants and have, therefore, omitted the charcoal filters. The apparatus is too small to justify the use of a roll type filter and we have shown a combination coarse and diffusion filter of the replacement type. The functioning of the apparatus would be substantially as for the major system.

For all of the air conditioning systems the dewpoint

would be controlled at the apparatus. Booster heaters with automatic control would be used to control the temperature in the various rooms. Hot water boosters would be used in lieu of steam as providing more flexibility for installation and operation. Booster heaters will be installed in the attic of Congress Hall and the attic of Old City Hall to serve the second floor of these buildings. Booster heaters will be installed in the second floor of the West Wing to serve the first and second floors of this building. All other areas will be served by booster heaters in the basements.

AIR DISTRIBUTION

General

We have tried to locate the air supply and return outlets in such a way as to offer minimum interference with the original architectural effect. Where possible, we are suggesting the use of grilles in the floor, adjacent to the windows. (See Sheet 15, Plan and Section.) For floor installations we recommend that the grilles be of cast metal. Iron has proved quite satisfactory in the past. The grilles are quite substantial and the slots are only 1/4" wide so they will offer minimum heel hazard.

Air is delivered at a 7° angle to the vertical and, depending on location and at will, the delivery can be changed from 7° away from the wall to 7° towards the wall.

In some locations it appears desirable to locate grilles in the windowsills, in which case they can be of either metal or well-seasoned wood.

Old City Hall

Sheet 2 - Basement Plan. Existing openings and ducts have been used wherever feasible. The plan shows the central apparatus, the distribution to existing and new flues, booster heaters for control, and the location of the individual refrigeration machines to serve Old City Hall if a central plant is not installed.

On Sheet 3, for the main hall, new floor grilles are shown in the rostrum. All floor grilles used for supply are of the type previously described. The return grilles are new grilles in existing openings. A new floor grille and opening is provided below the stairs in the northwest corner for the return of air from the first floor.

Sheet 4. The air distribution of the second floor is by grilles located in the partition walls. An alternate method using ceiling diffusers is shown.

Sheet 5. The air conditioning apparatus to supply the second floor is similar to that for the basement except that the coarse filters would be the stationary type instead of the roll type as the apparatus is too small to justify the use of an automatic filter and the dust load is considerably less than it would be on the first floor.

East Wing

Sheet 6. The air conditioning apparatus will receive its refrigeration effect from a central plant or from the isolated plant in the basement of Independence Hall. In order to supply and return air to the first and second floors we propose to

use the existing chimney.

Sheet 7, first and second floors. We have shown an exposed duct which can either be of streamline construction exposed or of standard construction furred in. We prefer the former.

Independence Hall

Sheet 8. There are two air conditioning apparatuses. We are using all of the existing flues now used for heating only and supplementing as required. All apparatus, other than ducts, is confined to the basement. Apparatus can either be served from the central refrigeration system or from isolated units as shown on the drawing. If an isolated system, these units would serve the East and West Wings as well as Independence Hall.

Sheet 9. In both the east and west halls we have shown the air supply grilles located in the windowsills in order to provide better air distribution should these halls be used for public assembly. The grilles could be located in the floor.

South Room: Due to the large amount of glass and the structural difficulties of adequate air distribution, we are not recommending the supply of sufficient air to hold this room at temperature under peak conditions of occupancy and sunlight. The departure will not be great as air is returned from the second floor thru this open space.

The two grilles at the north entrance door, now used for heating, will be replaced with a different type grille and both used for air supply. Two new grilles in the corresponding location at the south end of the foyer would be used for return.

Sheets 10 and 11, Second Floor. Three different methods of supplying air to these areas are shown:

Method 1, as illustrated by Section AA, Sheet 9, would require grilles over each of the doors of the closets at the east and west ends. Mechanically, this is the simplest method but it is appreciated that there are objections to showing grilles in this location.

Method 2 would be to extend the existing risers at the second floor level up to the attic and distribute air as shown on Sheet 11, the final air distribution to be thru substantially concealed slots just above the cornice in the wood mold as shown on Section AA, Sheet 11.

Method 3, Sheet 10, would utilize floor grilles with a duct location between the floor and the hung ceiling of the rooms below as shown on Section BB. Altho this distribution is feasible, it would be quite difficult to install.

Of the three methods, Method 2 appears to be the most desirable for final effect architecturally but will involve replastering of the cove after the installation of the ductwork as shown on Section AA, Sheet 11.

West Wing

The air treating apparatus would be located in the attic, as shown on Sheet 13. The ductwork would be below the second floor ceiling and of either streamline construction or standard construction furred in as desired. The location of the air conditioning monitor board is shown adjacent to the present fire control board.

Sheet 12. Air distribution on the first floor would again be by a duct below the ceiling, either streamline or furred in as required.

Congress Hall

The atmospheric control of Congress Hall has been covered in a previous report. Sheets 14 and 15 are included

here for convenience.

Since the restoration of Congress Hall is now in progress, it would appear desirable to install the air conditioning plant at this time. We believe that as other buildings are conditioned it will be desirable to have a central refrigeration plant. The investment for refrigeration in Congress Hall at this time would be approximately \$19,000.00. Since it would be of the unitary water chiller type it should have reuse or resale value.

REFRIGERATION CYCLE

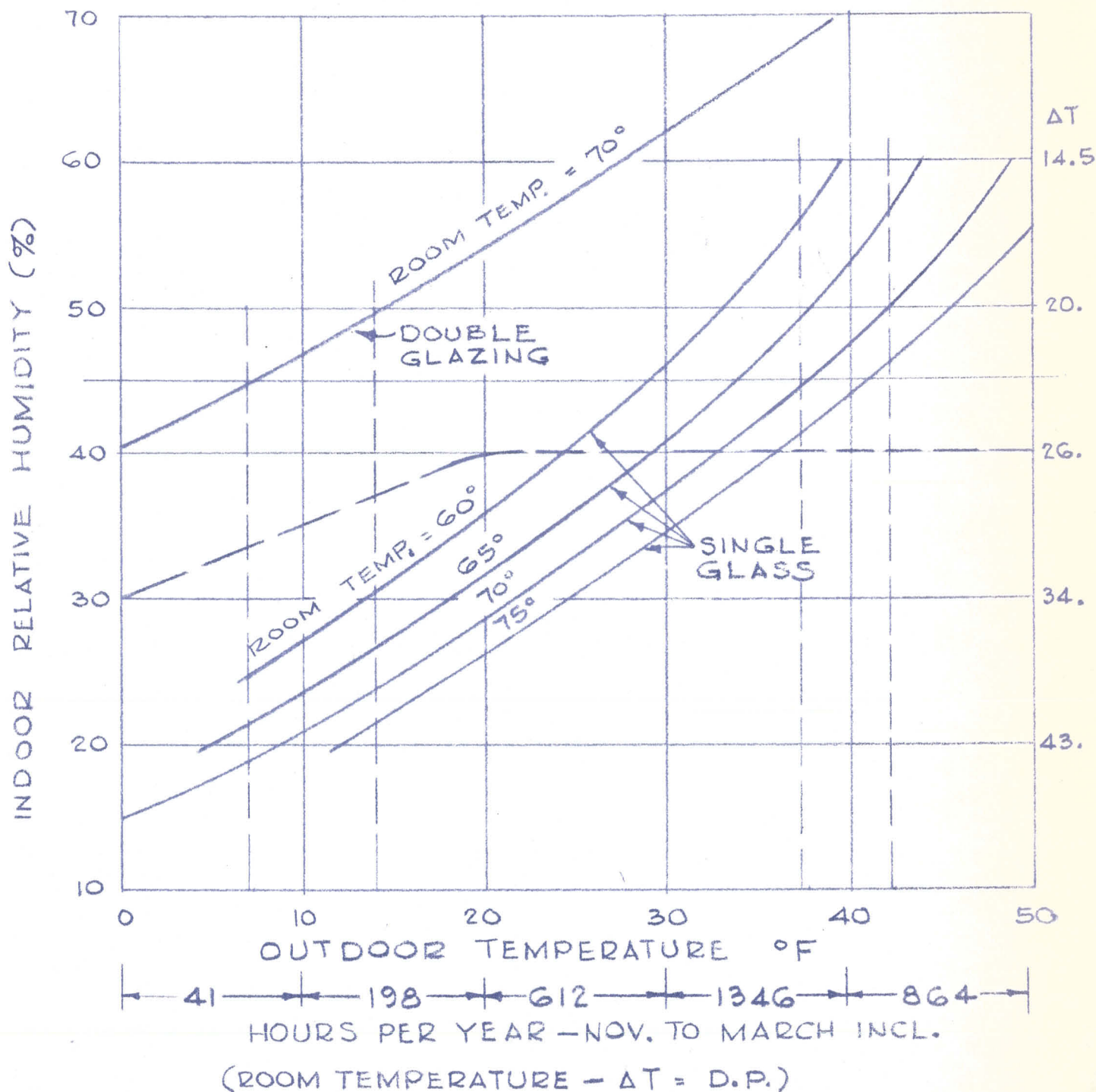
The refrigeration requirements are:

Old City Hall		30 tons
East Wing	10	
Independence Hall	50	
West Wing	10	70 tons
Congress Hall		<u>40 tons</u>
Total		140 tons

In the interest of simplicity in operation, the systems have been planned for constant outdoor air, thereby eliminating relatively complicated outdoor air controls. This type of operation does require more use of the refrigeration in the spring and fall than would be required if the admission of outdoor air were made variable.

We have investigated the possibility of using City water to reject the heat from the condensers of the refrigerating units in preference to the use of a cooling tower or evaporative condensers. This would greatly simplify the operation of the refrigerating cycle and eliminate the need, spring and fall, for guarding against freezing on sudden changes in temperature.

RELATION OF OUTDOOR TEMPERATURE TO
INDOOR RELATIVE HUMIDITY TO PRODUCE
CONDENSATION ON WINDOWS



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PHILADELPHIA, 7, PA.
MAY 11, 1960

FIGURE 1

It would further eliminate all of the maintenance and chemical treatment required by cooling towers or evaporative condensers.

For commercial customers the City does not permit this type of operation but will consider providing this service for the Independence Hall Group when requested. The first problem is whether an adequate water supply is available and this study they will make without charge, upon request from the National Park Service. The second question is the rate they would charge but even were this rate the same as for private consumers, we would recommend city water in preference to a cooling tower or evaporative condenser for this project.

If the water supply is not ample, we would suggest providing a central cooling tower for use from May 15th to October 1st, using city water at such other times in the spring and fall when cooling is required.

It is not feasible to install either a cooling tower or an evaporative condenser in any of the five buildings so, if city water is not used, it would be necessary to locate the cooling tower (not an evaporative condenser) somewhere on the grounds.

On Sheet 1 we have indicated an underground vault adjacent to Sixth Street to house a cooling tower of the air washer type and a centrifugal refrigerating machine, if it is elected to have central refrigeration. We also recommend a walk-thru tunnel connecting to the basement of Independence Hall. The vault and equipment are shown on Sheet 16.

The air washer type cooling tower would take in air

from a horizontal grille at approximately grade level and discharge it thru a vertical stack approximately 12 ft. high. We have selected the Sixth Street Side, toward Walnut Street, as being the least conspicuous place for the moist warm air discharge.

If city water is available for condensing and central refrigeration is used, a refrigeration vault could be located adjacent to Independence Hall, as indicated. There is a present entrance opening into the basement of Independence Hall.

In summary, the possible methods of supplying the refrigeration effect are:

- A. Reciprocating compressors in three locations, city water condensing.
- B. Reciprocating compressors in three locations, with a cooling tower below grade located towards Sixth Street and serving all buildings.
- C. A central refrigeration plant to serve all buildings, located in a vault adjacent to Independence Hall, with city water condensing.
- D. A central refrigerating plant to serve all buildings located in the same vault as the central cooling tower on the Sixth Street side.

For minimum attention and maintenance, we would recommend the centrifugal plant with city water, if available, or with a cooling tower should city water not be available.

ELECTRICAL SERVICE

At present there are independent electrical services to Old City Hall, the East Wing which also serves Independence Hall, and to Congress Hall which also serves the West Wing.

Philadelphia Electric would prefer a single service for all usage in all buildings but the potential saving in

operating cost does not appear to justify the cost of making this change. The problem is somewhat complicated by the need to maintain the dual source of supply for the existing fire pumps.

In our cost estimates we have assumed for Methods A and B that we would increase the service in the East Wing to supply the added capacity and for Methods C and D we would increase the service in Congress Hall.

CONTROLS AND SUPERVISION

Twenty-four hour fan operation is probably justified thruout the year. It is essential in winter because of the relatively rapid heat loss thru the large windows. When maintaining 45% or 50% R.H. a rapid drop in temperature within the structure would cause a large increase in relative humidity.

We recommend that the operation of the system be monitored from a board located adjacent to the fire control center on the second floor of the west wing.

In cold winter weather it will, at times, be not feasible to maintain the same relative humidity as maintained in summer if excessive condensation on the windows is to be avoided. An automatic control is contemplated to adjust the relative humidity by changing the apparatus dewpoint in accordance with the outside temperature (See Fig. 1).

The recommended maintained dry bulb temperature in summer will be approximately 76° and in winter approximately 70°. There will be transition periods in the spring and fall when the dry bulb and apparatus dewpoint will require resetting.

The day to day operation of the controls may be fully automatic with the exception that the amount of outdoor air introduced may be reduced at night to effect an economy in steam.

COST ESTIMATES

First costs are shown on Exhibit I.

Operating costs are shown on Exhibit II.

Estimates of first cost include the cost of mechanical and electrical installations, the cost of construction external to the building if required. They do not include the cost of cutting and patching within the buildings, nor do they include engineering fees.

Labor is not included under the heading, "Other Operating Costs". "Outside Service" includes the items listed as "Other Operating Costs".

With outside service on a 24-hour basis, we believe that a force of one engineer having knowledge in this type of installation will be sufficient in the daytime, with someone always on duty in the guard room at night.

APPENDIX I

PRESERVATION OF MEMORABILIA

The data on the factors which have a deleterious effect on organic materials have been well investigated for extreme conditions as represented by accelerated tests, high temperatures, high humidities and extreme low humidities but they are less conclusive as to the optimum for minimum deterioration. For example, the Bureau of Standards, in their document on the preservation of the Constitution¹ (parchment) state that "...if the relative humidity is maintained at 65%, and less than 1% of sulfuric acid is present (in the air), little deterioration occurs in 24 months of aging. At 85% R.H. considerable deterioration, as measured by loss in tensile strength, is apparent." They further state that "All strongly water-absorbing groups appear to be saturated at a relative humidity of about 25%. Under these conditions, collagen or other forms of hide will combine with about 10% of moisture which is considered to be sufficient to assure stability."

For the preservation of the Declaration and the Constitution, they have recommended 25% to 35% R.H. at room temperature. These documents are preserved under glass in an atmosphere of helium.

Plenderleith² states: "...A test applied to a representative sample of parchment showed that it contained 10% of its weight of water when in equilibrium with an atmosphere at 40% R.H.; when ... suddenly raised to 80% R.H. the parchment adsorbed moisture until, in the course of three days, it attained equilibrium with its new surroundings and the water content was then found to amount to no less than 30% of its dry weight. ... If parchment is exposed to over-dry or moist conditions for a short period no harm will result, but if extreme conditions persist for a time, then deterioration will follow. When kept in an atmosphere that is too dry, say at 40% R.H. or less, parchment tends to become rigid ... flexibility can always be restored by exposing the membrane to moisture, but, meantime, damage may have been caused to inks and colours through desiccation.... On the other hand, the damage resulting from exposure to high humidity is even more severe ... Although so sensitive to moisture changes, parchment retains its strength and resiliency and is very durable, provided it is not exposed to extreme conditions for long periods.

The Bureau of Standards considers 25% to 35% optimum; Plenderleith considers 40% to be dry.

There is agreement as to the deleterious effects of acid gases, such as sulphur dioxide, on book and writing papers^{3,4,5,6}.

There is agreement as to the deleterious effects of sunlight which, when sufficiently important, can be substantially eliminated by using filters which will adsorb ultra violet, violet, and a portion of the blue.

For stretched canvas, as for oil paintings, there is agreement as to the need for a constant relative humidity.

Plenderleith states that pictures from the National Gallery were placed in a repository where the air was conditioned at 58% R.H. and 63°; deterioration of the pictures was almost eliminated and returned when the pictures were brought back to London. Also, for the pictures from the British Museum and the Victoria and Albert Museum collections (antiquities, books, textiles, prints, drawings, manuscripts, furniture, etc.) the air was controlled at the constant figures 60% R.H. at 60°F., and not a single case of deterioration was recorded in this repository.

He further states: "While for the majority of collections such strict atmospheric control as 60% R.H. at 60°F. is not essential, there is everything to be gained by fixing an upper and lower limit of relative humidity and temperature and ensuring as far as possible that conditions are maintained within these predetermined limits..." He further states that 70% is a danger point for material which is subject to staining by damp and mould, and "...Taking into consideration the susceptibility of all organic materials to damage by desiccation, the lower safety limit should be fixed at 50% R.H. If, on taking observations, the figure is observed to fall, say, to 45%, no great harm would be likely to result, but if such a figure PERSISTED over a period, this might well be dangerous..." Mr. Plenderleith does not quote his authorities for the danger of low humidity.

The English preference for higher humidities than American practice may have some basis in the fact that the English climate is generally cooler and more moist than the climate in the States and, since the tests are at the extremes rather than the optimum, the selection of an optimum must, in part, be based on judgment.

In 1934 we added some dehumidification to an existing humidification system at the Barnes Museum. The owner specifically requested that we not provide summer cooling. From 1934 until 1951 this system operated at a relative humidity of 45% year round, with an inside temperature of 70° in winter and in summer with varying temperatures up into the middle 80's. Shortly after 1951 we were informed that some cooling was added. During the entire twenty-six years it has been unnecessary to restretch any of the canvases, other than when first received, and there has been no apparent deterioration.

The Barnes Museum also houses antique furniture, some tapestries, and paintings on wood and glass as well as canvas - both modern and antique.

In addition to the environmental factors that we can control, there will remain the intangible of the original method of manufacture of the materials to be stored.

For Consideration

Paper.

Wood as furniture.

Wood as paneling.

Leather and parchment.

Silk and cotton fabrics, and wool.

Stretched canvas, as for paintings.

Metals.

Paper

Deleterious Effects:

- a. Acid atmospheric gases such as sulphur dioxide.^{3.4.}
- b. Sunlight^{5.6.}
- c. Extreme dryness^{1.5.}
- d. Moisture levels which accelerate the growth of mold^{1.6.}

Protection for

- a. Remove the acid gases either by solid sorbents or by passing the air thru an alkaline spray.
- b. The use of special filters which substantially eliminates ultra violet and near ultra violet for exhibits stored in places where they can be reached by sunlight.
- c. Previously discussed.
- d. At ordinary room temperatures the relative humidity should not exceed 60% as the danger of mould increases rapidly above this point.

Wood as Furniture

There should be no problem in the preservation of wood furniture provided extreme dryness and extreme moisture are avoided. Checking of seasoned wood is usually in evidence in extremely low humidities.

Any condition satisfactory for paper should be ample for the preservation of wood furniture.

Wood as Paneling

This problem differs from furniture in that the wood may be exposed on one side to a cold wall and on the other side to a warm room. Homogeneous wood paneling will possibly show some dimensional change between summer and winter even tho the room side is maintained at the same temperature and humidity. This dimensional change will be noted in the cross-grain direction rather than with the grain and it is well to consider providing for a slight movement in installing the paneling.

This dimensional change could be further minimized by installing insulation and a vapor barrier in back of the panel but our experience on other projects has indicated that this expense is probably not justified. Paneling on interior partitions presents no more problem than that of preserving furniture.

Leather and Parchment

Previously discussed.

Silk and Cotton Fabrics, and Wool

Silk, cotton and wool are subject to the same deteriorating effects as paper and the atmosphere to protect paper will also be satisfactory for these fabrics. With wool there is the further problem of protection against insects.

Stretched Canvas as for Paintings

Previously discussed.

Metals

The conditions necessary for the preservation of the other materials are also adequate for metals provided they are not handled.

Recommendations

Altho the proposed design will permit operation at anywhere from 45% to 55% R.H., we recommend a temperature of 75-76° with a relative humidity of 45% in summer. For winter operation the compromise for the desirable temperature for visitors, with coats, and the permanent personnel is approximately 70° dry bulb. The relative humidity would be maintained at 45% and an automatic control provided to lower the relative humidity to a point which would just prevent excessive condensation on the windows.

These recommendations are to a considerable degree supported by the Davis Chemical Corp. comprehensive report of 1948, "Long Term Storage of Ordnance Materiel", which ends with the conclusion that for mothballing all types of army ordnance, which does include leather, wood, paper, canvas, and metals, the proper relative humidity to maintain is between 35% and 50%. The recommendations are also consistent with the paper, "Dehumidification Protects Materials from Deterioration" by Commander George C. Wells, USN, who reached substantially the same conclusion by separate test. The principal concern of this paper is the deteriorative effects of relative humidity over 60%.⁷

The Bureau of Standards⁵ recommends a temperature range of 65° to 75° and a humidity range of 45% to 55%.

The substantial removal of dust is essential. There are two types of dust, one the relatively coarse particles which can be captured on an ordinary filter, and the other the extremely fine particles which comprise a smoke cloud. To capture these latter particles would require either an electrostatic filter or a diffusion filter. We recommend the diffusion type filter which has no moving parts and does not require the use of electronics for its operation.

There is some difference of opinion as to whether the amount of ozone generated by an electrostatic filter in normal operation would be deleterious.

The removal of dust is important not only from the standpoint of soilage but as forming a condensation nucleus for acid gases.

Even with good filters there will be dust carried in by visitors. If the fine particles which form a greasy deposit are eliminated, the dry dust can be readily removed.

REFERENCES

- (1) "Preservation of the Declaration of Independence and the Constitution of the United States", National Bureau of Standards Circular 505.
- (2) "Conservation of Antiquities and Works of Art", H. J. Plenderleith 1956.
- (3) "Deteriorative Effect of Sulphur Dioxide upon Paper in an Atmosphere of Constant Humidity and Temperature", Arthur E. Kimberly; Bureau of Standards Research Paper No. 407.
- (4) "A Study of the Removal of Sulphur Dioxide from Library Air", Arthur E. Kimberly and Adelaide L. Emley; Bureau of Standards Miscellaneous Publication No. 142.
- (5) "A Survey of Storage Conditions in Libraries Relative to the Preservation of Records", Arthur E. Kimberly and J.F.G. Hicks, Jr.; Bureau of Standards Miscellaneous Publication No. 128.
- (6) "Report of Bureau of Standards Research on Preservation of Records", The Library Quarterly Vol. I, No. 4, October 1931.
- (7) "Long Term Storage of Ordnance Materiel, Comprehensive Report 1948" by The Davison Chemical Corporation, Engineering Division, Baltimore, Md.

EXHIBIT I

FIRST COST

METHOD A - Separate Refrigeration Each Building;
City Water Condensing.

Mechanical

Old City Hall	\$55,000		
East Wing	18,300		
Independence Hall	60,500*	68,100**	64,500***
West Wing	17,200		
Congress Hall	63,100		
Separate Refrigeration	52,600		
City Water Piping	15,000		
	<u>\$281,700</u>		

Electrical 15,300

Total \$296,000

METHOD B - Separate Refrigeration Each Building;
Central Cooling Tower.

Mechanical

Old City Hall	\$55,000		
East Wing	18,300		
Independence Hall	60,500*	68,100**	64,500***
West Wing	17,200		
Congress Hall	63,100		
Cooling Tower	28,400		
Separate Refrigeration	69,600		
	<u>\$312,100</u>		

Construction C.T. Vault 22,000
\$334,100

Electrical 17,000

Total \$351,100

* Air distribution in Independence Hall by grilles over each of the doors of the closets, east and west ends, as shown on Section AA, Drawing 9.

** Air distribution in Independence Hall thru slots above cornice in the wood mold, as shown on Section AA, Drawing 10.

***Air distribution in Independence Hall thru floor grilles, as shown on Section BB, Drawing 9.

EXHIBIT 1 - FIRST COST

(CONTINUED)

METHOD C - Central Refrigeration; City Water Condensing.

Mechanical

Old City Hall	\$55,000		
East Wing	18,300		
Independence Hall	60,500*	68,100**	64,500***
West Wing	17,200		
Congress Hall	63,100		
Central Refrigeration	47,000		
City Water Piping	10,000		
	<u>\$271,100</u>		

<u>Construction Refr. Vault</u>	<u>14,000</u>
	<u>\$285,100</u>

<u>Electrical</u>	<u>17,800</u>
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Total	\$302,900
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METHOD D - Central Refrigeration; Central Cooling Tower.

Mechanical

Old City Hall	\$55,00		
East Wing	18,300		
Independence Hall	60,500*	68,100**	64,500***
West Wing	17,200		
Congress Hall	63,100		
Central Refrigeration	56,500		
Cooling Tower	28,400		
	<u>\$297,000</u>		

<u>Construction Refr. Vault</u>	<u>27,200</u>
	<u>\$324,200</u>

<u>Electrical</u>	<u>19,500</u>
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Total	\$343,700
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* Air distribution in Independence Hall by grilles over each of the doors of the closets, east and west ends, as shown on Section AA, Drawing 9.

** Air distribution in Independence Hall thru slots above cornice in the wood mold, as shown on Section AA, Drawing 10.

***Air distribution in Independence Hall thru floor grilles, as shown on Section BB, Drawing 9.

EXHIBIT II

OPERATING COSTS

	<u>METHOD A</u>	<u>METHOD B</u>	<u>METHOD C</u>	<u>METHOD D</u>
<u>UTILITY COSTS</u>				
Power	\$15,100	\$21,700	\$15,850	\$21,900
Water	6,084	--	6,084	--
Phila. Elec. Co. Steam	9,800	9,800	9,800	9,800
Water Treatment	--	500	--	500
	<u>\$30,984</u>	<u>\$32,000</u>	<u>\$31,734</u>	<u>\$32,200</u>
<u>OTHER OPERATING COSTS*</u>				
Filter media	\$ 1,930	\$ 1,930	\$ 1,930	\$ 1,930
Reactivation of Charcoal	620	620	620	620
Refrigerant and Oil	700	300	700	300
Miscellaneous supplies	600	600	600	600
	<u>\$ 3,850</u>	<u>\$ 3,450</u>	<u>\$ 3,850</u>	<u>\$ 3,450</u>
<u>OUTSIDE SERVICE</u>				
Annual cost	\$ 7,800	\$ 7,800	\$ 5,500	\$ 5,500

*Labor not included.