U. S. DEPARTMENT OF

W. AVERELL HARRIMAN,

NATIONAL BUREAU OF STANDARDS

E. U. CONDON, Director

CIRCULAR OF THE NATIONAL BUREAU OF STANDARDS C453

# APPARATUS FOR DETERMINING WATER-VAPOR PERMEABILITY OF MOISTURE BARRIERS

By

FREDERICK T. CARSON and VERNON WORTHINGTON

Issued November 8, 1946

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1946

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 10 cents

## PREFACE

Considerable attention has been given recently to the measurement and specification of the water-vapor permeability of caselining and packaging materials intended to protect articles exposed to hot, humid air. The National Bureau of Standards has developed improved equipment for the purpose, the chief feature of which is a conditioning and testing cabinet which is capable of closely controlling the hygrometric conditions, and which is equipped with mechanism for weighing specimens in place in the controlled atmosphere. The apparatus is also well suited for use in determining the equilibrium moisture content of hygroscopic substances, and it could readily be adapted to other uses. The equipment is not difficult to build, and it can be made of available, easily worked materials. To facilitate compliance with requests for detailed information about this equipment this circular has been prepared.

E. U. CONDON, *Director.*

# APPARATUS FOR DETERMINING WATER-VAPOR PERMEABILITY OF MOISTURE BARRIERS

By Frederick T. Carson and Vernon Worthington

ABSTRACT

A conditioning and testing cabinet is described in which the hygrometric conditions are maintained by equilibrium with a saturated solution of an appropriate salt. The temperature of this solution and of the testing chamber is held constant by means of an envelope of moving air that completely surrounds the testing chamber, an open-coil heater and a thermoregulator being used to control the temperature of this air bath. Devices for supporting and weighing the permeability cells in the cabinet, without disturbing the hygrometric conditions, are explained in detail. The cells, hung by hooks from a rotary suspension disk, can be suspended one at a time from a weighing rod attached to a balance. Interlocking mechanisms for selecting and picking up the cells facilitate the weighing and protect the apparatus and the permeability cells from accidental injury. A method and apparatus for mounting the specimens in the permeability cells are described also. Materials covering a large permeability range can be accommodated. Some suggestions are made for accelerating the testing of good moisture barriers.

CONTENTS



## I. INTRODUCTION

A conditioning cabinet fitted with mechanism for weighing permeability cells while suspended in the cabinet has been designed to facilitate the determination of the water-vapor permeability of materials. The apparatus was designed to carry out the test according to method T464m–44 of the Technical Association of the Pulp and Paper Industry, which requires one face of the specimen to be exposed to a tropical atmosphere, specified as 90 ±2 percent relative humidity at a temperature of 100° ±1° F. Permeability cells containing a desiccant, over which the specimen is sealed, are exposed in the specified tropical atmosphere, and are weighed periodically. The rate of gain in weight of the desiccant (after the rate of gain has become constant) per unit area of the specimen is a measure of the water-vapor permeability under the conditions of the test.

The apparatus permits the making of periodic weighings of a number of permeability cells while they remain in the conditioning atmosphere, whereas the usual procedure for determining water-vapor permeability under tropical conditions requires the cells to be removed for weighing. The opening of a conditioning cabinet to remove cells for weighing results in upsetting the hygrometric conditions. During the weighing outside of the cabinet, there is an interruption of the continuity of the specified vapor-pressure gradient across the specimens in the cells that are weighed. When the cells are replaced in the hot, humid atmosphere there is likely to be condensation of moisture on the cooled specimens. These difficulties are overcome by weighing the cells in place in the cabinet.

Other important features of the new apparatus are the use of an air bath to produce a uniform temperature and to prevent condensation in the conditioned space, auxiliary ports and preheating arrangements to allow permeability cells to be put in the cabinet or taken out at will without disturbing the conditions within the cabinet, and an improved permeability cell and mounting technic.

The apparatus was required on short notice during the war, when it was difficult to get such equipment built. It was designed to be as small, compact, and simple as the requirements would permit. and it was made in the laboratory from available, easily worked materials. As it is still somewhat difficult to get new apparatus made, a detailed description of the equipment may be helpful to those requiring such apparatus.

## II. PERMEABILITY CELL

### 1. DESCRIPTION OF THE CELL

The permeability cell (or dish), illustrated in figure 1 and in most of the other illustrations, is made of aluminum. It has an outside flange and waxing groove of the type illustrated in figures 1 and 4 of TAPPI method T464m–44 (q. v.). The surface of contact with the specimen is made very narrow to better define the test area. The outside diameter of the cell is 3⅞ inches. Cells of this type were made of annealed sheet-aluminum disks, about 20-thousandths of an inch thick, by pressing them to shape between steel dies.

These cells are convenient also for use in determining water-vapor permeability under standard paper-testing conditions in a testing room, as they fit nicely on the balance pan of most analytical balances. The test area, which is determined by the size of the contact face of the template, 6 (fig. 1), is 50 $cm^2$, a convenient figure to use in calculating the permeability.[1]

[1] In testing a good moisture barrier, it is usual to weigh at 1- or 2-day intervals over a period of about 2 weeks. With a test area of 50 $cm^2$ and a weighing interval of 24 or 48 hours, the difference in grams between successive weighings, when multiplied by 200 or 100 gives the permeability directly in grams per square meter per day.

The permeability cell, although it is only about a quarter of an inch deep, will hold enough of the desiccant to allow the absorption of 2 or 3 grams of moisture while the desiccant is in prime condition.[2] A number of the permeability cells suspended by hooks are shown in figure 5. A small loop, formed in the turned-under edge of the aluminum cell (shown as an enlarged detail in fig. 8), accomodates one end of a hook, 37, which is used to support the cell, 1, in the conditioning cabinet.

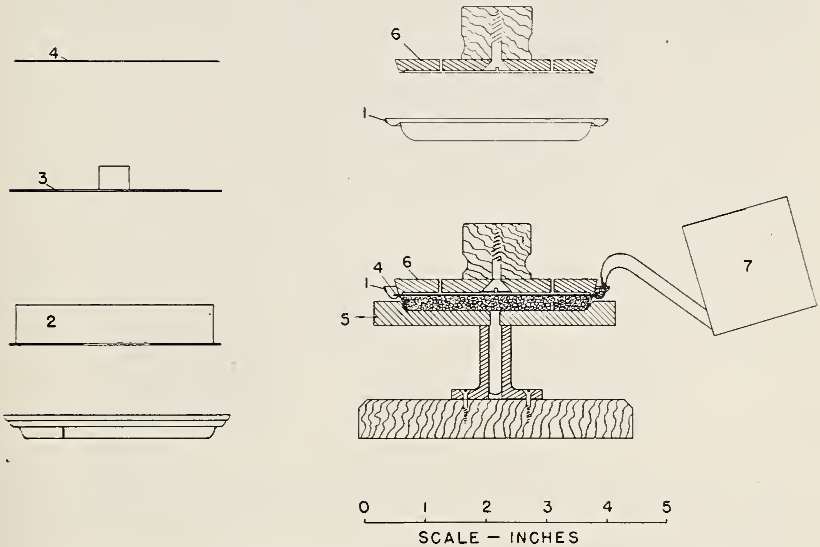


FIGURE 1.—*Water-vapor-permeability cell, and apparatus with which the specimen is mounted over a desiccant and sealed in the cell.*

## 2. MOUNTING THE SPECIMEN

To prepare a specimen for a test, a circular piece of such size that it will extend about half way into the waxing groove all around is cut from the sample to be tested. A hopper, 2 (fig. 1), with a flat bottom having a hole in the center about a square inch in area is placed on the cell, 1, in the position that the specimen would normally occupy. Somewhat more desiccant than is required to fill the cell is poured into the hopper. The cell and hopper are held together in the hands and shaken with a rotary motion, which forces the desiccant out to the edges and completely fills the space under the hopper.[3] The hopper is removed, the excess desiccant remaining in it is put in a covered container for use in preparing the next cell, and a leveling plate, 3, is placed on the cell, with which the desiccant is smoothed

[2] Anhydrous magnesium perchlorate is an excellent but expensive desiccant. Anhydrous calcium chloride, 8-mesh, is almost as good for this purpose and is much less expensive.

[3] An additional advantage of this method of filling the cell and mounting the specimen is the shaking of the powdered portion of the desiccant into the bottom of the cell. In some other methods of mounting the specimen the fine powder collects and clings to the surface of the specimen inside the cell, creating the possibility of clogging and interfering with the flow of the moisture, or otherwise causing uncertainty about its effect on the test. Completely filling the cell eliminates also the problems associated with an air space between the specimen and the desiccant, involving expansion with change in temperature and the possibility of an unknown vapor-pressure gradient across the air space.

down evenly and level with the contact surface. The leveling plate and the hopper have the same diameter as the specimen. The leveling plate is then replaced by the circular specimen, 4, and the cell is transferred to the turntable, 5, and covered by the template, 6, which is carefully centered.

The beveled edge of the template has previously been coated with a film of petrolatum to prevent the wax from sticking to it. This is done by rotating the template while the beveled edge is held in contact with a felt pad saturated with petrolatum. Any excess is removed from the face of the template by rubbing it across a sheet of absorbent paper. If possible, the template, after the beveled edge has been coated with petrolatum, should be kept in a refrigerator in the interval between preparations of successive cells, so that it will chill the contact film of molten wax and insure sharp definition of the test area.

While the turntable is slowly rotated, molten wax, composed of approximately equal parts of paraffin and microcrystalline wax, is poured into the waxing groove from a pot, 7. When the wax has cooled, the edge of the specimen being completely enveloped and molded in it, the template is removed with a twisting motion. Holes through the template admit air and facilitate the removal. The mounted specimen, underlain with desiccant and sealed against access of moisture except through the test area, is now ready for testing.

## III. CONDITIONING CABINET

### 1. AIR BATH

The cabinet in which the prepared permeability cells are hung consists of a tight sheet-metal box within a thermally insulated box. The two boxes are separated by an air space on all six sides. In this space, air of the desired temperature is circulated, providing an air bath, or air jacket, similar to that used by Wiegerink,[4] which is very effective in maintaining a uniform temperature within the inner box.

### 2. TABLE-TYPE CABINET

The conditioning and testing cabinet described herein was made small and compact, and was designed specifically for use in the determination of the water-vapor permeability of moisture barriers. Two conditioning cabinets were made, a table type and a floor type, which are shown in figures 2, 3, and 4.

The table-type cabinet, although it is less than a foot high and weighs about 50 pounds, has a capacity of 40 of the permeability cells described in a previous section. This cabinet is intended for use on any convenient table or bench, and is sufficiently wieldy to be put out of the way when not in use. It is shown in detail in figures 6 and 7.

An outer box of half-inch plywood, 8, is lined with insulating board, 9. To conserve height, insulation is omitted from the bottom, the table top being depended upon for some additional insulation. A piece of napped fabric is placed between the two surfaces. Within is supported a sheet-metal box, 10, measuring 15 by 16 inches and

[4] J. Research NBS 24, 639 (1940) RP1303.

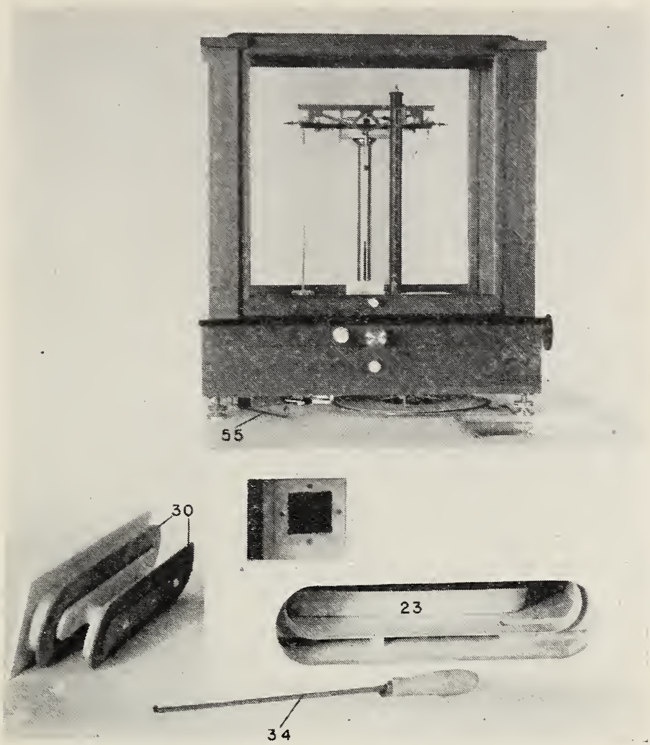


FIGURE 2.—*Conditioning and testing cabinet, table-type, in which permeability cells are suspended and weighed in place.*

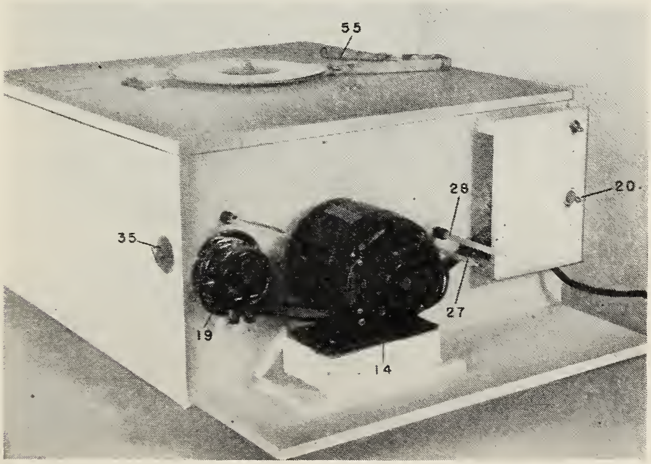


FIGURE 3.—*Back of cabinet pictured in figure 2, with balance removed.*

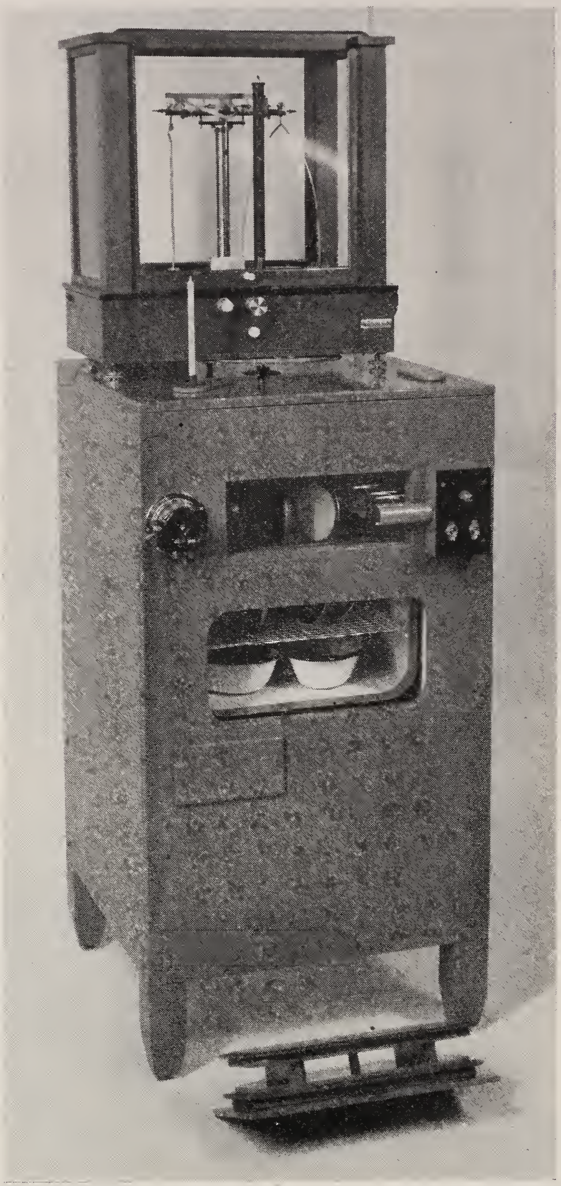

FIGURE 4.—*Conditioning and testing cabinet, floor type, for determining water-vapor permeability of sheet materials*

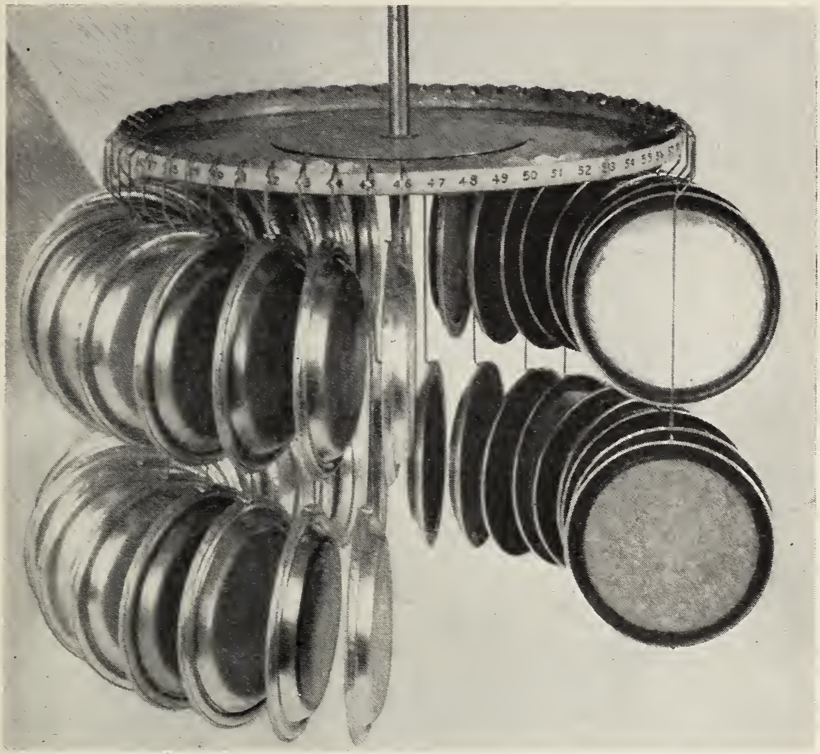


FIGURE 5.—*Water-vapor-permeability cells attached to rotary suspension disk.*

7 inches high,[5] with a space, 12, separating the two boxes on all sides. Preliminary experiment showed that the width of this space could be reduced to 1 inch, or somewhat less, without impairing the effectiveness of the air bath.

A small centrifugal blower wheel, 13, driven by a 1/20-horsepower motor, 14, circulates air in the air bath, 12. A scroll, 15, over the blower wheel directed the air downward underneath the box, 10, and along one side of it. The air then passes across the front and flows back over the top and along the other side, passing over open heating coils, 16, before reentering the centrifugal fan, 13. A dividing wall, 17, which is the front of the scroll, 15, separates the incoming and the outgoing air. Wooden strips, 18, at diagonally opposite edges of the box further divide and direct the air stream in the course indicated.

[5] In making this cabinet every effort was made to keep the height small, and the effort was somewhat overdone. The tolerances in the dimensions of the various parts proved to be so small that considerable difficulty was experienced in putting the apparatus together. It would be preferable to make the inner box about 8 inches high. This would also permit the use of a slightly different type of suspension disk, to be described later (figs. 9 and 11), which is preferable to that shown in figures 6 and 7, but which requires more height in the testing chamber.

715283—46——2

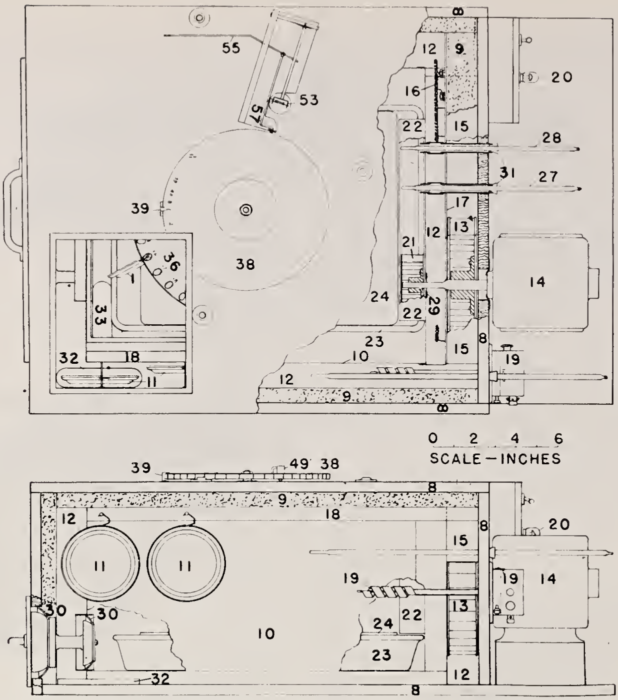


FIGURE 6.—*Plan and side elevation, showing details of cabinet pictured in figures 2 and 3.*

A sensitive bimetal thermoregulator, 19, in series with the 80-watt heating coil, 16, maintains the selected temperature. A 0.1-microfarad condenser is placed across the thermoregulator to minimize arcing. The heating-coil circuit is in parallel with the motor. A glow tube, 20, shunted across the heating coil, shows when heat is being supplied to the air bath. The heating coil is made of about 40 feet of Nichrome wire, having a resistance of 4 ohms per foot, wound in a long helix. It is supported in the air space at the back of the cabinet where the return air passes through and around it just before reentering the blower wheel, 13. Such an open-coil heater responds more readily to controls than enclosed types, and contributes to close regulation of temperature.

A smaller blower wheel, 21, on the same shaft with the blower wheel, 13, circulates the air inside the sheet-metal box, which is the conditioning and testing chamber. A scroll, 22, over blower wheel 21 directs the air downward into a photographic tray, 23, covered (except at the ends) with a glass plate, 24, supported by glass pedestals, 25. The tray contains a saturated solution, 26, of a suitably chosen salt,[6] over which the air flows until it emerges at the other end of the tray. The air, heated to the desired temperature by the

[6] Some salts whose saturated solutions at 100° F. have a relative vapor pressure (indicated in parentheses) within the range specified in TAPPI method T464m–44 are potassium nitrate (89), monoammonium phosphate (91), sodium tartrate (91.) The last one is not suitable for use above 140° F, a transition point. The solution should contain an excess of the salt.

air bath surrounding the metal box and charged with moisture in equilibrium with the vapor pressure of the saturated salt solution, flows past the permeability cells, 1, suspended above the tray, and back to the centrifugal fan, 21. Two matched thermometers, dry-bulb, 27, and wet-bulb, 28, graduated to read to 0.1° C, or 0.2° F, pass through sealed tubes into scroll 22, where the air coming directly from blower wheel 21 impinges upon them. Windows in the top and the front of the cabinet permit observation of the interior.

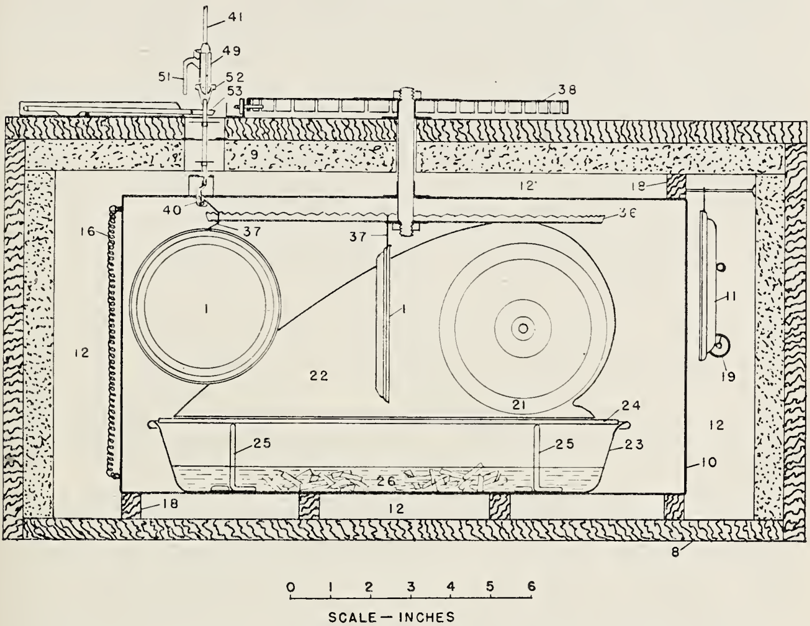


Figure 7.—*Front sectional view of cabinet pictured in figures 2 and 3.*

An effort was made to make the boxes tight, particularly the inner box, because it is not possible to maintain the rated relative vapor pressure of the saturated salt solution in the test chamber if there are appreciable leaks in it. The principal opening that affords access to the inner box is sealed by a plug-type closure. This opening is seen in figure 2 as an oblong aperture with rounded ends in the outer box and a similar but slightly smaller aperture in the inner box. The closure is seen in perspective at the left of the cabinet in figure 2, and is shown in section in figure 6. The seal is made by stiff rubber plates, 30, a little larger than the respective apertures, which press against the smooth faces of the flanged apertures when the plug is forced in, both apertures being sealed simultaneously. The rubber plates, 30, are lubricated with powdered talc to facilitate inserting and removing the closure. To seal the hole through which the motor shaft enters the box, a disk of leather or of felt, 29, saturated with oil, is used. The suspension-disk shaft is sealed by oil in the bearing. Rubber stoppers, 31, prevent leakage past the thermometers.[7] Leakage through the weighing-rod aperture will be slight if there is no replacement leakage anywhere else. However, leakage at this aperture is minimized by disks on the weighing rod which cover the aperture at all times except when weighing is in progress. This device will be more fully described later.

### 3. AUXILIARY PORTS

Frequently it becomes desirable in the midst of a test to put additional or new specimens into the cabinet, or to remove cells from the cabinet. To open the cabinet would change the conditions in it and interrupt the continuity of the test. Transferring cells is facilitated by a small port, 33, in the bottom of the cabinet, just large enough to admit a permeability cell. When new specimens are put in, it is highly desirable to avoid consdenation of moisture on them, which would occur if the relatively cool specimens were put directly into the hot, moist atmosphere used in simulating tropical conditions. Condensation is avoided by preheating the cells in the air bath, 12, before they are introduced into the testing chamber. For this purpose a similar small port, 32, is provided which opens into the air bath, whereas port 33 opens directly into the inner box through a short tunnel. These small ports are closed by the same type of closure used to seal the large opening in the front of the cabinet.

The cells are handled by means of the special tool, 34, shown lying in front of the cabinet in figure 2. This tool is a kind of remote-control pincers, with which the suspension hook, 37, is grasped and, together with the permeability cell, is carried through the port and hung up.

When the newly prepared cell is to be introduced during a test, it is first taken through port 32 and hung up in the space, 12, between the boxes (cells, 11, fig. 6). After about 5 minutes the motor is stopped, both of the ports, 32 and 33, are opened, the cell is withdrawn through port 32, and is immediately thrust through port 33 into the inner box and hung in the appropriate position on the suspension disk, 36, after which the two ports are closed and the motor is again started.

The port, 32, leading into the air bath sometimes has another use. In warm weather the continuous operation of the closely coupled motor [8] and blower wheels may add enough heat to raise the temperature of the air bath above 100° F. This extraneous heat can be largely neutralized by venting air from the room through port 32 and out at port 35 (fig. 3) situated opposite the centrifugal fan, 13 (fig. 6).

### 4. FLOOR-TYPE CABINET

This floor-type conditioning cabinet, shown in figure 4, is similar in principle to that just described, but it has a smaller base and a greater testing capacity. It is 19 inches square and 36 inches high. The inner sheet-metal box is a 14-inch cube. It will accommodate 60 specimens, the permeability cells being hung in two tiers from the

[7] This seal is doubly important because leakage around the thermometers is likely to result in a spurious wet-bulb reading.

[8] To avoid extra bearings the two blower wheels were mounted directly on the motor shaft, and the motor was placed as close to the cabinet as possible.

suspension disk, as illustrated in figure 5. Alternately placed short hooks and long hooks are used to support the cells. Each hook is hung in a notch in the rim of the suspension disk, the shape of the notch preventing the cells from twisting about and touching one another.

The motor is placed underneath and drives a vertical, centrally located shaft, on which is mounted a blower wheel in the air bath and a propeller fan in the inner box. The saturated salt solution is contained in two crescent-shaped pans, one on each side of the shaft. The conditioned air in the inner box is forced down and across the solution in the pans, up around the permeability cells, and then down through the center of the box to reenter the circulating fan. The temperature of the conditioned air is shown by a thermometer that passes through a tube in the top of the cabinet. The wet-bulb thermometer, for determining the relative humidity, is put in horizontally through a tube in the large plug-type closure, the bulb lying just under the circulating fan.

It was necessary to put the small auxiliary ports in the top of this cabinet. Transferring cells through these ports is done very simply by means of a wire 6 or 8 inches long, ending in a hook or an eyelet.

## IV. WEIGHING THE PERMEABILITY CELLS IN PLACE

### 1. METHOD OF SUPPORTING CELLS IN CABINET

The permeability cells, 1, are suspended from the rotary suspension disk, 36, by hooks 37 (fig. 7). The suspension disk, about 11 inches in diameter, has a narrow turned-up rim that slopes slightly outward. In the rim are 40 equally spaced notches with gently sloping sides. The bottom of each is sharply notched, so that the round section of the suspension hook, 37, lying in it holds the hook in radial alinement. Opposite each notch there is a hole in the disk (fig. 6) through which the suspension hook engages the notch. Each position is numbered. Connected to the disk, 36, by means of a shaft through the top of the cabinet, is another numbered disk, 38, which can be rotated until the number of the cell to be weighed is under the pointer, 39, at which time the correspondingly numbered permeability cell is brought into register with the weighing hook, 40. At its lowest position the weighing hook reaches just below disk 36, clearing slightly the suspension hooks 37 as the suspension disk is rotated. But when the weighing hook, 40, the end of which is provided with a V-notch similar to those in disk 36, is raised to the weighing position (fig. 7) it lifts hook 37 and the attached cell, freely suspending them from the balance arm.

### 2. ALTERNATE DESIGN OF SUSPENSION DISK

A slightly different form of suspension disk and arrangement of hooks was used in the cabinet illustrated in figure 4 and is pictured in figure 5. The rim of the disk is sloped inward (see fig. 9), the suspension hooks are placed in the notches from the outside instead of from the inside, no holes are required in the suspension disk, and the weighing hook is on the inside of the rim. The relation of the weighing hook, 40, at its lowest position, to the suspension hooks, 37, is made clear in figure 9. This form of suspension disk is in many respects preferable to the other form, but it requires longer hooks and a little more operating height.

### 3. WEIGHING ROD

A detailed drawing of the weighing rod, 41, is shown in figure 8. The contact surface of the hook at the top is shaped like that of the bow of the balance pan which it replaces, in order to keep the weighing rod from twisting about. Where the weighing rod passes through a hole in the base, 42, of the balance, a stirrup, 43, is interposed to accommodate the movement of the pan-arresting lever, 44. A suitable weight, 45, is added to make the weighing rod counterbalance the remaining balance pan.

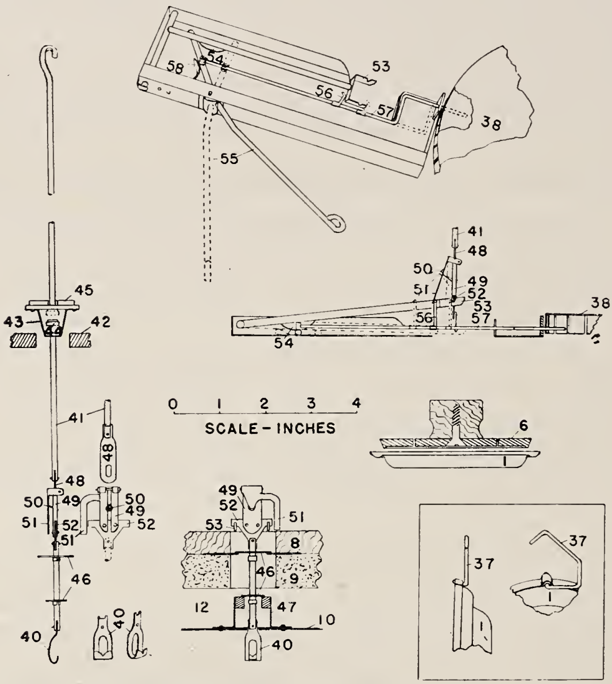


Figure 8.—*Details of weighing rod, coupling mechanism, and permeability cell.*

### 4. METHOD OF HANGING CELL TO BALANCE ARM

The weighing rod is made separable by a coupling so that the weighing hook can be lifted or lowered without movement of the upper part of the weighing rod, which is attached to the balance arm. This coupling (fig. 8) is composed of a tab, 48, having a hole through it near the bottom, a tab guide, 49, and a hinged coupling pin, 50, that passes through the hole in the tab, 48, and a corresponding hole in tab guide 49 to couple the weighing hook, 40, to the weighing rod, 41. In the uncoupled position the lower end of the tab, 48, remains in the top of guide 49. All parts of the weighing rod, except the weight, 45, are made of aluminum or aluminum alloy.

In the uncoupled (lowest) position, the weighing-hook assembly is supported by the lifting fork, 53, acting on the cross bar, 52, which is integral with tab guide 49. Lifting fork 53 is pivoted at such a distance that cross bar 52, when lifted, deviates very little from a vertical plane. The notches in fork 53 hold the weighing-hook assembly in a definite position and prevent it from twisting. The lower part of cross bar 52, is V-shaped to aid in centering the assembly.

To lift the weighing hook the lever, 55 (fig. 8) is pushed to the left. The other end moves to the right in contact with the sloping boss, 54, situated near the pivot of the lifting fork, 53, causing the fork to rise. When the end of the lever, 55, has reached the middle of the boss, 54, the lifting fork, carrying the weighing-hook assembly, is at its greatest height. Up to this point the coupling pin, 50, has been held out of engagement by a projection, 56, acting on the coupling-pin lever 51. The projection, 56, is integral with rod 57, which is pivoted to the lever, 55, as indicated. At midtravel of the operating lever, 55, when the tab guide, 49, has ridden up on the tab, 48, until the two holes are in coincidence, the projection, 56, has advanced until the coupling pin, 50, engages the two holes and locks the tab and its guide together. As the operating lever is pushed all the way over it leaves the boss, 54, and allows the fork, 53, to drop again to its low position, leaving the cross bar, 52, and the whole weighing-hook assembly, with a permeability cell attached, hanging freely from the balance arm.

When making weighings in this manner, one should stop the motor to quiet the air in which the cell is hanging and to avoid vibration. Between weghings, however, while picking up another cell and preparing to weigh it, one should allow the motor and the heater to operate.

During the transit of the boss, 54, by the end of the lever, 55, the end of rod 57 remains in one of the 40 equally spaced slots in the selector disk, 38, thus making it impossible to turn the selector disk while a cell is being weighed. The selector disk can be turned only when the transit in the opposite direction has been completed, and the weighing-hook assembly has been uncoupled from the weighing rod and returned to the low position where the hook will clear the suspension hooks. In the position shown by the perspective view at the top of figure 8, a stopped spring, 58, holds the tip of rod 57 in one of the selector-disk slots. A slight movement of lever 55 against spring, 58 releases disk 38 so that it can be turned to the next position selected. This interlocking mechanism makes it impossible to damage the apparatus by turning the selector disk while a cell is suspended from the weighing hook, 40, and also makes it impossible to lift the weighing hook except when it is in exact position to engage the suspension hook attached to the cell selected for weighing. There is one exception. At a certain position on the selector disk there is an extra slot that allows the weighing hook to be lifted between two adjacent cells, and to hang freely without a load, for the purpose of adjusting the zero point of the balance. This extra slot registers with the end of the locking rod, 57, when the position B on the dial (fig. 6) is under pointer 39.

## 5. ALTERNATE COUPLING MECHANISM

An alternate coupling and interlocking device is shown in figure 9. It is the form that has been used on the cabinet illustrated in figure 4. The weighing-hook assembly is much like that just described, except that the tab guide, 49, and cross bar 52 are not in the same plane, but one is turned 90° to the other. The lifting is done by a crank, 65. A short crank pin, 64, working in a slot in the lifting bar to which fork 53 is attached, lifts the weighing-hook assembly. At the same time it acts on the coupling-pin lever, 51, to hold the coupling pin out of engagement. When the crank pin approaches top center, however, the coupling pin falls into the holes in tab 48 and tab guide 49, coupling them together. As the crank goes over, the fork descends, leaving the weighing-hook assembly freely suspended, and the crank pin comes against a stop before reaching bottom center. After the suspended cell has been weighed, the crank is turned in the opposite direction to uncouple and return the weighing hook, 40, to the low position.

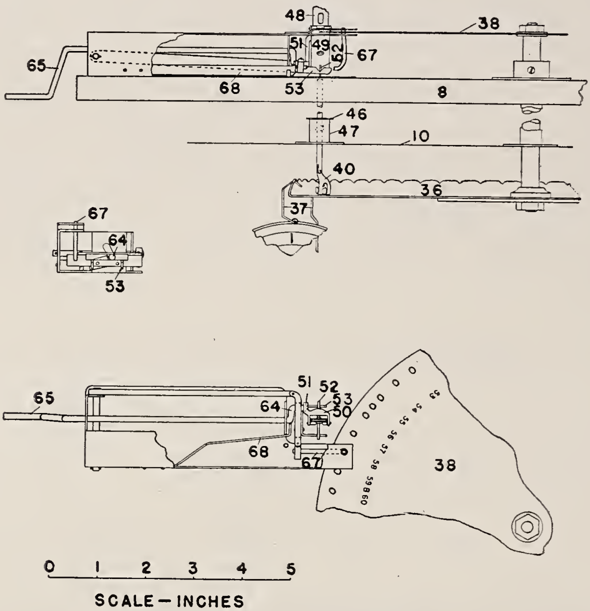


FIGURE 9.—*Details of the crank-operated coupling mechanism.*

During the above cycle the turned-up end of a rod, 67, integral with the lifting bar, and passing through fixed holes in the frame and through one of the holes in the edge of the selector disk 38, keeps the disk locked in position. At the end of the cycle, when the weighing hook, 40, has been returned to the low position, where it clears suspension hooks 37, a stopped spring, 68, holds the crank pin, 64, a little short of bottom center. When force is exerted to bring the crank pin to bottom center against the action of the spring, the tip of rod 67 falls below the selector disk, 38, and allows it to be turned to the next position selected. Then, when the crank is released, locking rod 67 snaps into the hole selected. Unless the selector disk is in the exact position to make the holes register, the lifter bar and fork 53 can not be raised. The function of this design is exactly the same as that previously described. This mechanism seems to work a little more smoothly than the other, but it is somewhat more troublesome to make. This device is shown in figure 10.

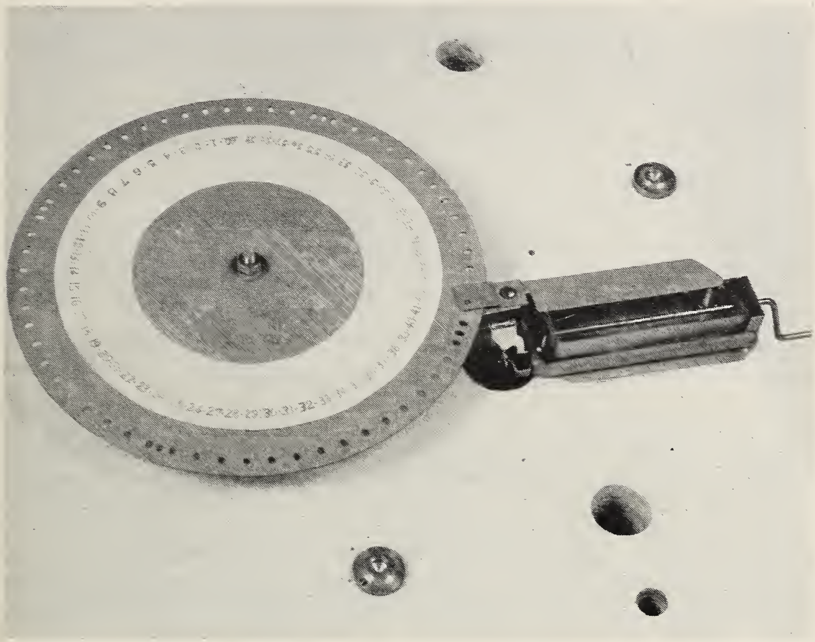

FIGURE 10.—*Top of cabinet (fig. 4), showing selector disk and crank-operated coupling mechanism illustrated in figure 9.*

### 6. SECOND METHOD OF HANGING CELL TO BALANCE ARM

A more rugged lifting device, which dispenses with the coupling in the weighing rod, is illustrated by figure 11. In principle it is somewhat like the selector mechanism designed by the Institute of Paper Chemistry,[9] in that the selector disk, suspension disk, and all the permeability cells in the cabinet must be lifted and let down again each time a single cell is hung on the weighing hook.

The apparatus normally rests in the position shown by full lines in figure 11; one cell is freely suspended from weighing hook 40, while all the others are supported by disk 36. To exchange the permeability cell hanging from weighing hook 40 for another, disk 36 must first be lifted to the position shown by broken lines where all the suspension hooks 37 will clear weighing hook 40. Disk 36 must then be turned until the cell selected comes underneath the weighing hook, after which the disk is lowered to its original position. The suspension

[9] Inst Paper Chem. Instrumentation Report No. 30, Part 6 (Feb. 15, 1944).

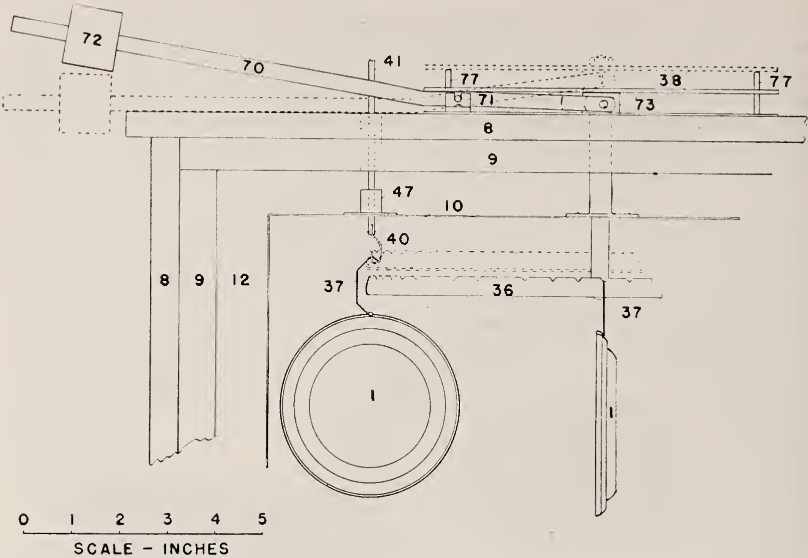


FIGURE 11.—*Another method of selecting and hanging permeability cells to balance arm.*

disk, 36, is lifted by depressing lever 70, pivoted at 71, and acting through a collar, 73, on selector disk 38. The load is partially counterbalanced by the weight, 72, the position of which can be adjusted to suit the load on the suspension disk.

While a cell is hanging from weighing hook 40, the two pins, 77, which are fastened rigidly to the top of the cabinet, and which pass through holes in the numbered selector disk, 38, prevent disk 36 from being turned. But when disk 36 is lifted to the position shown in broken lines, the selector disk is lifted above pins 77, and can be turned to the position selected. The disk can not be let down again until pins 77 register with the holes in disk 38 that determine the proper register of suspension hook and weighing hook.

This type of mechanism permits the zero point of the balance to be adjusted in any position of the selector disk while lever 70 is held down. If more freedom of movement is desired, it can be had by providing an extra pair of holes in the selector disk that will permit weighing hook 40 to bypass the suspension hooks and remain freely suspended when disk 36 is in the normal (low) position.

### 7. PREVENTING CONDENSATION ON THE WEIGHING ROD

In the early experiments on weighing the permeability cells in place, condensation of moisture on the weighing rod seriously interfered with the weighing. The weighing rod was brought into the cabinet in the usual manner through a tube extending between the inner box, 10, and the outside atmosphere. Although this arrangement would be quite satisfactory under ordinary conditions, the dew point of the tropical atmosphere used in the cabinet was so far above room temperature that air escaping around the weighing rod easily became chilled enough to deposit condensed moisture on the weighing rod. At times drops of water were seen to collect and fall from the weighing hook. The simple method used to prevent condensation is shown in figure 8, and indicated also in figures 9 and 11. Tube 47, is broken within air bath 12, so that any moisture-laden air that escapes is diluted with the relatively dry air of the air bath and its dew point is sufficiently reduced before it becomes chilled.

Leakage through the weighing-rod aperture is small if the inner box is otherwise free of leakage. The effect is felt most when port 33 (fig. 6) is opened to introduce or remove cells. The resulting lowering of the humidity seldom exceeds 1 or 2 percent, however. This leakage can be largely prevented in the case of the mechanisms containing the coupling device, but is difficult to prevent when the type of mechanism shown in figure 11 is used. Figure 8 shows two disks, 46, fitting loosely on the rod, which cover the two sections of the aperture when weighing hook 40 is uncoupled. To prevent friction during the weighing of a cell, these disks are lifted free when hook 40 is coupled to the weighing rod.

## V. PERFORMANCE AND USE OF THE APPARATUS

### 1. UNIFORMITY OF CONDITIONS

Measurements of temperature and humidity in both cabinets, with wet-bulb and dry-bulb thermometers and with a Dunmore electric hygrometer, have shown that uniform conditions prevail throughout the testing chamber.

Over a period of 2 weeks the change in hygrometric conditions with time is normally small. There has been no difficulty in keeping the temperature within $\pm 0.5$ deg F and the relative humidity within $\pm 1$ percent of chosen values, with occasional attention to the thermoregulator to prevent drift.

### 2. TESTING VERY PERMEABLE MATERIALS

This apparatus permits satisfactory testing of very permeable materials that are difficult or impossible to test with some other types of equipment. When the desired hygrometric conditions must be built up after the specimens are put in the cabinet, and this process must be repeated each time after the permeability cells are removed for weighing, it is not practicable to test a material having a permeability of several hundred grams per square meter per day, because the desiccant becomes exhausted before enough weighings can be made, and because the change in weight between weighings does not correspond to the actual time of exposure in the stated hygrometric conditions. With the apparatus described above, which allows the permeability cells to be put in after the desired hygrometric conditions have been attained and to be weighed in the conditioning atmosphere, treated textile fabrics having a water-vapor permeability of 1,500 $(g/m^2)/d$ have been tested with ease. When it is necessary to test such permeable materials, however, it is advisable to have only a few cells in the cabinet at one time, because otherwise the moisture may be absorbed so rapidly from the atmosphere in the cabinet that the chosen relative humidity cannot be maintained consistently.

### 3. ACCELERATING THE TESTING OF GOOD MOISTURE BARRIERS

A disadvantage of the usual gravimetric technic of determining water-vapor permeability is the time required to complete a test. The delay is particularly annoying in production control. Recently some new methods have been tried to speed up the test, but the problem is a difficult one because of the slowness with which the rate of flow of moisture approaches the steady state after a given pressure difference has been established across the specimen.

A study of data obtained from more than 200 tests of materials used as moisture barriers reveals that in nearly all cases a good approximation to the final value for water-vapor permeability can be obtained in less than 2 days. These tests were made with the equipment described above and under the tropical conditions set forth in the introduction. With a few exceptions, the steady state is nearly enough attained in about 16 hours that a value within 5 percent of the final value (obtained after 10 days to 2 weeks) can be obtained in the next 24 hours, provided the water-vapor permeability is greater than about 5 $(g/m^2)/d$. Therefore, if a permeability cell is prepared and put in the cabinet some time during the day, allowed to remain overnight, weighed the next morning and then again 24 hours later, the result obtained will usually be good enough for most purposes. If the permeability is between 2 and 5 $(g/m^2)/d$, it may be necessary to lengthen the preconditioning period to 40 hours and the period between weighings to 48 hours. If the permeability is less than about 2 $(g/m^2)/d$, a considerably longer period may be required. As the necessity for quick results occurs chiefly in production control, where particular types of products are made day after day, it should be possible in each case to work out the minimum preconditioning period and the minimum test period that will yield a result that will not differ from the long-period result by more than a given, acceptable amount.

WASHINGTON, January 21, 1946.

O