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NATIONAL RESEARCH COUNCIL

CANADA

DIVISION OF BUILDING RESEARCH

DESIGN OF A MASONRY LEAKAGE TEST APPARATUS

by

W. G. Plewes

A report on the apparatus and methods used by other research organizations for investigating the problem of masonry leakage, and the factors considered in the design of an apparatus for the Division of Building Research

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PREFACE

This Division has found in the course of field investigations and from inquiries directed to it that rain penetration of masonry is a serious problem in Canada as it is in many other countries. The climate, materials, and design and construction practices vary from one region to another, making it necessary for each country to carry out certain phases of rain penetration studies on its own. There was therefore no doubt that such studies should be undertaken as one of the major projects of the Division.

Field surveys of masonry leakage and deterioration have already been made and reported. The literature on the subject generally has been studied and a review prepared. The next step was the planning of laboratory work, including the selection of experimental methods and apparatus. It is the latter part of this section of the work, involving the design of apparatus following a careful study of the methods and equipment used by others, which is covered in this report. A limited series of experiments using the apparatus has already been carried out, and plans for further testing have been made.

Ottawa,
August 1956.

N.B. Hutcheon,
Assistant Director.

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by

W. G. Plewes

Since the formation of the Division of Building Research, architects, builders, and owners have frequently asked for advice regarding problems of damp or leaking masonry walls. Studies of technical literature show that such problems occur in most countries and a great deal of research has been devoted to them. Progress has been made in determining the factors involved in masonry leakage but the problem is complicated by so many variables that present information does not, in many cases, provide clear-cut solutions. Since further contributions to the technology of masonry were obviously meeded and because some of the exposure conditions in Canada, particularly with regard to frost action, are more severe than in most other countries, a program of masonry leakage investigations was given early consideration.

When it was possible to begin active laboratory research into the problem, one of the first steps was to review investigations made by other research organizations. It was desirable to take full advantage of existing information to avoid unnecessary duplication in planning the work of this Division. Also, since an extensive study of masonry leakage was most likely to involve a variety of tests, it was possible through the literature study to profit from the experience of others with different types of apparatus.

This report deals with the factors considered in the design of an apparatus at the Division of Building Research. With this apparatus it will be possible to test small masonry test walls which, though not large enough to be entirely representative of a wall, will be sufficiently large to yield significant information on the water resistance of different unit and mortar combinations. There will be a further advantage in that the properties of each material in the wallettes can be previously determined. Unfortunately this is seldom the case in field studies which causes some confusion in the interpretation of the performance of walls of existing buildings. While a thorough study of the problem will require a number of other complementary tests on masonry materials individually and in combination, tests with this apparatus should yield the most direct indication of the probable performance of the materials in an actual wall.

Similar apparatus has been used by a number of other organizations, the only new feature in this instance being the provision made for controlling the temperatures at the faces of the test panel. The test equipment of other organizations is briefly described in Part A of this report; Part B is a discussion of the design of the DBR apparatus.

PART A

APPARATUS AND METHODS USED BY VARIOUS OTHER RESEARCH ORGANIZATIONS

1. American Face Brick Association at the U.S. National Bureau of Standards - L. A. Palmer (1)

Experiments were carried out to determine the relation between the permeabilities of brick and mortar when tested singly and in assemblages. The apparatus consisted of a metal reservoir attached to the side of a single brick or to small assemblages (Fig.1). Water was maintained in the reservoir at constant head and the time for moisture to appear on the opposite face recorded.

2. American Face Brick Association, National Lime Association, Portland Cement Association at the U.S.National Bureau of Standards - L.A.Palmer and D.A.Parsons (2)

A series of tests on the permeability of 8-inch brick wallettes was carried out on brick-mortar assemblages similar to that shown in Fig.2. A head of water was applied by impounding it in a metal frame sealed to the specimen along the dotted lines shown. For the tests this surface was turned uppermost. The number of leaks, the elapsed time before they appeared, their location, and the leakage rate per minute were recorded.

3. U.S.National Bureau of Standards - J.W.McBurney, M.A. Copeland, and R.C.Brink (3)

An investigation of masonry permeability was carried out by these authors in a manner very similar to that used by Palmer and Parsons.

4. United States National Bureau of Standards - C.C.Fishburn et al

The United States National Bureau of Standards has carried out a comprehensive series of permeability tests on masonry panels and has issued a series of reports (4,5,6, 7,8). The test panels used were approximately 40 inches wide by 50 inches high of various thicknesses. Three types of tests were performed, " capillarity", "heavy-rain", and "light-rain" tests.

The capillarity tests involved setting up a panel on the laboratory floor and applying water near the top of the exposure face by means of a perforated metal pipe (Fig.3). The water was allowed to run down the face in a thin sheet at a rate of about 10 gallons per hour per lineal foot of wall.

The heavy-rain test simulated the pressure and moisture conditions set up by a wind storm accompanied by heavy rain. A pressure chamber was clamped to the exposed face of a test panel and a pressure of 10 lb. per square foot above atmospheric maintained. Water was applied at the top of the panel by means of a perforated pipe (Fig.4) and allowed to run down the wall at a rate sufficient to maintain a thin sheet of water over the whole face, usually 10 gallons per lineal foot of wall per hour. The pressure chamber was equipped with observation windows, a manometer, a gooseneck water outlet, and a sensitive pressure-relief outlet. The air pressure of 10 lb. per square inch (2 inches of water) was considered to represent the pressure difference across a wall which would result from a wind of 50 m.p.h.

The light-rain test differed from the heavy-rain test in the amount of water applied and the method of application. About 0.5 gallon of water, equivalent to a depth of approximately 0.2 inch per hour over the whole surface, was applied through two atomizers moving horizontally back and forth in front of the wall.

Newly built walls were left in the testing room for two days and then placed in a drying room for one month before testing. The panels were also dried between tests. Drying room temperature was maintained 30 to 40°F. above outdoor temperature. Walls were considered at constant weight when the loss of weight was less than 0.2 per cent in seven days. The backs of some walls were whitewashed to show up moisture.

Provision was made to keep the temperature of the water above the dew-point temperature of the air in the testing room to prevent condensation.

The heavy-rain test was most commonly used, the capillary and light-rain tests being employed as auxilliary tests to determine the relative rates of leakage under various conditions.

Observations made during the tests were:

(a) Time required for the appearance of moisture (dampness) on the backs of the wall above the flashings;
(b) Time required for the appearance of visible water on the backs of the walls above the flashings;
(c) Time required for leakage to flow from the flashings;
(d) Maximum rate of leakage, if any;
(e) Extent of damp area on the backs of the walls, including that produced by the capillary rise of moisture from water on the flashings.

An arbitrary system of rating the walls, based on the above observations was used. It was assumed that visible water, large damp areas on the back, or leakage through the base of a wall, would damage plaster applied to it or injure the interior trim. The ratings were as follows:

Excellent (E) - No water visible on back of the wall (above the flashings) at the end of one day. Not more than 25 percent of the wall area damp at the end of five days. No leaks through the wall in five days.

Good (G) - No water visible on back of wall at the end of one day. Less than 50 percent of the wall area damp at the end of one day. No leaks through the wall in one day.

Fair (F) - Water visible on back of wall in more than three or less than 24 hours. Rate of leakage through the wall less than one liter per hour at the end of one day.

Poor (P) - Water visible on the back in three hours or less. Rate of leakage less than five liters per hour at the end of one day.

Very Poor (VP) - Rate of leakage through the wall equal to, or greater than five liters per hour at the end of one day.

5. University of Minnesota - Professor J. A. Wise

Bulletin No. 27 (9) of the University of Minnesota describes permeability tests on 42- by 60-inch panels of structural clay tile. The apparatus used was practically identical to that devised by the National Bureau of Standards with one or two additional features. Advantage was taken of the fact that the tiles were hollow. The open ends of the panels were sealed with glass so that the actual process of leakage could be watched. Provision was made to maintain the relative humidity of the testing room at 80 to 90 per cent.

For the first three hours of each test, the water was dosed with fluorescein so that even minute amounts of penetrating moisture could be observed under ultraviolet light. The following data were recorded after 24-hour and 5-day testing intervals:

(a) Time in hours for first dampness to appear;
(b) Time in hours for first free water to appear;
(c) Ratio of joints showing free water to total length of all mortar joints;
(d) Ratio of area showing dampness to total area of panel; and
(e) Rate of flow from flashings.

The walls were rated by relating the above test observations using a formula developed by Professor Wise which gave a numerical rating to each wall. The derivation of the formula is not explained in the paper.

6. Detroit Edison Company - John C. Thornton (10)

In a series of tests investigating the effect of brick surface texture on bond, the bricks under investigation were built into chimneys 4 feet square, 8 inches thick and 6 courses high (Fig.5). Each chimney side was built of different brick.

Chimneys were cured for 30 days then water was introduced into them and leakage measurements taken. In some instances dye was placed in the water to help trace the unbonded areas.

This method appears to have been effective for comparing the bonding characteristics of different brick and mortar combinations. It has also been used by two or three brick manufacturing companies.

7. Portland Cement Association - R.E.Copeland and C.C.Carlson (12)

An extensive series of tests was carried out by the Development Department of the PCA on 32- by 48-inch test panels 4, 8 and 12 inches thick, of brick, concrete masonry, and plain concrete. The apparatus consisted of a large propeller which sent an air blast through a duct to impinge on the masonry test panel at 45°. Water was introduced into the air stream through oscillating nozzles to simulate rain. The blast was directed at 45° to the panel because of the necessity to direct rebound away from the wall and also on the assumption that rain usually strikes a vertical surface at an angle. A 40-inch propeller was capable of producing an air speed of 25 m.p.h.; a 60-inch propeller was capable of 56 m.p.h. air speed (Fig.6).

The exposure conditions used were 24 hours with a 25-m.p.h. wind and a $2\frac{1}{2}$-inch-per-hour rain intensity for the majority of tests. For very impermeable materials 12 hours with a $2\frac{1}{2}$-inch-per-hour rain intensity and 25-m.p.h. wind immediately followed by another 12 hours with 12-inch-per-hour rain intensity and 25-m.p.h. wind were used.

Moisture penetration was recorded by several means:

(a) Copper electrodes were attached to the backs of wall panels and also in the cores of hollow units. Moisture penetration was indicated by change of resistance readings;

(b) Notes were kept of the extent of damp areas on the backs of walls and of the measured amounts of leakage;

(c) In some tests the presence of moisture was detected by placing the test panels on a scale and noting the increase in weight

Wall performances were rated as follows:

Excellent - No fluid leaks or back face dampness in 24 hours of testing;

Good - No fluid leaks and a dampening of less than 25 per cent of the back face in 24 hours testing;

Fair - Not more than 15 lb. of fluid leakage nor a dampening of more than 50 per cent of the back face in 24 hours of testing;

Poor - 15 to 50 lb. fluid leakage and/or a dampening of 50 to 75 per cent of the back face in 24 hours testing;

Very Poor - Rapid penetration resulting in fluid leakage of over 50 lb. and usually a general dampening of the back face

8. Department of Scientific and Industrial Research, Building Research Station, England

In England, tests have been carried out on 4½-inch brick masonry panels 4 feet, 1½ inches wide by 8 feet, 3 inches high, having rendered finishes. They are built outdoors in a continuous row with a brick pier between adjacent panels. Water is sprayed over the whole face of a panel by means of atomizing jets without any added air pressure to simulate the pressure due to wind. The rate of spraying is about 4 inches per hour and records of the extent of penetration are made at 5, 15 and 30 minutes and 1, 3 and 6 hours. Any external rendered finish that fails to prevent the penetration of water during the period of the test is not considered satisfactory.

9. South African Council for Scientific and Industrial Research

S.J.P. Joubert

The South African Research Council describes an apparatus for "evaluating the resistance of walls to penetration by rain" (11). It consists essentially of a number of nozzles arranged to spray either masonry test panels 6 feet wide and 9 feet high or actual building wall areas (Fig.7 (a)). Nozzle pressure is maintained constant at 50 p.s.i. and it is believed that the change in momentum of the spray particles striking the wall simulates the pressure resulting from wind under natural conditions. A galvanized metal chamber was built around the spraying apparatus to protect it from gusts of wind. The equipment has been used on the sides of full-sized test houses to compare the results of tests on wall panels with the effect on walls of the same materials under natural conditions.

The test panels are laid in rows between brick piers (Fig.7 (b)).

10. <u>Norwegian Building Research Institute</u> - Sven D. Svendsen (13)

Apparatus for testing the permeability of small test walls has been devised by the Building Research Institute of Norway. It was made principally to test wood-frame wall panels, but is also used for masonry leakage tests. Similar to the apparatus of the U.S.National Bureau of Standards it consists of a pressurized chamber which is attached to the panel to be tested. The spray method is more elaborate however. Water is dripped into the air streams from a bank of air nozzles moving continuously up and down over the panel face. The drops are broken up and driven against the test panel in a manner similar to rain. The angle of the nozzle tips is changed for each passage over the face of the panels so that the angle of incidence of the water drops is varied. The equipment has not long been completed and there are as yet little published data ragarding its use in masonry panel tests.

11. <u>Other Tests</u>

A number of other European research organizations have engaged in water penetration tests on masonry or other types of wall constructions (13). In most cases some sort of spraying arrangement is employed, with or without an applied air pressure.

PART B

FACTORS CONSIDERED IN THE DESIGN OF MASONRY PERMEABILITY TEST APPARATUS FOR D.B.R.

1. Type of Apparatus

There are two main types of laboratory apparatus commonly used for testing the permeability of masonry assemblages: the reservoir or chimney type where the brick-mortar assemblages are subjected to a constant head of water and the spray type where panels may be sprayed with water and subjected to air pressure if desired.

The reservoir or chimney type is the simpler to construct and appears to give good results on some aspects of the bonding characteristics and absorption qualities of materials. It does not, however, permit as wide a variety of tests on such factors as workmanship as does the spray type. In addition, the method of construction is likely to be too remote from actual construction practice and the size of the specimens is not usually sufficiently large to be representative of the wall.

The spray-type apparatus is more easily adapted to larger specimens and so permits the testing of a wide variety of construction types. Furthermore the technique used in laying the units is more likely to resemble actual practice. Spraying of test panels with or without wind pressure is also somewhat more closely related to the action of rain on walls and the test data are likely to be more easily related to natural exposure conditions.

The spray-type apparatus was chosen as the method of test for DBR because of its greater flexibility and the likelihood of its producing the more valuable data.

2. Size of Panels

Although it is desirable that test specimens of wall constructions be as large as possible to be representative of actual walls there are limiting factors beyond which it is impracticable to go. Preliminary calculations indicated that a test panel 3 feet 6 inches wide by 4 feet 6 inches high would give a suitable compromise between size and weight. A 12-inch solid brick wall of even these dimensions might weigh as much as 1800 lb. and if it is to be handled with care requires special equipment to move it. With larger panels both the moving and testing equipment become increasingly cumbersome. Increased size of panels and equipment also add to the cost and the laboratory space requirements.

3. Type of Spray

For the spray-type apparatus there is a choice of spraying the test panels at the top so that the water flows down the face in a thin sheet or of spraying or blowing the water over the whole panel face to simulate rain. The first-mentioned equipment may be used to determine the relative resistance to water penetration of different masonry panels under the test conditions, but might not give an absolute indication of their behaviour under natural rain. However, it should be possible to control the conditions fairly closely and obtain useful information regarding the relative importance of the numerous factors involved in the masonry leakage problem.

Where apparatus is made to simulate rain by spraying or blowing water uniformly over the panel face, it is open to question whether the results are any more reliable as an indication of wall performance under natural weather conditions or whether they again permit only a relative comparison of panel performances. After careful study of weather data, some investigators have found it necessary to make some assumptions in deciding on their test conditions. This is usually caused by the difficulty in actually duplicating rain or to the desire to accelerate the test. For instance, Copeland and Carlson (12), who used the apparatus shown in Fig 6, made a study of climate data in 11 cities for a 20-year period. They discovered that of 1759 rain storms of 1-inch or more in 24 hours only 36 were accompanied by an average wind velocity greater than 25m.p.h. Such heavy rains could be continuous for 24 hours or intermittent for several days. In actual tests these investigators used a wind speed of 25 m.p.h. and an intensity of $2\frac{1}{2}$ inches per hour, which, tests indicated, was roughly equivalent to a $\frac{1}{2}$-inch rainfall over a much longer period. This may be true, but it is a departure from duplicating actual rain conditions. In some cases also the simulated rain intensity was increased to 12 inches per hour. Observing Fig.6, it is a question also whether the wind velocity and air pressures at the restricted outlet of the duct duplicated natural conditions.

At the Norwegian Building Research Institute (13) there is no doubt but that the method of blowing water onto the panels is a fairly close duplication of driving rain. It has the advantage of being arranged to make it possible to alter the angle of incidence of the water particles which would be important in testing frame construction, window details, etc., for which it was mainly designed. In their standard test, water is delivered onto the panel at the rate of 8 to 10 litres/m^2/hr., and the applied air pressure is kept constant at 50 mm. of water. These conditions were assumed after careful study to correspond to the ultimate severity of driving rain to be found in Norway. In order to accelerate the test it was found desirable to increase the super-pressure to 75 mm. of water. This is a departure from normal conditions and is considered to be more severe than the standard test. Some tests have been carried out at the same Institute by running water down the face of plastered masonry panels in a thin sheet rather than spraying it. It has been observed that, "No noticeable difference in results was discernible with the two methods, and there is reason to believe that the effect of drops is not significant for walls of this type".

It is known that for most masonry walls the first rapid absorption is satisfied within a few minutes and thereafter in normally heavy rains the water does in fact form a thin film on the face of the wall (1, 13, 14). Not only does the water actually falling on the area of wall in question contribute to this film but also the run off from other areas of wall above it. For this reason and because any apparatus providing an artificial rain is apt to be of doubtful success in actual duplication of natural conditions it was decided to incorporate in the DBR test apparatus a method of spraying water at the top of the test panels and allowing it to run down in a thin film under a constant super-pressure. These conditions can be fairly accurately controlled and should be suitable for determining the factors governing the relative water permeabilities of panels made of different materials, types of construction, and workmanship. It then remains to correlate the data obtained with the behaviour of actual structures and climates, possibly using some type of outdoor exposure test on selected materials and constructions in several locations.

4. Air Pressure

Where a masonry wall has no cracks or openings in its face, penetration will occur through the pores of the material, principally by capillarity (13, 14, 15). The effect of wind or particle impact will have a relatively minor effect. Where large pores, cracks, or fissures extend through the wall, wind pressure has a major effect on the penetration (13). For this reason it was thought that the apparatus should have provision for the application of air pressure to the sprayed face of test panels.

5. Temperature Control

Although tests on masonry panels have been made in a number of places there is no record of tests being made under any but isothermal conditions. The influence of exterior and interior temperatures on wall permeability has not been investigated in tests of this type. Temperature gradients may be of some importance to both the migration of moisture through a wall and the amount of drying that takes place following successive periods of rain. It was proposed, therefore, to provide means of controlling temperature on one or both sides of the test panels. This arrangement was envisaged as consisting of a panel sealed between temperature-conditioned spray chambers but insulated from direct contact with the supporting metal framework. Besides allowing for control of the temperature gradients it would be possible to subject wall panels to cycles of freezing and thawing between sprayings.

6. Provision for Moving The Panel

It was obvious from the outset that some method would have to be devised for transporting the panels to and from the test apparatus or to a possible exposure site.

7. DBR Apparatus Design and Construction

Figure 8 shows the DBR masonry permeability test apparatus. The panels are built on a slab of rigid, foamed-plastic insulation 6 inches thick. For testing they are placed in a steel framework having means of clamping similar slabs of insulation on the sides and top of the panel. It is, therefore, isolated from any wood or metal part by at least 6 inches of insulation.

The frame is provided with casters so that it can also be used for moving panels short distances. For transporting them longer distances, such as to an exposure site, provision has been made to attach two automobile trailer wheels and a suitable hitch to the frame so that it can be towed by a truck.

The spray chambers consist of boxes made of special sheets of extruded aluminum having provision for carrying copper refrigeration coils. Outside this is a layer of fibre-glass insulation covered with plywood, and then a copper sheath. The chambers are designed to rest on steel frames with casters and are clamped to the panel insulation during tests. For early tests a temporary plywood-and-copper spray chamber without cooling coils was used. (Figs. 9, 10 and 11).

Air pressure is supplied from the laboratory compressed air service through a pressure regulating device, with a water manometer used to measure pressure. Water is pumped from a storage tank through a meter to the spray device which consists of a perforated copper tube placed to deliver small streams of water at the top of the panel. Water reaching the bottom of the panel is deflected into a trough by a flashing from where it drains into the storage tank for re-circulation. Water passing through the panels in sufficient quantity to run off the back face is collected by another flashing and drained into a pan for measurement.

8. Exploratory Program of Tests

A series of panels was planned to test the apparatus under isothermal conditions and provide exploratory data. Test conditions were more or less arbitrarily chosen. The rate of water delivery was set at 0.5 gallon per minute. Experiment showed that this was about the minimum necessary to provide an unbroken film of water over even the most absorptive panels.

The air pressure within the spray chamber was set at 13 lb. per square foot of a panel area which is equivalent to the velocity pressure of a 70-m.p.h. wind on a flat surface 30 feet from the ground. This is a severe condition but not impossible since the maximum recorded gust speeds over most of Canada are over 100 m.p.h. and on high buildings or on the sea coasts winds of high velocity are not uncommon. A high air pressure was chosen purposely to produce readily recognizable results with the idea of revising it for future tests in the light of test observations. It is not believed that a high wind is necessary to produce masonry leakage but tests show that the rate of leakage is sensitive to increases in air pressure.

When the initial series of tests is completed the experience and data obtained will assist in setting up the test conditions to be used for the main program of tests. The following are some factors that will have to be reviewed:

(a) Air pressure - Although the test conditions do not duplicate natural exposure the air pressures used should approximate actual wind pressure. It will probably be desirable to set this as high as practicable to reduce the testing time;

(b) Water spray rate - The water should form an unbroken film over the face of the panel so that the opportunity for leakage will be the same for all panels. Consideration will have to be given to the effect of film thickness, if any. The control of water temperature in temperature control tests will be important;

(c) Methods of rating the performance of test panels - Methods of panel rating and failure criteria will have to be decided upon in detail.

The initial series of tests may also indicate some desirable changes in the design of the apparatus although at present no major changes appear necessary.

9. Laboratory Conditions

Since the panels are to be water sprayed on one face and exposed to the laboratory air on the other, the desirability of controlling the relative humidity of the laboratory air will require consideration. It is possible, if the relative humidity is low, that in cases of slow penetration, moisture may evaporate on some plane below the panel surface and not be visible. On the other hand it may at times be desirable to control the relative humidity of the laboratory air to avoid condensation on the back of a cooled panel.

10. Measurement of Absorption Rate

When masonry units and mortar are dense and nonabsorptive, water penetration of a wall, if any, is likely to occur through cracks or unfilled joints and the amount of water actually absorbed by the materials is not significant. In other cases where the masonry units absorb relatively large quantities of water, penetration of the wall may not begin until the absorption capacity of the materials is satisfied, that is, the wall acts as a reservoir (14, 15).

It may at some time be desirable in investigations of this latter type of wall to measure the amount of water absorbed in a given time. This might be done either by weighing the panels periodically or by metering the spray and leakage water to obtain a mass balance. The development of this feature of the apparatus is under consideration, but some exploratory testing is needed.

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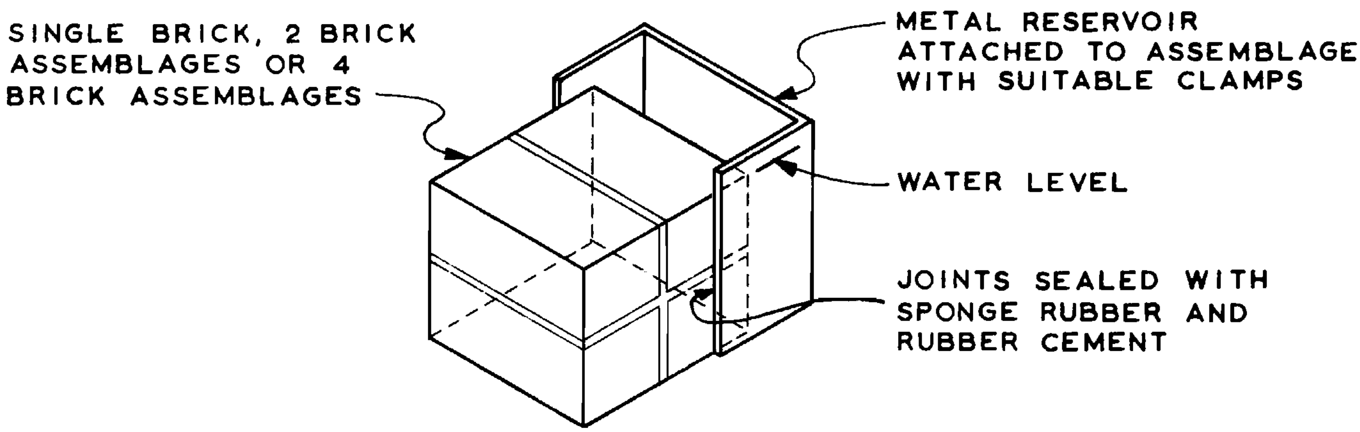


FIGURE 1

BRICK MASONRY ASSEMBLAGE PERMEABILITY TEST APPARATUS (PALMER[1])

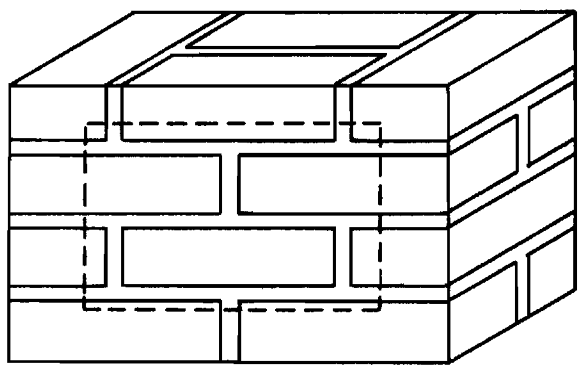


FIGURE 2

WALLETTE FOR WATER PERMEABILITY TEST (PALMER & PARSONS [2])

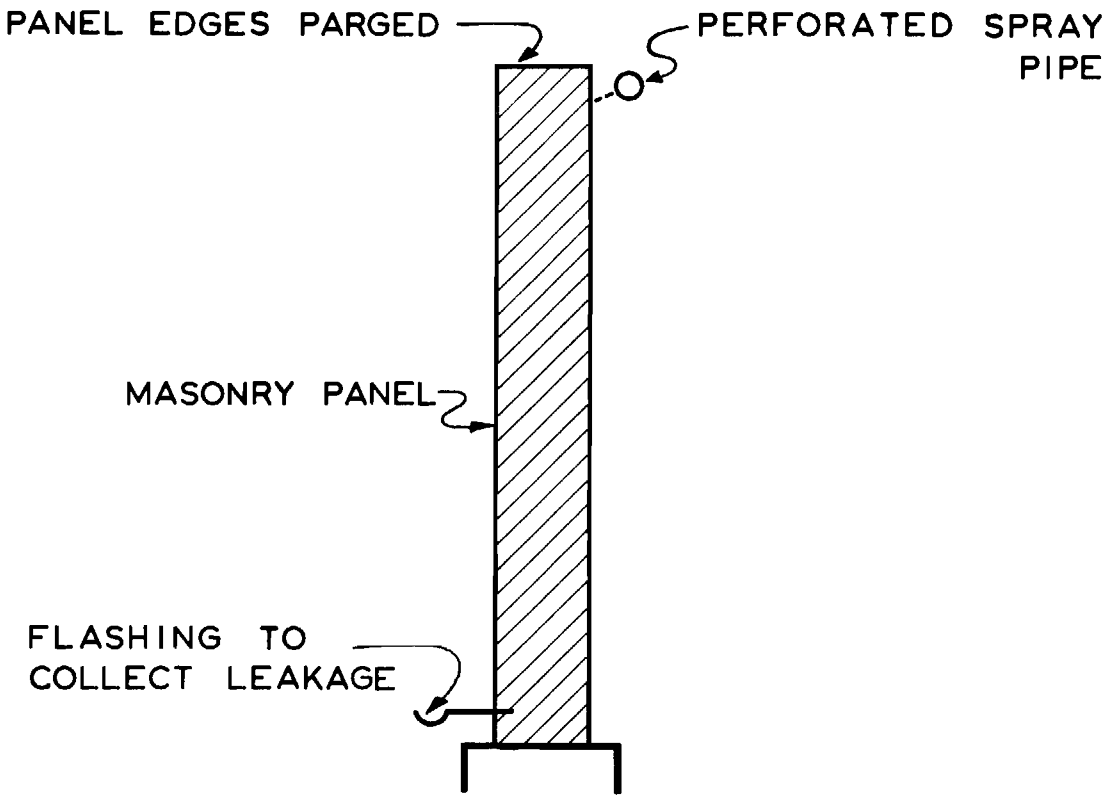


FIGURE 3

"CAPILLARITY" TEST AT U.S. NATIONAL BUREAU OF STANDARDS

(FISHBURN, WATSTEIN AND PARSONS[4])

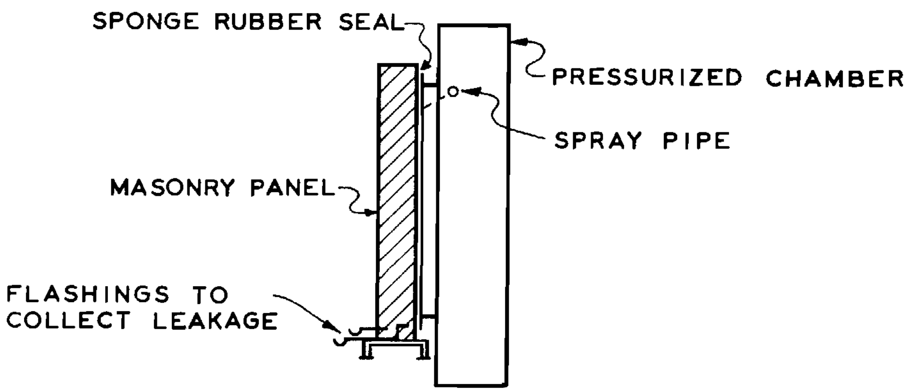


FIGURE 4

SCHEMATIC DRAWING SHOWING THE TYPE OF APPARATUS USED FOR THE HEAVY-RAIN TEST AT THE U.S. NATIONAL BUREAU OF STANDARDS
(FISHBURN, WATSTEIN AND PARSONS[4])

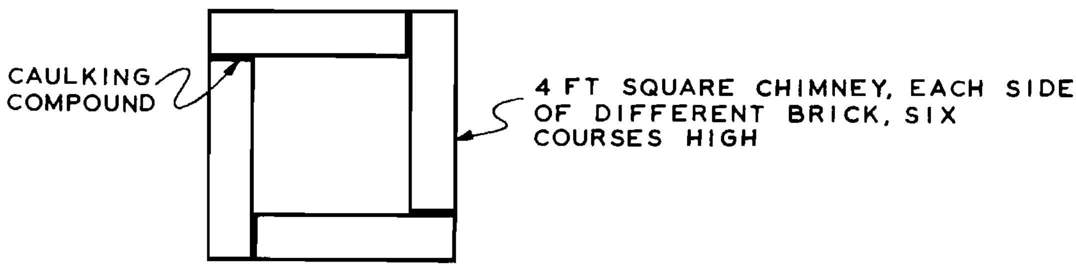


FIGURE 5

BRICK CHIMNEY USED BY THE DETROIT EDISON COMPANY
(THORNTON[10])

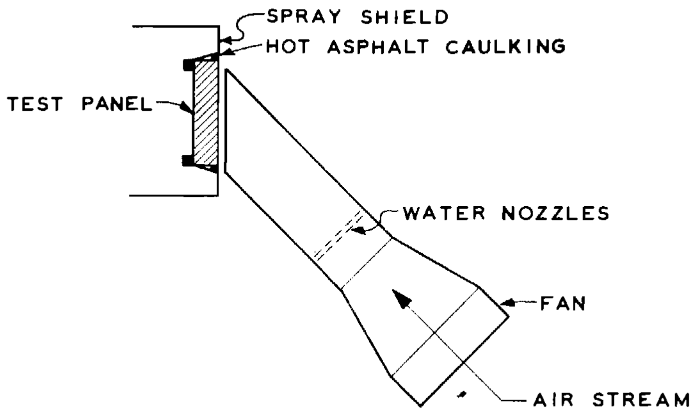


FIGURE 6

TYPE OF APPARATUS USED BY THE PORTLAND CEMENT ASSOCIATION (COPELAND AND CARLSON [12])

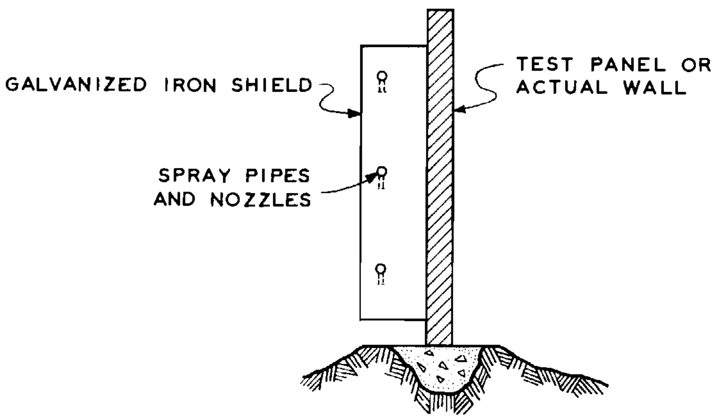


FIG 7A

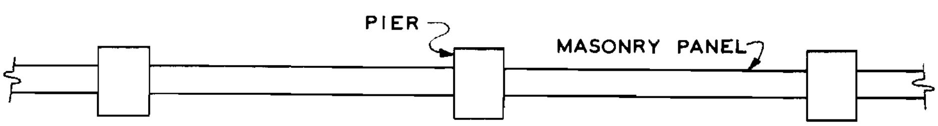
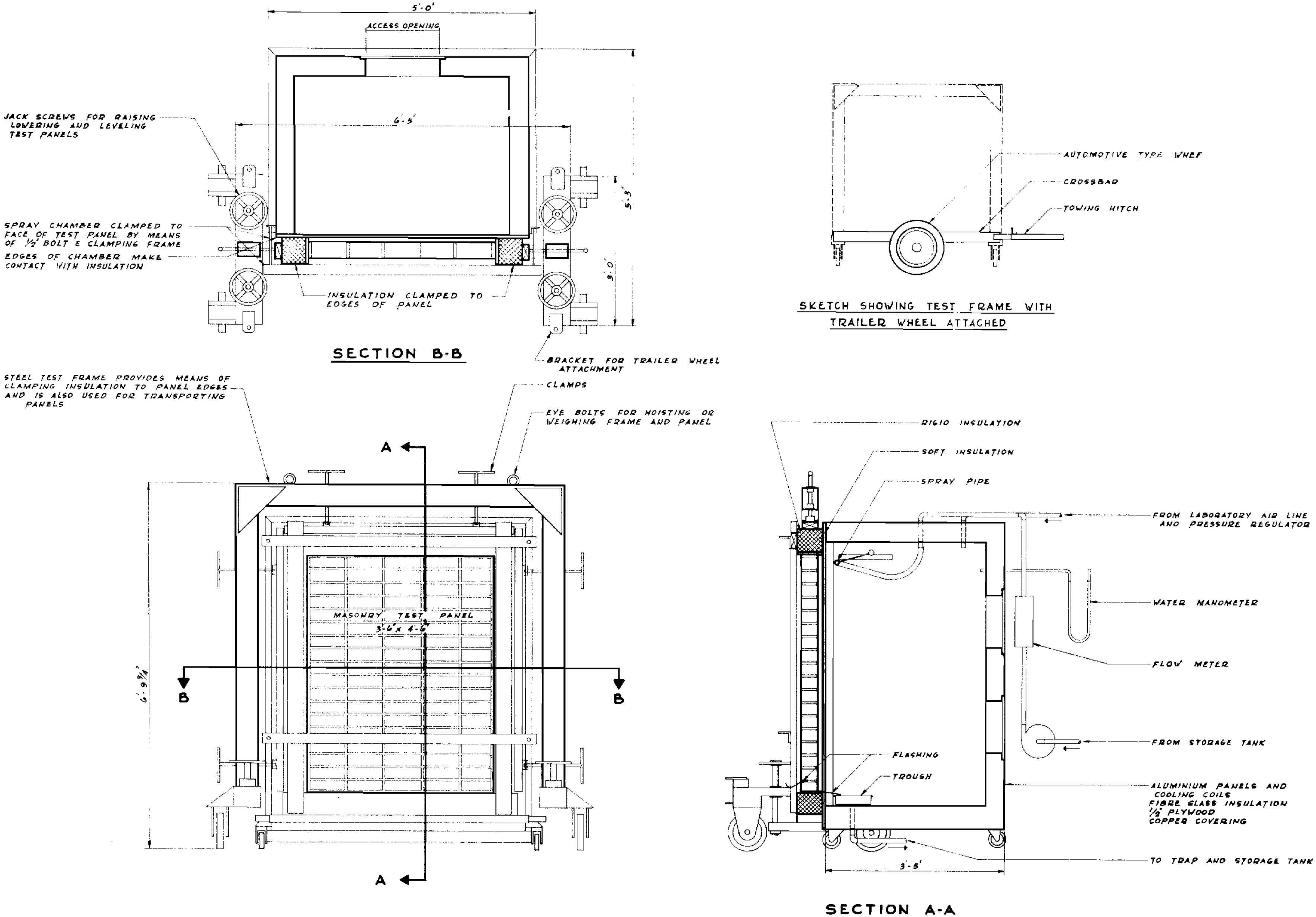


FIG 7B

FIGURES 7A & B

SCHEMATIC DRAWING SHOWING THE TYPE OF APPARATUS USED BY THE SOUTH AFRICAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (JOUBERT [11])



NOTE:

TYPICAL MASONRY TEST PANEL SHOWN WITH TEMPERATURE CONTROLLED CHAMBER CLAMPED TO ONE FACE ONLY. PROVISION IS MADE FOR CLAMPING A SECOND CHAMBER TO THE OPPOSITE FACE WHEN DESIRED.

FIGURE 8

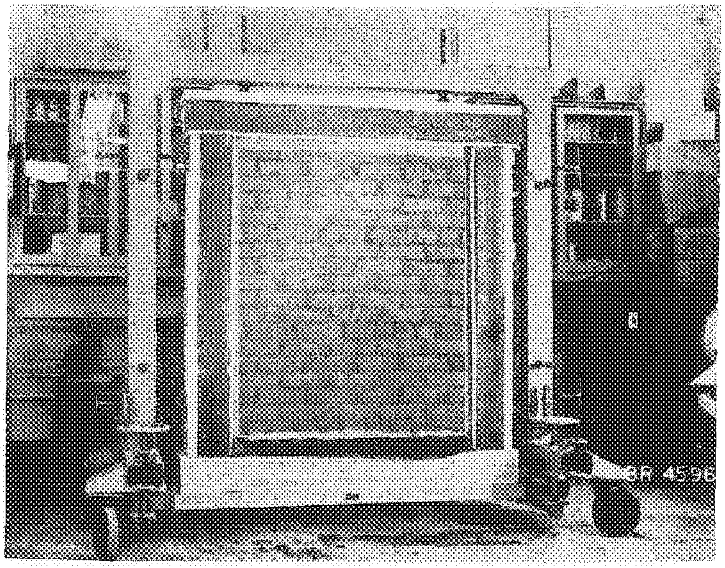


Fig. 9 Panel in frame ready for test.

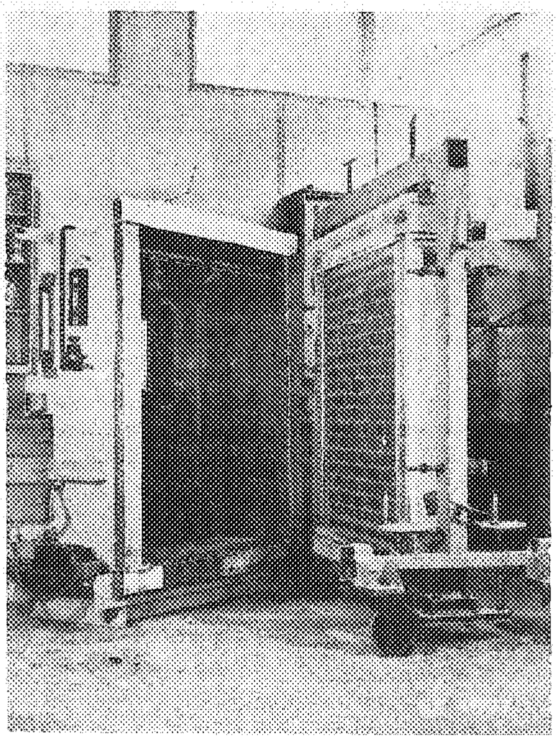


Fig. 10 View showing interior of temporary spray chamber, water pump, water flow meter, manometer, air pressure regulator and a test panel about to be installed for test.

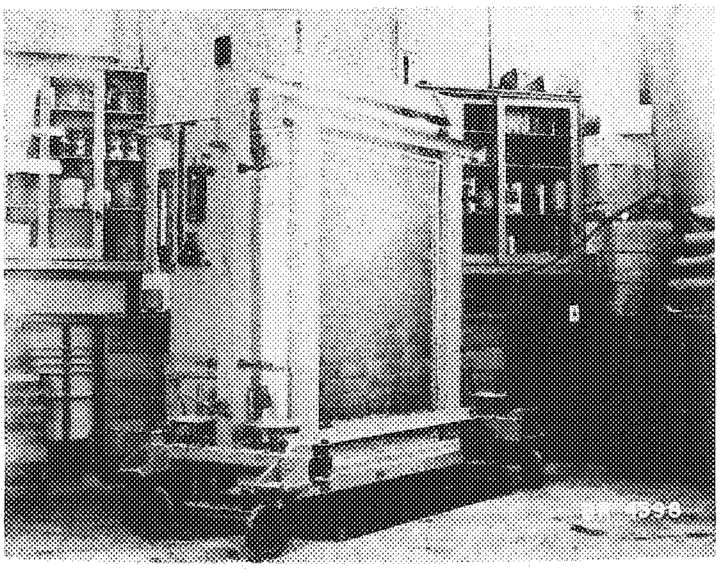


Fig. 11 Panel clamped to spray chamber and under test.