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Preservation of the Declaration of Independence and the Constitution of the United States

UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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UNITED STATES DEPARTMENT OF COMMERCE • Charles Sawyer, *Secretary*
NATIONAL BUREAU OF STANDARDS • E. U. Condon, *Director*

Preservation of the Declaration of Independence and the Constitution of the United States

A Report by the National Bureau of Standards
to the Library of Congress

National Bureau of Standards Circular 505

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I. Introduction

At the request of the Librarian of Congress, an investigation was undertaken by the National Bureau of Standards to determine the best means of preserving the original copies of the Declaration of Independence and the Constitution of the United States. An important proviso in this assignment was that these revered historical documents should continue to be on display to the American people in the Shrine at the Library of Congress.

After a survey of the conditions under which the documents are now on display and consideration of the various factors which might lead to deterioration of the parchments, the following recommendation was submitted on March 16, 1940, by the National Bureau of Standards to the Library of Congress:

"It is recommended that both Documents be enclosed within sealed receptacles, and that the air within these receptacles be replaced with a chemically inert gas, such as nitrogen, helium, or argon, the gas to contain approximately 4 grains of moisture per cubic foot. By thus sealing the receptacles, the absolute humidity would be kept constant and low enough to avoid all possibility of excessively high relative humidities for the temperature range encountered. This would eliminate the danger of having excessive moisture in the Documents at any time. Storing the Documents in an inert gas will remove the possibility of deterioration from oxidation, or from acid hydrolysis resulting from absorption of sulphur dioxide from the atmosphere."

Further work on this project was postponed because of World War II. When our efforts were renewed in 1945, consideration was given to three aspects of the problem:

1. Preservation of the documents in an inert atmosphere.
2. Filter to protect against harmful radiation.
3. Lighting conditions to improve the viewing of the documents.

This report summarizes the investigations of the National Bureau of Standards on the first two subjects of the project; the third subject will be discussed in a separate report upon completion of investigations still in progress.

While the present report is specifically concerned with the preservation of the Declaration of Independence and the Constitution of the United States, the findings are pertinent to the general problem of preservation of documents. The care and custody of precious documents has always been a perplexing problem; the present study indicates how this problem can be solved in a practical way.

II. Preservation of the Documents

Provided that reasonable care is taken, documents made of animal parchment or pure cellulose will suffer practically negligible deterioration, as a result of atmospheric contamination, over a period of many years. Reasonable care means protection of the documents against any obvious forms of contamination such as dirt or corrosive substances, chemically active gases such as sulfur dioxide, excessive or deficient moisture, and insects and microorganisms.

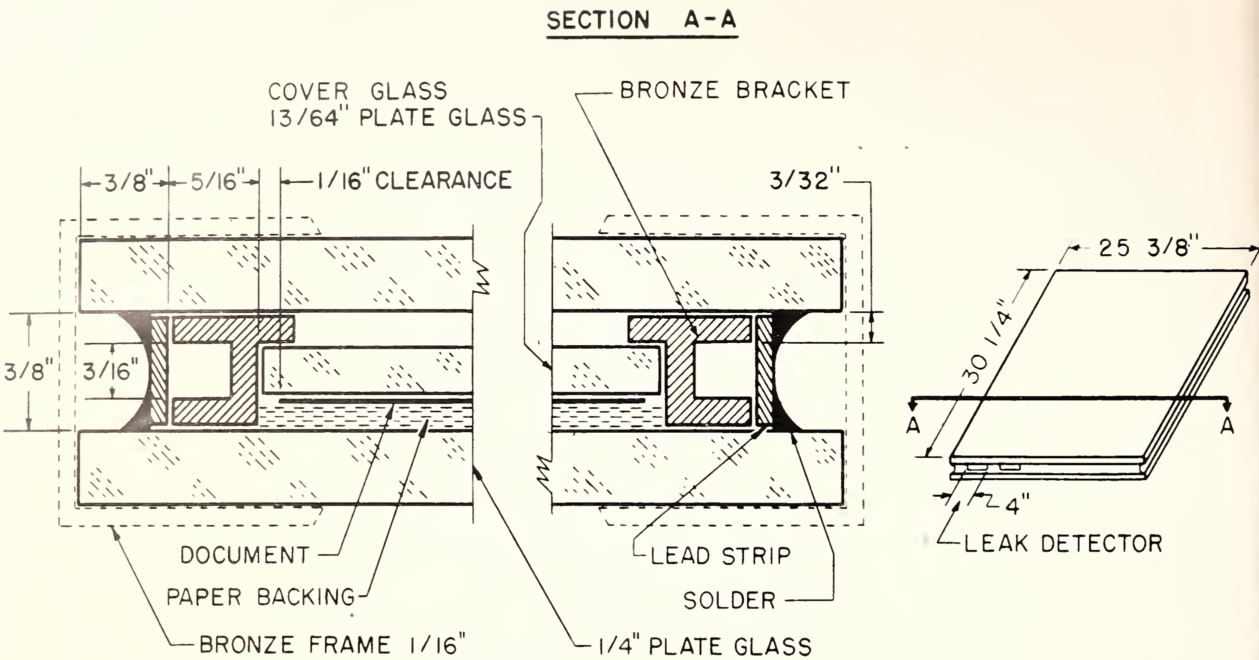


Figure 1.—Section sketch of the glass enclosure recommended for the preservation of the Declaration of Independence and the Constitution of the United States. The backing paper and cover glass position the document, the bronze bracket separates the glass plates from the assembly, and the lead strip soldered to the glass plate completely seals the document from the outside atmosphere. The size shown is for the Constitution.

If, however, the nature of the documents is such that their preservation for an indefinite number of centuries is vital, then even harmful effects that appear only slowly or to a slight extent become important. The Declaration of Independence and the Constitution of the United States are precious and irreplaceable documents of this type. Except for a short period during the Revolutionary War, when exigencies of warfare interfered, adequate measures of care were taken in keeping with the scientific knowledge of the times. This care accounts for the present excellent condition of the documents.[1]

The principal considerations in the analysis by the National Bureau of Standards of the problem of preservation of the Declaration of Independence and the Constitution of the United States were the following:

First, the selection of a suitable inert gas is necessary because the atmosphere contains components which are destructive—in particular, oxygen.

Second, the presence of either too much or too little moisture contributes to deterioration. It is necessary to determine and establish an atmosphere surrounding the documents that has just the right amount of moisture.

Third, a suitable enclosure is required, in part to retain the protective gas mixture chosen and in part to afford an enclosure that is satisfactory for viewing the documents.

Fourth, because it is difficult to ensure the airtight nature of any enclosure, particularly over extended periods of time, a method of detecting and measuring gas leakage is required.

Fifth, it is necessary to provide a backing substance for the documents that will afford cushioning and that will compensate for any moisture absorption or desorption by the documents as a result of temperature changes during the various seasons of the year.

Sixth, it is necessary to determine the harmful effects of light radiation on the documents and to determine the properties of a suitable filter that will eliminate practically all such damaging radiation.

[1] For an excellent account of the travels of the Constitution, see *The Constitution of the United States together with an account of its travels since September 17, 1787,* by David C. Mearns and Vernon W. Clapp, The Library of Congress, Washington, 1948 (printed by the Government Printing Office and available from the Superintendent of Documents, Washington 25, D. C., 15 cents a copy). See also, "A Few Notes, &c. upon the Declaration of Independence," published by the Library of Congress, Washington, D. C., 1948.

Figure 2.—In the first step of the test sealing of the Declaration of Independence facsimile, backing paper of pure cellulose, made at the National Bureau of Standards, is centered on the bottom panel of tempered glass. This paper serves as a protective cushion for the document and as a reservoir of moisture to prevent excessive changes in relative humidity inside the enclosure. Left to right: Dr. Roy W. Wampler, assistant director of Research, Libbey-Owens-Ford; Mr. Alvin W. Kremer, keeper of the collections, Library of Congress; Dr. G. M. Kline, Chief of Plastics Section, National Bureau of Standards.

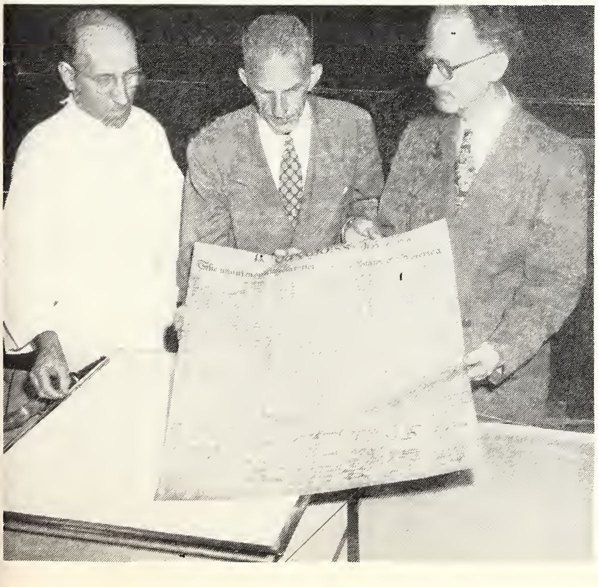


Figure 3.—After the special backing paper has been positioned in the enclosure frame, the facsimile document is placed on top of the paper.

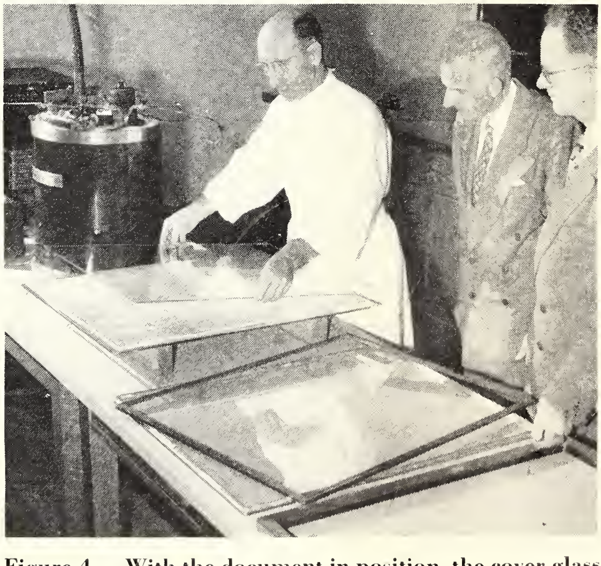


Figure 4.—With the document in position, the cover glass is placed over it to keep it from wrinkling. On the table, ready for succeeding steps in the test sealing are the bronze bracket and front glass plate (center), and the bronze outer frame (extreme right).

Figure 5.—Before placing the bronze bracket, two leak detector cells are sealed in slots cut in the bracket. These cells detect any change in the composition of the gas within the enclosure. Wires leading to the cells pass through a Kovar tube in which they are fixed by a glass bead. Mr. Louis Gilles of Libbey-Owens-Ford is sealing the Kovar tube in a hole in the lead strip, which is attached to the glass panels of the enclosure.

Figure 6.—The bronze bracket around the edge of the cover glass holds the assembly of backing paper, document, and cover glass in position in the enclosure. The bracket also serves to keep the document away from the area heated by soldering during the final sealing operation. Left to right: Mr. A. W. Kremer, Dr. R. W. Wampler, and Dr. G. M. Kline.

III. The Inert Gas

The presence of oxygen in the atmosphere, as well as the possible presence of other harmful gases, indicates that an inert gas should surround the documents at all times. Theoretically, a perfect vacuum would appear to be ideal, but even a partial vacuum is difficult to maintain for any protracted period of time. A vacuum would also create a mechanical problem, for the enclosure and the bond would be subject to considerable stress.

An inert gas is satisfactory for the preservation of the documents primarily because such a gas is not chemically active and does not enter into a chemical reaction with the material of the documents, as would oxygen. Moreover, an inert gas does not support organic life and thus protects the documents against the presence of those living organisms that require air. Of the inert gases available, the National Bureau of Standards has selected helium. Helium is available from the United States Bureau of Mines in a very pure state, free of oxygen and having impurities of less than 0.01 percent. It has a relatively high thermal conductivity compared to air, which makes it easy to detect the leakage of air into the enclosure. The equipment for detecting such leakage is described later in this report and further data on the inert gas problem are presented in appendix 1.

IV. The Moisture Problem

The presence of large amounts of moisture leads to deterioration of documents in two ways: There is a loss in strength of the parchment material and there is the danger of attack of the material by micro-organisms that do not require air but which do require high-moisture environments. On the other hand, too little moisture leads to brittleness and cracking and eventually to a breaking up of the parchment.

Research at the National Bureau of Standards indicates that the appropriate relative humidity of the helium should be between 25 and 35 percent at room temperature. This relative humidity is found to be best for the long-range durability of protein material, which is the basic component of the parchment of the documents. Studies by the Bureau revealed that a relative humidity greater than 85 percent leads to deterioration of the parchment. A relative humidity less than 25 percent dehydrates the protein molecules of the parchment, and this condition leads to brittleness and cracking. Further data on the moisture problem will be found in appendix 1.

V. The Enclosure

The requirements for the enclosure are essentially fourfold: It must be airtight, it must be transparent, it must be made of chemically inert components, and it must not be fragile. The requirements for transparency and chemical stability are of such importance that the National Bureau of Standards decided that a glass enclosure should be used.

The danger of damage to the documents as a result of breakage of the glass enclosure is minimized by three factors. First, the special care that must be accorded the documents, no matter what the nature of the enclosure may be, affords a very large measure of protection. Second, an especially tough glass, prepared by a tempering process, has been selected for use in the construction of the enclosure. Third, the presence of special backing paper, produced by the National Bureau of Standards, and of the cover plate will also minimize the chance of injury to the documents in the event of breakage of the enclosures.

The considerations determined the Bureau's choice in selection of the type of the glass enclosure: (1) The need for glass plates that would be as uniformly transparent as possible and, (2) an enclosure whose components could be assembled and sealed, providing an airtight structure, without involving sealing operations that might damage the documents. Here the principal consideration was the effect of heat on the documents. Any process that involves the sealing of materials within an airtight enclosure requires the use of heat at some stage in the sealing operation. It was necessary to select that process which required a minimum of heat and which precluded the transference of a possibly harmful amount of heat to the documents.

On the basis of the analysis of these requirements, the National Bureau of Standards determined that double-glazed panels made commercially as insulating windows would be suitable for the purpose. In August 1947 the Libbey-Owens-Ford Glass Co. agreed to cooperate on the project by preparing thermopane enclosures for the documents.

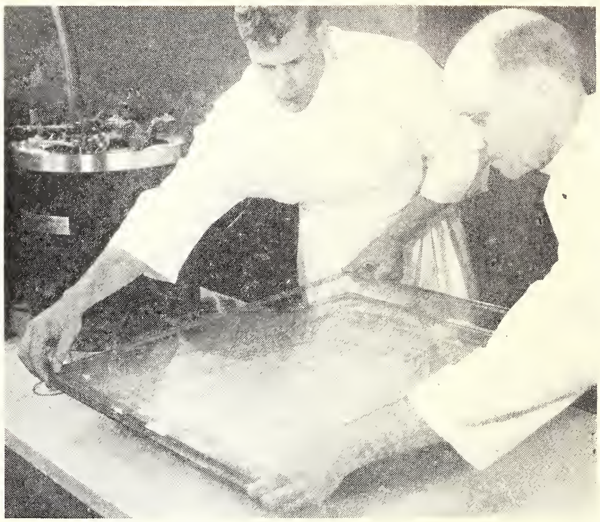


Figure 7.—The top glass panel is fitted over the bronze bracket to complete the assembly of the test enclosure and its contents. Once in place, the enclosure is ready for the soldering operation. Left, Mr. Louis Gilles; right, Dr. R. W. Wampler.

A trial sealing of a facsimile of the Declaration of Independence in such a glass enclosure was conducted at the National Bureau of Standards in June 1950. This test was intended to provide information on the detailed steps in the sealing process and on the performance of the equipment, needed in planning the sealing operations for the original copies of the Declaration of Independence and the Constitution of the United States. Following this trial sealing, the National Bureau of Standards conducted tests on the airtightness of the enclosure. The test results indicate that the enclosure is satisfactory. Appendix 2 discusses in more detail the enclosure problem.

VI. The Leak Detector

The realization of an enclosure which is airtight is a formidable problem, particularly if the periods of time are of indefinite duration. The objectives of the National Bureau of Standards were to provide for a method of protecting the documents for many centuries with negligible hazards and to devise, at the same time, a simple system that would reveal any change in the atmosphere in the enclosure.

The difficulty in retaining the properly humidified helium intact within the enclosure and in excluding atmospheric gases is twofold. Any han-

Figure 8.—Following the assembly of all enclosure elements, the lead strip is soldered to the glass plates in one of the most critical steps of the sealing operation. In the foreground are shown the soldering accessories used in bonding the lead strip to glass.

dling of the enclosures or changes in temperature may produce stresses and strains in the bonding components between the two glass plates of the enclosure. There is some chance that such stressing might produce minute openings in the bond. Moreover, matter, in spite of its apparent imperviousness to change, is dynamic in nature by virtue of its atomic structure. Thus in the course of time, there are possible changes in the constitution of the bond—particularly those changes resulting from the seasonal temperature variations of the atmosphere surrounding the enclosure—which can lead to minute (microscopic and submicroscopic) openings.

If the presence of such openings is known, it is a relatively simple matter to find and reseal the openings long before any harmful change in the helium content of the enclosure occurs. The problem is to provide a suitable detector.

After consideration of several methods of accomplishing this objective, the National Bureau of Standards selected a thermal-conductivity type of gas analyzer as the leak detector. This detector is based upon the fact that each gas has a unique quality in its ability to transfer heat. Any change in the composition of the gas can be observed by measuring the change in its thermal conductivity.

The equipment developed by the National Bureau of Standards has two important advantages. First, it is small enough so that the detector can be built permanently into the enclosure. Second, it is simple enough so that observations can be made either continuously or as frequently as desired without moving theenclosure from the shrine.

The leak detector consists of measuring cells which are sealed within the enclosure and of certain components comprising the external leak detector instrument. The basis of the detection is the change in resistance with temperature of the thin platinum wire in each of the measuring cells. Thus, if electric current is passed through such a wire when it is surrounded by gas having a low thermal conductivity, the heat generated in the wire by the current cannot readily escape by transfer to that gas. This leads to a rise in the temperature of the wire and its resistance becomes higher. Thus, if the instrument is set to read zero in an atmosphere of pure helium, leakage of air, which has a lower thermal conductivity, into the helium atmosphere will be detected by the increase in the resistance of the platinum wire.

Investigations of thermal conductivity by the National Bureau of Standards provided the basis for the Bureau's development of the cells for the enclosures. For each enclosure, four cells are in-

Figure 9.—Tubes are sealed in holes drilled through the lead strip in diagonally opposite corners of the document enclosure to serve as inlet and outlet ports for helium. The ports permit the complete replacement of the air atmosphere around the document with specially humidified helium.

volved. Two of these are sealed within each enclosure. Two are located in the channel along the edge of the enclosure. By plugging the instrument into the leads of the four cells, a small current energizes the enclosure cells and the outside cells. The circuit of these four cells is so arranged that the instrument compares the resistance of the four cells—the two measuring cells with the two outside reference cells. This comparison indicates whether any change has occurred in the composition of the gas within the enclosure and the instrument reveals its determination on a visible meter. If a change has occurred, the presence of a leak is indicated. The features of the detector and its operation are more fully described in appendix 3.

VII. The Backing Paper

Several conditions which will exist at varying times within the enclosure call for the presence of backing paper for the documents. First, as the temperature changes with the seasons of the year, the relative humidity within the enclosure will change. To act as a compensing reservoir for moisture, particularly if the enclosures are subject to rapid temperature change, suitable backing paper is desirable.

In addition, no matter how stable are the conditions attained within the enclosure, there will be minute movements of the molecular aggregates of the parchment. To provide for such motion, a resilient, cushioning backing is necessary. Finally, some backing substance which affords protection to the documents in the event that the enclosure is seriously damaged is desirable.

These requirements for a backing, and the additional requirements of purity and chemical stability of any backing substance, led to the choice of a pure cellulose for the backing material. The proper composition of the cellulose, in terms of the above requirements, was determined by the National Bureau of Standards, and sheets of such cellulose were prepared in the Bureau's special paper mill. Appendix 4 presents additional details on this topic.

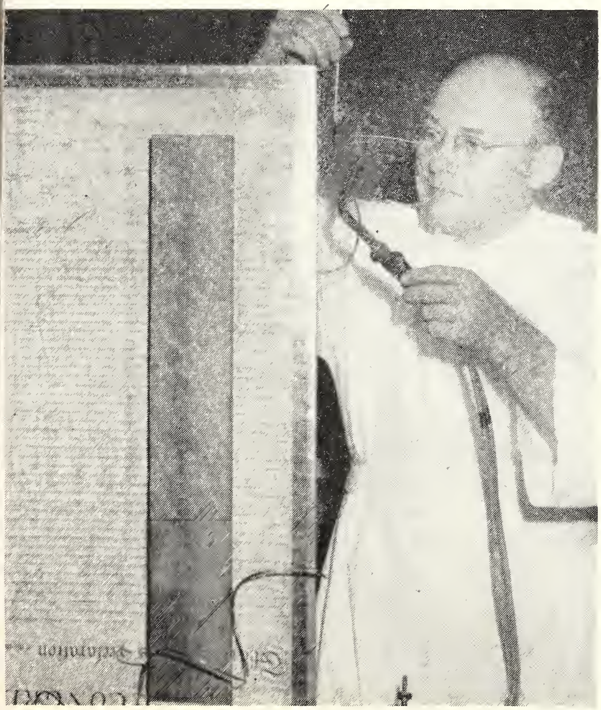


Figure 10.—Copper tubing leading from the source of pure helium is connected to the inlet tube of the test enclosure in order to flush completely all air from within the assemby. Mr. E. C. Creitz of the National Bureau of Standards is sealing the joint.

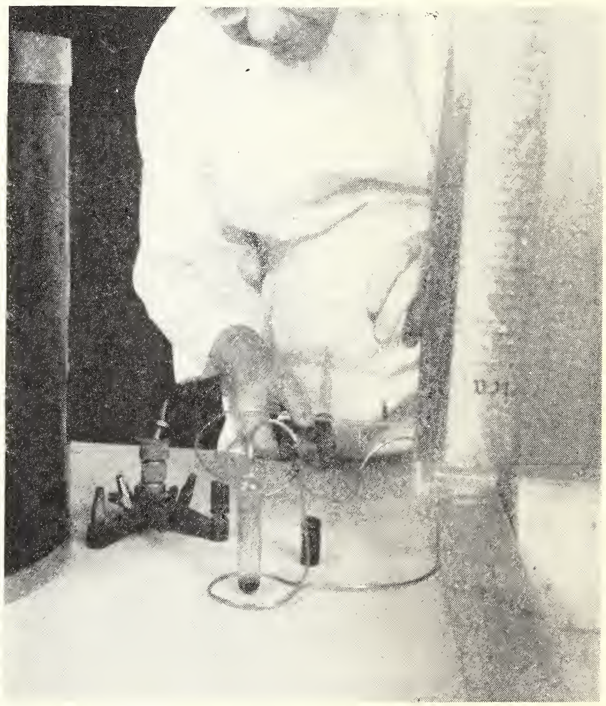


Figure 11.—The outlet tube of the enclosure is connected by copper tubing to a bubble counter and gas seal, consisting of a glass tube dipping just below the surface of a small quantity of oil. Humidified helium passes through the enclosure, over the document, and out through the liquid seal. The seal prevents air from backing up into the enclosure should the flow of helium be interrupted. Mr. E. C. Creitz is installing the liquid seal apparatus.

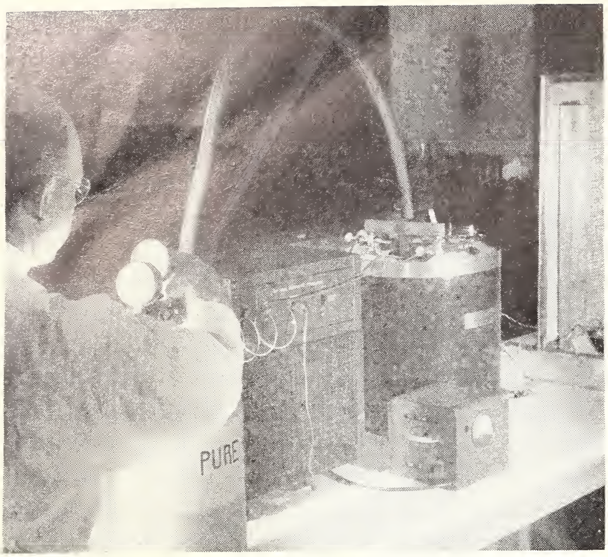


Figure 12.—Pure helium from a cylinder at high pressure is passed through a pressure-reduction gage into the humidifying unit, from which it is directed into the document enclosure. The gas is allowed to flow through the enclosure for several days to flush out the air and replace it with an inert atmosphere. Mr. E. C. Creitz is adjusting the helium flow preparatory to flushing the test enclosure.

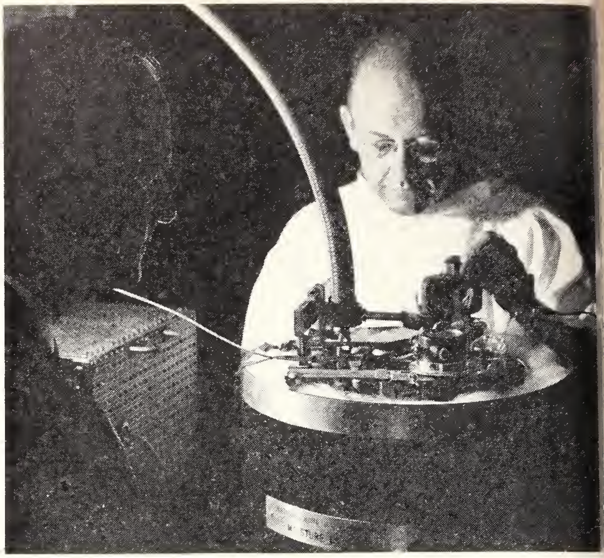


Figure 13.—The pure helium is humidified by adding sufficient water vapor to produce a relative humidity of 25 to 35 percent. The proper humidity is achieved by passing the helium through distilled water maintained at a temperature of 4° to 6° C. The insulated water bath in which the humidification tower is immersed, is thermostatically controlled at the desired temperature. Dr. G. M. Kline and Mr. E. C. Creitz are checking the temperature of the bath.

VIII. The Radiation Filter

One of the causes of deterioration of documents is light radiation, which induces chemical reactions in a variety of substances. The effect of light radiation depends, in general, upon the nature of the light radiation and the nature of the substance involved. Substances which will react to light of a particular kind may not react to light of another kind. Studies at the National Bureau of Standards revealed that damage to documents like the Declaration of Independence and the Constitution of the United States is caused largely by ultraviolet light and by visible blue and violet light.

Taking into account these studies, as well as the nature of the lighting at the shrine, which will be the subject of a later report, the National Bureau of Standards established the requirements for a suitable filter. This filter consists of a laminated glass, made with a plastic interlayer, which will be placed over the enclosure. The appropriate light-absorbing material, which will eliminate the harmful radiation while transmitting those radiations which will light the documents, is a yellow cellulose acetate sheet. Appendix E presents the details pertinent to this problem and the filter.

E. U. Condon,
Director.

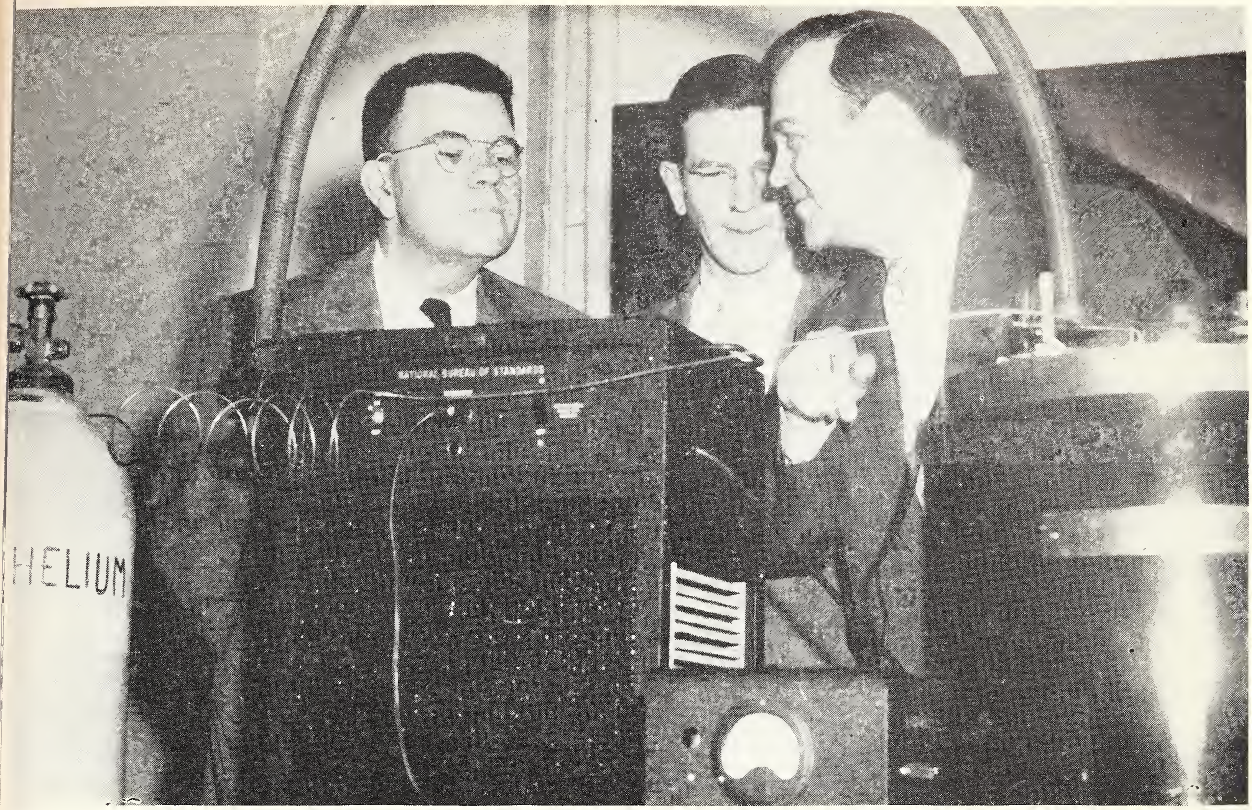


Figure 14.—The water bath (right) of the gas humidifying unit is cooled by a coil connected to a compressor unit by the arched hose shown in this photograph. The instrument in the center foreground is the ammeter of the leak detector. Inspecting the apparatus are Dr. E. U. Condon, Director of the National Bureau of Standards, Mr. H. M. Alexander, Director of the Development Department of the Libbey-Owens-Ford Glass Co., and Dr. L. H. Evans, Librarian of Congress.

IX. Appendices

1. The Atmosphere Problem

Documents which are on display or are stored in ordinary air are subject to various deteriorating factors. Thus, oxygen in the air is responsible for a slow oxidation of the organic base. Sulfur dioxide and other harmful gases which may be present in the atmosphere are absorbed by the documents and promote chemical reactions which degrade the base.

The absorption of moisture during periods of high relative humidity can result in excessive moisture content in the documents, which brings about damaging hydrolytic reactions. Warm, moist conditions are also conducive to the growth of fungi and bacteria. On the other hand, an excessively dry surrounding atmosphere leads to desorption of moisture from a document, leaving it in an embrittled condition.

In addition to these sources of contamination and deterioration, the depredations of insects, which depend on air for survival, are a serious and difficult problem in the preservation of documents.

These several factors are described and discussed in NBS Miscellaneous Publication 154.[1]

(a) Selection of Inert Gas

The above considerations emphasize the desirability of storing valuable documents in an inert atmosphere whenever possible. The National Bureau of Standards has chosen helium, an inert gas, for this purpose in the project on the preservation of the original copies of the Declaration of Independence and the Constitution of the United States.

Helium has been chosen because it is available with less than 0.01 percent of impurities from the United States Bureau of Mines plant in Amarillo, Tex. The chief constituent of this very small

[1] A. E. Kimberly and B. W. Scribner, Summary report of National Bureau of Standards Research on preservation of records (1937).

portion of impurities is nitrogen, itself an inert gas. Moreover, such helium is essentially free from oxygen. Helium also has a relatively high thermal conductivity compared to air, which makes it simple to detect the leakage of air into a helium atmosphere by equipment described in appendix 3.

The following thermal conductivity data indicate that helium is much superior in this latter respect to other inert gases which might otherwise be satisfactory:

Gas	Relative thermal conductivity at—	
	0° C.	100° C.
Air	1.00	1.00
Argon	.606	708
Helium	6.08	5.54
Nitrogen	1.004	.999

(b) Relative Humidity

It is necessary to add water vapor in controlled amounts to the helium in order to provide a relative humidity condition which will ensure the most satisfactory moisture content of the documents. The Declaration of Independence and the Constitution of the United States are inscribed on animal parchment. Animal skins, from which animal parchments and leathers are made, have as their essential constituent collagen, a protein compound.

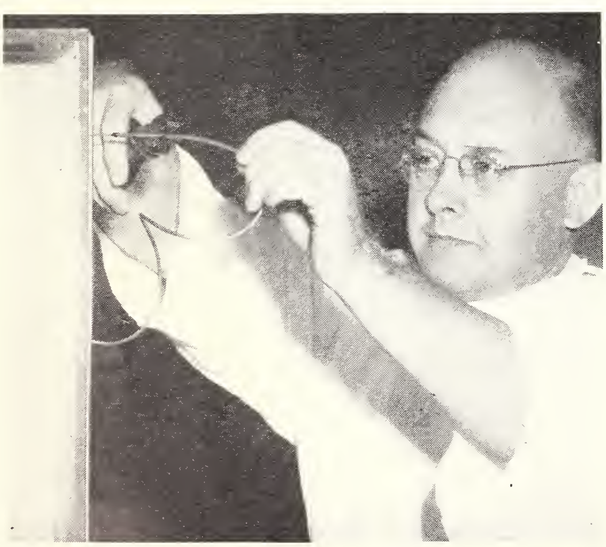


Figure 15.—The air in the document enclosure is flushed out with humidified helium for several days until a reading taken with the leak detector indicates that the air has been completely driven from the capsule and the unit is ready to be sealed. Then the copper inlet and outlet tubes are constricted and cut with pliers.

Extensive studies have been conducted by the National Bureau of Standards on the stability of collagen.

Results of a study on the effect of acid and humidity conditions on deterioration of leather at room temperature, indicate that if the relative humidity is maintained at 65 percent, and less than 1 percent of sulfuric acid is present, little deterioration occurs in 24 months of aging. At 85-percent relative humidity considerable deterioration, as measured by loss in tensile strength, is apparent. These data are contained in a report entitled, The Effect of Atmospheric Moisture on the Deterioration of Commercial and Quebracho Tanned Leathers Containing Sulfuric Acid.[2]

Results of a study on "Effect of Oxygen and Moisture on the Stability of Leather at Elevated Temperatures"[3] indicate that the rate of the deterioration of leather increases with temperature and is greater in the presence of oxygen and air than in the presence of helium. The amount of deterioration over a short period of time is too small to measure accurately at temperatures under 70° C. Results in this paper also show that at low relative humidities leathers are quite stable.

As to stability in the presence of micro-organisms, an unpublished report prepared in March 1947 gives data on the optimum relative humidities for mildew growth. No evidence of mildew growth was noticeable at relative humidities at or under 85 percent and 80° F.

A report on "The Adsorption of Water Vapor by Untanned Hide and Various Leathers at 100° F.,"[4] gives data on the variation of water adsorption with relative humidity. All strongly water-adsorbing groups appear to be saturated at a relative humidity of about 25 percent. Under these conditions, collagen or other forms of hide will combine with about 10 percent of moisture which is considered to be sufficient to assure stability.

These studies by the National Bureau of Standards provide the basis for the determination of the best relative humidity for the preservation of the Declaration of Independence and the Constitution of the United States—namely, that sufficient water vapor be added to the helium to give a relative humidity of 25 to 35 percent at room temperature.

[2] R. C. Bowker and W. D. Evans, J. American Leather Chemists Association 27, 81 (1932).

[3] J. R. Kanagy, J. Research NBS 25, 149 (1940), RP1319.

[4] J. R. Kanagy, J. of American Leather Chemists Association 42, 98 (1947).

2. The Enclosure

(a) The Transparent Enclosure

A survey of possible hermetically sealed enclosures indicated that a double-glazed panel made commercially as an insulating window would be suitable for our purpose. In August 1947 the Libbey-Owens-Ford Glass Co. agreed to cooperate on the project by preparing Thermopane enclosures for the documents.

These enclosures (fig. 1) consist of two rectangular panes of tempered plate glass separated 3/8 inch by a 1/16-inch-thick lead strip, which is set in approximately 3/8 inch from the edges of the glass panes and completely encircles the enclosure. The two panes of glass have a special metallic coating applied on them where they make contact with the lead strips. This coating makes it possible to bond the lead strip to the glass panes by solder, thus completely sealing the interior cavity from the outside atmosphere. A bronze bracket 7/16 inch wide is inserted inside of the enclosure to frame the document completely and to hold in place the glass cover plate, which rests on the document to keep it flat.

The temperature to which the documents will be subjected during the sealing operation was determined in the laboratory of the Libbey-Owens-Ford Glass Co. Areas 1/4 inch in diameter on one of the glass panes were metallized at distances of 1 and 2 inches in from the center of one edge and also at two corners. Thermocouples were soldered to these metallized areas and connected to a Brown temperature indicator. Immediately after tacking the two panes of glass to the lead strip, the fillets were rerun with the 350-watt, spade-shaped soldering iron, three passes being made. The temperature readings were then taken at 1 minute intervals and it was found that maximum temperatures of 103° and 106° F. were obtained at the end of 8 minutes at the points located 1 inch in from each of the corners. The maximum temperature in the other locations was 87° and the minimum temperature was 70° F. The unit was then allowed to cool to room temperature and the fillets were rerun twice, which is comparable with production procedure. The maximum temperatures 1 inch from each of the corners were obtained at the end of 3 minutes and were respectively 91° and 92° F. The maximum temperature in other locations was 88° and the minimum was 72° F. On the basis of this test it is concluded that the document will not be subjected to temperatures exceeding 106° F. during the soldering operations.

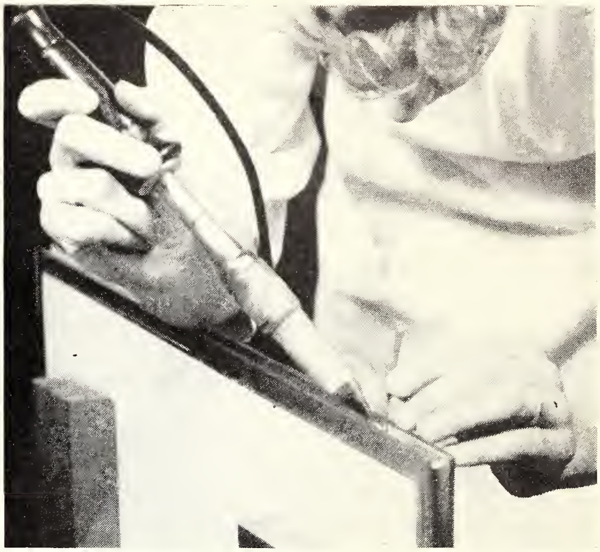


Figure 16.—The constricted tubes, which extend through the lead strip, are removed from the strip and the holes sealed with solder. The facsimile document is now entirely sealed within the test enclosure.

(b) Sealing Operations

A trial sealing of a facsimile of the Declaration of Independence in one of the glass enclosures was conducted by the National Bureau of Standards in June 1950 to provide information on the detailed steps and performance of the equipment, which would be helpful in planning the sealing operations of the original documents.

The sealing of the enclosure was performed by technicians of the Libbey-Owens-Ford Glass Co. at the National Bureau of Standards. Operations concerned with the substitution of helium for the atmosphere in the enclosure and the leak detector were performed by personnel of the National Bureau of Standards. The sequence of operations is as follows:

The bottom pane of tempered glass is set up on two 2 by 4's to permit access later to the lead strip for the soldering operation. Several sheets of the pure cellulose backing paper are centered on this glass pane (fig. 2). The document is placed on top of the backing paper (fig. 3) and the cover glass is placed over the document (fig. 4). The bronze bracket to hold the cover glass and document in position inside the enclosure is put in place (fig. 6). The two measuring cells of the leak-detector unit, which are to be inside the enclosure in slots cut in the bronze frame, are shown in figure 5 with the Kovar tubes, which extend through the lead strip being soldered to it. The top pane of glass with the lead strip previously soldered to it is placed in position (fig. 7). The lead strip is then soldered to the bottom pane of glass (fig 8). Small metal tubes are inserted through and sealed in the lead strip at diagonally opposite corners to serve for the introduction and exit of the helium (fig. 9). The inlet tube from the helium supply is sealed onto the tube at the upper left-hand corner of the enclosure (fig. 10). Similarly an exit tube, connected to a bubble counter and gas seal consisting of a glass tube dipping just below the surface of a small quantity of oil, is sealed to the tube at the lower right-hand corner of the enclosure (fig. 11). Helium from a cylinder at high pressure is passed through a pressure reduction gage (fig. 12) into a gas washing bottle containing distilled water. The gas washing bottle is maintained at a temperature of 4° to 6° C. in a constant temperature bath (fig. 13). This bath is cooled by a coil connected to a compressor unit by the arched hose shown in figure 14. The air in the enclosure is flushed out with the humidified helium for several days until a reading taken with the leak detector indicates that the unit is ready to be sealed (fig. 15). The inlet and exit tubing are cut loose with a pair of pliers which constricts the orifice of the tubing. The tubes which extend through the lead strip are removed (fig. 16) and the holes sealed with solder. The outer bronze frame is then fitted to the enclosure, the reference cells are soldered in place in the recessed channel at the top of the enclosure, and the lead wires from these and the inner measuring cells are connected to a cable running through the top member of the outer frame (fig 17). This cable terminates in a socket which will be located outside of the shrine so that a connection can be made at any time to the microammeter of the leak detector unit shown in the foreground of figure 19.

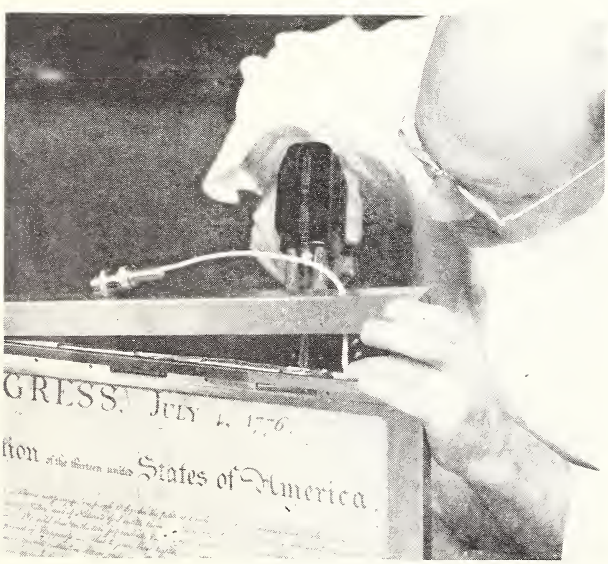


Figure 17.—After the holes have been sealed, the outer bronze frame is fitted to the enclosure. The wires from the reference cells and the two cells inside the enclosure are connected to a line that passes through the bronze frame and terminates in a socket. At any time, the ammeter of the leak detector can be plugged into this socket to determine whether air has leaked into the enclosure. Here Mr. E. C. Creitz is soldering the lead from a reference cell to the external lead.

3. Leak Detection

The National Bureau of Standards considers that equipment for the detection of a leak in the enclosure is essential to ensure that the documents are being kept under the optimum storage conditions, out of contact with atmospheric oxygen or other harmful gases present in the air. After examination of several methods of accomplishing this objective, a thermal conductivity type of gas analyzer was selected as the leak detector. This equipment has the advantages of being small enough to be built permanently into the enclosure and of being simple in operation so that observations can be made as frequently as necessary without opening the two cases of the shrine.

The thermal conductivity cells were developed at the National Bureau of Standards by E. C. Creitz of the Gas Chemistry Laboratory. Much of this development is based on investigations of thermal conductivity made by E. R. Weaver, Chief of the Gas Chemistry Laboratory.

The thermal-conductivity cell (fig. 18) consists of a filament of 0.001-inch-diameter platinum wire wound into a helix and supported on a pair of Kovar wires which in turn are mounted by sealing them into a 1/4-inch Kovar tube by means of a glass bead. The assembly is slipped inside of a 1/4 inch inside diameter copper tube 1 1/2 inches long and soldered in place so that the position of the filament is fixed in relation to the tube. Four of these cells are connected so as to form the equal arms of a wheatstone bridge. Two of the cells in opposite arms of the bridge are used as reference cells by filling the copper tubing with helium and sealing by pinching off and soldering. The other two cells are mounted inside the enclosure and are used as measuring cells.

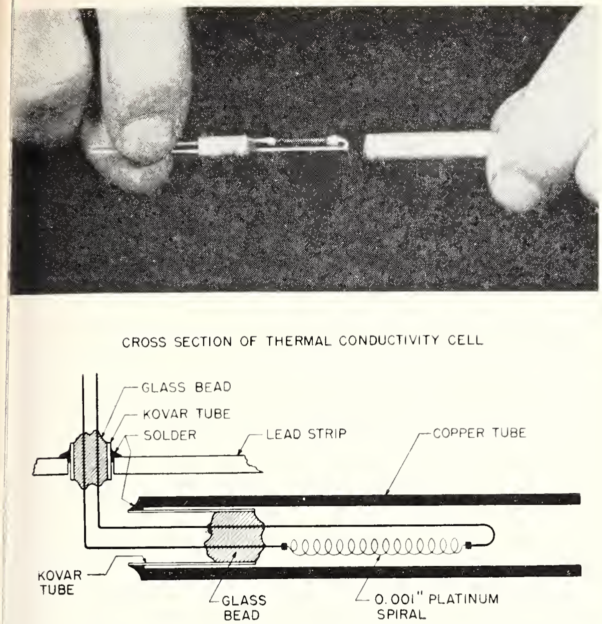


Figure 18.—The special thermal conductivity cell developed at the National Bureau of Standards for the preservation of the Declaration of Independence and the Constitution. The small filament (left in the photograph) consists of a fine platinum wire, wound into a helix, and supported on a pair of Kovar wires which, in turn, are sealed in the Kovar tube by a glass bead. The assembly is soldered in the copper tube (right) so that the position of the filament is fixed in relation to the tube. An electrical current passing through the platinum spiral causes it to increase in temperature, with a corresponding increase in electrical resistance; this increase is greater in air than in helium. The ammeter of the leak detector unit is set to read zero when the platinum spiral is in helium and 100 when it is in air.

Electrical leads to the measuring cells are carried through the metallic spacer of the enclosure by means of special insulated seals. These seals are made by mounting a pair of Kovar wires inside a ⅛-inch-diameter Kovar tube by means of a glass bead. Since the glass is fused to both the wires and the tube, a gastight insulated lead-through is obtained which may be soldered to the metallic spacer of the enclosure. Fabrication of the lead-through seals as well as the cells was done in the Electron Tube Laboratory of the National Bureau of Standards under the direction of W. B. Haliday.

In operation, regulated current is supplied to the bridge from a unit containing dry cells and an iron-hydrogen ballast tube. The unit also contains a 0- to 50-microampere meter for determining the balance point of the bridge. The portable unit is connected to the bridge within the enclosure by means of a cable and plug.

When the unit is plugged into the socket connecting it to the bridge, sufficient current (75 ma) flows through the filaments to heat them above room temperature. The filaments then lose heat to the copper tubing surrounding them, chiefly by conduction and at a rate that is a function of the gas in the space between filament and copper tubing. When the enclosure and the reference cells are filled with helium and the bridge adjusted to balance, all four cells behave essentially alike. However, if a leak should develop and the helium in the enclosure become contaminated with air, the measuring cells in the enclosure would lose less heat, their resistance would increase because of their higher temperature, and the bridge would become unbalanced as evidenced by an up-scale reading on the microammeter. The calibration is such that full scale deflection on the meter is approximately equal to 100 percent air. Should a reference cell leak there would be a corresponding meter deflection but it would be off scale below zero.

4. Backing Paper

Sheets of pure cellulose were made from cotton rags in the experimental paper mill at the National Bureau of Standards (fig. 20) to be used to back up the documents and to serve as a humidity reservoir to offset any changes in the water-vapor content of the atmosphere in the enclosure resulting from temperature variation. The fiber content of this paper is 60 percent of No. 1 white shirt cuttings and 40 percent of No. 1 old whites, and the paper contains small percentages of calcium carbonate and titanium dioxide.

The results of physical tests on the paper at 47-percent relative humidity are as follows: Weight (25 by 40 inches—500 sheets), 79.3 pounds; thickness, 0.0062 inch. The results of chemical tests on the paper are as follows:

Test	Original paper	Heat-treated paper [1]
Alpha-cellulose .... percent	92.0	90.7
Beta-cellulose .... percent	7.1	8.0
Gamma-cellulose .... percent	.9	1.3
Copper number	.5	.5
Acidity: [2]		
pH after cold-water extraction	8.9	8.6
pH after hot-water extraction	9.0	8.8
Ash on oven-dry basis .. percent	5.4	----------

[1] Paper heated for 72 hours at 105° C. before testing.
[2] The acidity was determined by the glass-electrode method.

5. Radiation Hazard

(a) Effect of Radiant Energy

Studies of the deterioration of irradiated cellulose products show that, although the greatest damage is caused by ultraviolet energy of wavelengths shorter than 360 millimicrons, damage is still appreciable for wavelengths up to 500 millimicrons. This includes all of the violet and blue part of the visible spectrum. An investigation of the deterioration of low-grade paper when irradiated at certain wavelengths gave the results shown in table 1. The figures indicating damage are on an arbitrary scale and show relative values. Correction was made for incident flux density and time, to make the irradiance corresponding to each wavelength equal.

Table 1.—*Relative damage of radiant energy*

Wave length in millimicrons	Relative damage, arbitrary scale
546	1
436	22
405	60
389	90
365	135

The deterioration of animal parchment is not as rapid as that of the low-grade paper for which the damage factors were determined. The energy in the short-wavelength end of the visible spectrum and in the ultra-violet are, however, known to be the most damaging.

(b) Incident Radiant Energy

Radiant energy from incandescent-filament lamps and from diffused daylight is incident on the cases at the present location of the shrine. The incandescent-filament light is predominant. Direct sunlight cannot reach the documents. The spectral distribution of the radiant energy from these sources is taken to be equivalent to that of a black body at 2,800° K. and 6,500° K. for the incandescent-filament lamps and the diffused daylight, respectively.

The effectiveness of the incident energy in causing damage and in usefulness for viewing are compared in table 2. The values for the damage factors were derived from the table and the luminosity factors are those adopted by the International Commission on Illumination (ICI).

A study of the data in table 2 indicates that energy of wave lengths shorter than about 500 millimicrons contributes very materially to the deleterious effect while its usefulness in seeing (as represented by the luminosity factors) is not as great as that of longer wave lengths in the range from 500 to 620 millimicrons. The wave lengths greater than 620 millimicrons contribute useful

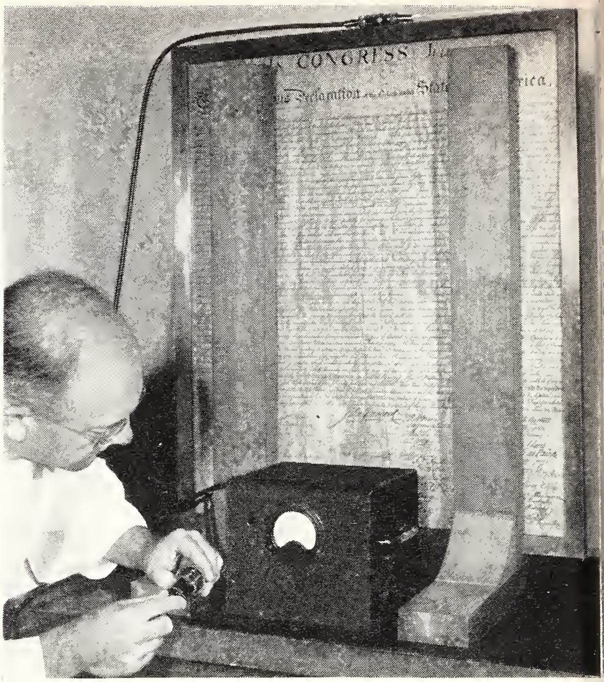


Figure 19.—After the facsimile document was sealed, periodic checks with the leak detector revealed that there was no leakage through the enclosure. The terminal of the cable leading to the thermal conductivity cells can be permanently installed outside of the Shrine at the Library of Congress, so that the enclosures may be checked at intervals. Mr. E. C. Creitz is connecting the ammeter of the conductivity cells.

Table 2.—*Comparison of damage and usefulness factors of radiant energy*

Wave length in millimicrons	Relative damage factors	Relative luminosity factors (usefulness)
360	145	0. 0000
380	107	. 0000
400	66	. 0004
420	37	. 0040
440	20	. 023
460	12	. 060
480	6. 5	. 139
500	3. 7	. 323
520	2. 1	. 710
540	1. 2	. 954
560	. 7	. 995
580	. 4	. 870
600	. 2	. 631
620	. 1	. 381
640	. 05	. 175
660	. 0	. 061
680	. 0	. 017
700	. 0	. 004
720	. 0	. 001

light (although in diminishing amount with increasing wave length) and cause comparatively little deterioration.

This means that an appreciable decrease in harmful radiant energy can be realized by excluding energy of wave lengths shorter than about 500 millimicrons. The filter required to accomplish this, although highly selective, does not produce in the observer an impression of a strongly chromatic illuminant, and is of sufficiently high luminous transmittance to permit adequate lighting of the documents without the use of excessively large lamps.

(c) The Protective Filter

It is proposed to install in the cover door of each case of the shrine a laminated glass made with a plastic interlayer in which the necessary light-absorbing material has been incorporated. The Eastman Kodak Co. has cooperated in supplying the necessary large yellow cellulose acetate sheet required for this project. The yellow acetate sheet is similar in optical properties to a Wratten four filter and absorbs completely in the range from 310 to 430 millimicrons. Both sides of the filter were coated with polyvinyl butyral to facilitate lamination with glass. The large size glass laminates were prepared by the American Window Glass Co.

The spectral transmittance of a 2-inch square, cut from an 8- by 10-inch sample lamination is given in table 3.

Table 3.—*Spectral transmittance of protective filter*

Wave length in millimicrons	Transmittance of sample	Wave length in millimicrons	Transmittance of sample
300	0. 000	530	. 83
320	. 000	540	. 84
340	. 000	560	. 84
360	. 000	580	. 84
380	. 000	600	. 84
400	. 000	620	. 83
420	. 000	640	. 83
440	. 000	660	. 82
460	. 000	680	. 80
470	. 01	700	. 79
480	. 17	720	. 78
490	. 50	740	. 76
500	. 70		
510	. 78		
520	. 82		

(d) Effectiveness of the Filter

In table 4, the spectral energy values for 6,500° K. have been adjusted to give equal luminosity with those for 2,800° K. (see sums of columns 5 and 6)—that is, for equal illumination from the two types of source, without any protective filter in use. When the protective filter is used, the radiant energy passes through the filter twice; once to reach the documents and the second time to reach the observer's eye. The values given in the seventh column are, accordingly, the squares of the transmittances for the filter. The relative usefulness with the filter in use is given in the last two columns of table 4 and a comparison of the

Table 4.—*Relative usefulness, in viewing documents, of sources at 2,800° and 6,500° K.*

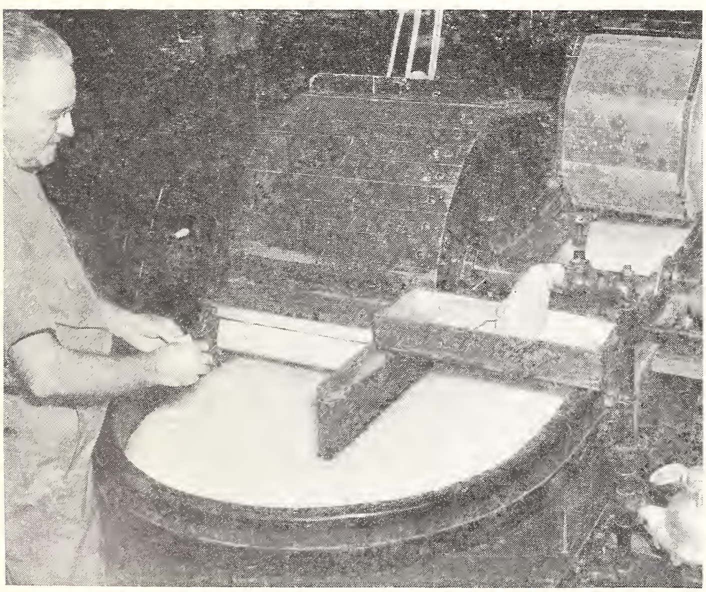
Wave length millimicrons	Relative luminosity factors	Relative energy		Relative usefulness in viewing		T^2, protective filter	Relative usefulness with protective filter	
		2,800° K.	6,500° K.	2,800° K.	6,500° K.		2,800° K.	6,500° K.
360	0. 0000	0. 06	1. 04	0. 00	0. 00	0. 00	0. 00	0. 00
380	. 0000	. 09	1. 08	. 00	. 00	. 00	. 00	. 00
400	. 0004	. 14	1. 11	. 00	. 00	. 00	. 00	. 00
420	. 0040	. 20	1. 14	. 00	. 00	. 00	. 00	. 00
440	. 023	. 28	1. 15	. 01	. 03	. 00	. 00	. 00
460	. 060	. 37	1. 14	. 02	. 07	. 00	. 00	. 00
480	. 139	. 47	1. 13	. 06	. 16	. 03	. 00	. 00
500	. 323	. 59	1. 11	. 19	. 36	. 49	. 09	. 18
520	. 710	. 72	1. 08	. 51	. 77	. 67	. 34	. 52
540	. 954	. 85	1. 05	. 81	1. 00	. 71	. 57	. 71
560	. 995	1. 00	1. 02	. 99	1. 02	. 71	. 71	. 72
580	. 870	1. 15	. 98	1. 00	. 85	. 71	. 71	. 60
600	. 631	1. 30	. 94	. 82	. 59	. 71	. 58	. 42
620	. 381	1. 46	. 90	. 56	. 34	. 69	. 39	. 23
640	. 175	1. 61	. 87	. 28	. 15	. 67	. 19	. 10
660	. 061	1. 76	. 83	. 11	. 05	. 67	. 07	. 03
680	. 017	1. 90	. 79	. 03	. 01	. 66	. 02	. 01
700	. 004	2. 04	. 75	. 01	. 00	. 62	. 01	. 00
720	. 001	2. 18	. 72	. 00	. 00	. 61	. 00	. 00
				5. 40	5. 40		3. 68	3. 52

sums of the corresponding columns shows that the filter reduces the usefulness by nearly the same amount, 32 percent for the 2,800° K. source and 35 percent for the 6,500° K. source.

In table 5, using the same energy values as in table 4, the sums of the fifth and sixth columns show that, for equal illuminations (without the protective filter), diffused daylight is materially (about eight times) more damaging than incandescent-filament light. When the protective filter is used, the relative damage is as given in the last two columns. When these sums are compared with those of the corresponding damage from unfiltered sources, it is seen that the damage is reduced by 90 to 98 percent for 2,800° K. and 6,500° K., respectively. As shown in the previous paragraph this is accompanied by reductions of only 32 and 35 percent in the usefulness of the light.

TABLE 5.—*Relative damage from sources at 2,800° and 6,500° K.*

Wave length in millimicrons	Relative damage factors	Relative energy (adjusted to equal luminosity)		Relative damage for equal luminosity		T, protective filter	Relative damage with protective filter	
		2,800° K.	6,500° K.	2,800 °K.	6,500° K.		2,800° K.	6,500° K.
360	145	0. 06	1. 04	8. 7	151	0. 00	0. 00	0. 00
380	107	. 09	1. 08	9. 6	116	. 00	. 00	. 00
400	66	. 14	1. 11	9. 2	73	. 00	. 00	. 00
420	37	. 20	1. 14	7. 4	42	. 00	. 00	. 00
440	20	. 28	1. 15	5. 6	23	. 00	. 00	. 00
460	12	. 37	1. 14	4. 4	14	. 00	. 00	. 00
480	6. 5	. 47	1. 13	3. 1	7. 3	. 17	. 53	1. 24
500	3. 7	. 59	1. 11	2. 2	4. 1	. 70	1. 54	2. 87
520	2. 1	. 72	1. 08	1. 5	2. 3	. 82	1. 23	1. 89
540	1. 2	. 85	1. 05	1. 0	1. 3	. 84	. 84	1. 09
560	. 7	1. 00	1. 02	. 7	. 7	. 84	. 59	. 59
580	. 4	1. 15	. 98	. 5	. 4	. 84	. 42	. 34
600	. 2	1. 30	. 94	. 3	. 2	. 84	. 25	. 17
620	. 1	1. 46	. 90	. 15	. 09	. 83	. 12	. 07
640	. 05	1. 61	. 87	. 08	. 04	. 82	. 07	. 03
660	------	1. 76	. 83	----	------	. 82	----	----
680	------	1. 90	. 79	----	------	. 81	----	----
700	------	2. 04	. 75	----	------	. 79	----	----
720	------	2. 18	. 72	----	------	. 78	----	----
				54. 43	435. 43		5. 59	8. 29



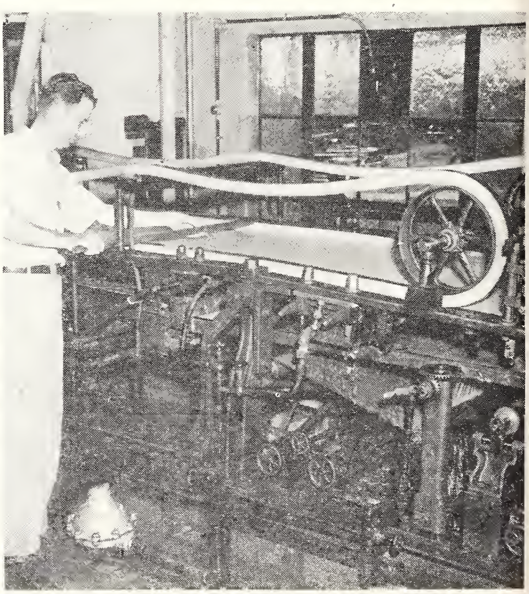


Figure 20.—The beater in the experimental paper mill at the National Bureau of Standards, in which the paper stock for the backing paper was prepared from cotton rags. The special backing paper serves as a physical protection and moisture reservoir without contaminating the documents (left). The experimental paper-making machine at the Bureau, on which the backing paper was made for use in the preservation of the Declaration of Independence and the Constitution of the United States in glass enclosures filled with helium (right).

DEPARTMENT OF COMMERCE

UNITED STATES OF AMERICA