DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BUILDING RESEARCH STATION

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REPORT ON THE AIR-AND WATER-TIGHTNESS OF WOODEN WINDOWS

(Rapport sur l'étanchéité à l'air et à l'eau des fenêtres en bois)

by
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Report, Centre Technique du Bois, April, 1962.

Translated from the French

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Report on the air-and water-tightness of wooden windows

Numerous purely theoretical, as well as practical studies have been made on the air-tightness and water-tightness of windows. The tests made up to the present time in these two fields (air and water) which are inseparable in practice for windows, are liable to become partly out-dated because of several recent factors which have crept into modern constructions. The technique in the construction of wooden windows allows for boldness, and the pressing needs of new dwellings sometimes tend to confuse the information on the problem of window-tightness.

(i) Large buildings are being constructed on more and more exposed sites; for example, on the edge of and facing the sea, or on hills overlooking a city which can no longer be extended into the valley.

(ii) The height of these buildings does not cease to grow: 10, 15 or even 20 storeys, without omitting the higher tower blocks intended for the transmission of radio waves or for use as offices.

(iii) Finally, in order to gain space or to incorporate prefabricated curtain walls, the architect may often reduce or even omit window recesses.

The wind velocities hitting the windows of modern buildings create pressures and depressions which are considerably greater than those existing around lower buildings. A constant precipitation at a given time, in conjunction with these higher pressures produces completely different effects on the window casements. Therefore the conditions for using the building become more severe, and require a more efficient water-tightness and air-tightness than ever obtained before. These problems will be described in this Report. Tests on prototypes are becoming more and more essential in order to remedy these faults and to know the behaviour of windows within the new framework of construction. For this reason the Technical Centre for Wood has a special laboratory performing air-tightness and water-tightness tests.

Two aspects of this problem may be considered:

(i) - The standards and testing procedures used at the present time.

(ii) - The apparatus used for these tests at the Technical Centre for Wood and the results obtained.

I. THE PRESENT STANDARDS AND TESTING PROCEDURES

A. Air-tightness

(a) Abroad - We have made contact with the Belgians who have carried out the following tests:

1st series: Five times in a row the pressure was varied between 0 and 50 mm. of water, and 50 and 0 mm. of water (a pressure of 50 mm. of water corresponds to a wind velocity of 102 km./hr.). This preliminary step allows the hinges and various window fittings to assume their final position.

2nd series: After the first test, the leakage is measured for pressure differences of 2, 5 and 10 mm. of water between 0 and 50 mm., and between 50 and 0 mm. of water.

3rd series: A test approximating hurricane conditions is performed by applying a pressure of 100 mm. of water, which corresponds to a wind velocity of 144 km./hr. In order to take into account the permanent deformation resulting from the "hurricane" test, the second series of tests is repeated.

This whole cycle of tests on pressure is also carried out on depression, but the holes for draining the water are closed off. The Belgian standards prescribe a maximum air flow (in m^3/hr./linear meter of the joint), for a pressure differential of 10 mm. of water, of $6m^3$/hr. under pressure as well as under suction (depression).

In addition the Belgian values agree with certain foreign prescribed values (German in particular).

(b) In France - For the time being the French Standardization Association (AFNOR) still has not fixed the standards for air-tightness tests on windows. Nevertheless, the Technical Centre for Wood established the following cycle of tests:

1st series: The escape of air is measured:

(a) for an air pressure of 1 mm. of water (wind vel.: 14.4 km./hr.)
(b) for an air pressure of 5 mm. of water (wind vel.: 32.2 km./hr.)
(c) for an air pressure of 10 mm. of water (wind vel.: 46 km./hr.)

The air flow from the window is measured in m^3/hr. per linear meter of the joint.

2nd series: the same procedure is repeated again after tests on water-tightness; i.e. after a slight, but real modification in the wood.

The average of the flows recorded during these two series of tests gives the air-tightness of the window.

In the course of these tests the air flow is recorded in m^3/hr. per linear meter of the joint; however, at present there exists an official window classification established by the Technical Institute of Building and Public Works (I.T.B.T.P.); it is based on an air flow in m^3/hr. per square meter of the openable surface, under a pressure of 1 mm. of water. This classification is the following:

0 - 3 m^3/hr./m^2	...	Class A	-	Special category
3 - 10 m^3/hr./m^2	...	B	-	good
10 - 30 m^3/hr./m^2	...	C	-	normal
30 - 100 m^3/hr./m^2	...	D	-	acceptable
100 and more	...	E	-	inacceptable

[T.N.: 1 m^3/hr./m^2 = 3.28 ft.^{3}/hr./ft.^{2}]

B. Water-tightness

As far as we know, the Belgians made no tests on water tightness in 1960.

In order to increase the accuracy of the results on water-tightness the Technical Centre for Wood considered the possibility of performing these tests in 4 successive stages:

1st stage: Flow of 0.75 l/min/m^2 of open surface without wind for 15 mins.

2nd stage: Water flow of 0.75 l/min/m^2 with a wind velocity of 32 km./hr. (5 mm. of water) for 5 minutes.

3rd stage: Water flow of 1.5 l/min/m^2 with no wind for 15 mins.

4th stage: Water flow of 1.5 l/min/m^2 with a wind velocity of 32 km./hr. (5 mm. of water).

During each test the following are recorded: the case of leakage, time, the place and seriousness of water leakage which may arise on the internal surface of the window.

II. APPARATUS USED AT THE TECHNICAL CENTRE FOR WOOD

RESULTS OBTAINED

A. Initial equipment - Test saisson

For several years air-tightness and water-tightness tests have been made by the Technical Centre for Wood using the flow method and according to the method described above with the help of a test caisson.

CAISSON - The tests were accomplished with the help of an air-tight caisson made of steel whose dimensions are:

length	:	2 m 50
height	:	2 m 35
width	:	0 m 52

One of the faces of this caisson (2 m 50 x 2 m 35) is open and the test windows are fixed on it. Since the windows have very diverse dimensions, the gap between the window and the edges of the frame is closed by means of plywood (15 mm. thick) which is nailed and joined with putty to the window and the caisson. Three openings are used: the first for the inlet of air; the second for the inlet of water; and the third for the removal of water. The latter is filled with putty during air-tightness tests.

This caisson consists of:

(a) - an external fan:

The air pressure is produced by a fan whose maximum output is 200 m^3/hr. With this installation this flow assures a maximum pressure of 40 mm. of water (i.e. a wind velocity of 90 km./hr.) for the specially tight windows.

(b) - a water spray-tube inside the caisson:

The water is atomized along the top of the window with the help of a horizontal spray tube having 1 mm. holes at 2 cm. intervals. The water enters the tube under pressure corresponding to the flow assigned for the test.

During the tests, the angle of incidence of the rain varies with the wind velocity; however, this angle does not exceed 45°. The advantage of this value is that approximately the same flow of water is maintained along the vertical surface.

However, the solution which we have adopted up to now has certain disadvantages:

- on the major portion of the window, the rain is in the form of trickles;

- preferential zones of run-off are formed on the window so that the water does not behave like a continuous film (however this phenomenon also appears in current practice);

- therefore, the flow of water along a window cannot be reproduced in the same way for all windows;

- undoubtedly, it is not true to reality that the amount of rain on 1 m^2 of window surface should be thrown on a horizontal strip.

(c) - measuring devices:

The air blown by the fan passes through a series of rotameters graduated from 0 to 20 m^3, 20 to 100 m^3 and 100 to 200 m^3. The pressure inside the caisson is measured by means of an alcohol manometer graduated in tenths of mm. of water up to a maximum of 40 mm. of water. The amount of water is measured by a simple flow meter graduated from 0 to 10 l/min with an accuracy of $\pm$ 1/5 l.

RESULTS OBTAINED

1. Air-tightness

As an example, we give the over-all results obtained on 70 windows of different types subjected to a pressure of 10 mm. of water (wind velocity: 46 km./hr.). Most of these windows were of the "French" type in two sections; the rest consisted of various types: sliding, pivoting, etc.

The windows were tested just as they were received (varnished or painted) without any preliminary touch-ups before the test. The results of classifying these 70 windows had the following distribution:

6	windows	transmitted	between	0 and 5 m^3/hr./linear m of the joint;	i.e.	9%
20	"	"	"	5 and 10 m^3/hr./linear m " " " ;	i.e.	28%
20	"	"	"	10 and 15 m^3/hr./linear m " " " ;	i.e.	28%
12	"	"	"	15 and 20 m^3/hr./linear m " " " ;	i.e.	18%
9	"	"	"	20 and 30 m^3/hr./linear m " " " ;	i.e.	13%
3	"	"	"	20 and 35 m^3/hr./linear M " " " ;	i.e.	4%

[1 m^3/hr./m = 10.77 $ft.^3$/hr./ft.]

2. Water-tightness

On 40 windows tested with artificial rain, it was established that:

8	windows	had no leakage throughout the 4 stages of the test;	
8	"	leaked during the 4th stage;	
4	"	" " " 3rd stage;	
8	"	" " " 2nd stage;	
12	"	" " " 1st stage.	

The causes of either air or water leakage are very diverse; nevertheless, there often are very definite correlations between air-tightness and water-tightness. For this reason (in our opinion) these tests are inseparable for the testing of windows.

As a result of those tests, the main causes of various types of leakage may be given:

- a poor overlap between the window casing and the free section due to insufficient tightness of the hinges;

- a poor fit between the bead and the groove;

- oversight of a continuous flow of water to the outside; this is explained by:

(a) escape grooves not reaching at least the stile of the casing,
(b) escape grooves with a too small cross-section,
(c) non-existence of drips at the bottom of the groove in the stile of the casing.

As a result, the various defects mentioned could be eliminated from some of the products tested, and for this reason, although the tests are empirical, they have led to improvements in various types of modern windows.

B. Second device - the test wall

With the initial equipment a maximum wind velocity of 90 km./hr. could be attained. However, this velocity is insufficient for "hurricane" tests on the one hand, and for tests on air-tight windows subjected to winds of 100 km./hr. and greater, on the other. (Wind velocities of that kind have been recorded under the most unfavourable conditions). A large wind tunnel containing a small facade with a window appeared to be too cumbersome. In addition, certain depressions along the facades cannot be reproduced in a wind tunnel, and for this reason, the results would be rather difficult to interpret.

Therefore, the Technical Centre for Wood tried the Belgian solution of using a test wall; this apparatus which is now barely completed consists of:

(a) - a wall

Provided with an additional plywood framework covered with rubber the window frame is placed against a vertical, plane, reinforced concrete wall (6 m x 4 m). Bolts are soldered on to the ends of steel cylinders which are embedded in the concrete when it is poured; these make it possible to screw in the threaded coupling rods.

Anchor plates which rest against the window and clamp it, are bolted by these coupling rods. The window placed in this way forms a caisson which is air-tight on all sides, except on the side of the wall containing an opening (30 cm. in diameter) for the entry of air under variable pressure.

(b) - an equalibration chamber

The blown or aspirated air is equalized in a 4 m^3 equalibration chamber adjacent to the testing wall (see diagram). Here ends the tube network coming from the fan.

(c) - a fan

The fan has a maximum air flow of 8000 m^3/hr. with absolute air-tightness at a pressure of 300 mm. of water. In practice a pressure of about 240 mm. of water (i.e. wind velocity of 223 km./hr.) is the maximum available for the tests. This device works as a blower or as an aspirator in order to create pressures or depressions.

(d) - water pipe

The water is atomized into fine droplets near the top of the window by means of a pipe containing nozzles in the shape of cones.

(e) - measuring devices

A gauge arranged on the plane surface of the wall inside the caisson gives the pressure reading.

Acting as an opening in a thin wall, a diaphragm is placed on the air inlet pipe inside the equalizing chamber. It reduces the cross-section of the air-inlet by a predetermined ratio, and thus creates a loss of head. This loss of head corresponding to a given air flow is measured automatically by means of two pressure gauges placed before and after the diaphragm. A series of three diaphragms makes it possible to cover the entire range of wind velocities useful for the tests. A flow meter measures the amount of water atomized in the course of the test.

The installation of the testing wall has not yet been completed; only the measuring devices have not yet been installed.

Nevertheless, tests have been made with the help of rotameters in the initial caisson. The maximum pressure measured with these devices was 110 mm. of water (i.e. a wind velocity of 150 km./hr.). Verification tests on a glazed door tested in the initial apparatus gave exactly the same results as the wall tests.

For the time being we cannot give any results of tests made with this new wall. Nevertheless, after a few preliminary tests it appears that this apparatus will measure the high forces to which the windows of some very tall, modern buildings are subjected. The pressure-depression cycles act on the whole system (uprights, hinges, etc.) and have a definite effect on the air-and water-tightness. Undoubtedly, this will lead to important modifications in the construction of modern window frames, and particularly in the field of water-tightness; one improvement may be the use of a covering with Neoprene rubber joints which seemed to give appreciable improvements in the initial tests.

Following the tests made with this wall, we will undoubtedly be forced to revise the general testing conditions in order to establish the necessary standards for the future. These should yield window frames which will be as air-and water-tight as possible and take into account the present evolution in modern constructions.

Paris, April 13th, 1962.

A. Villiere,

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Testing Service of the
Technical Centre for Wood.

Appendix I

Information on precipitation in France

In order to get an idea of the water flow which should be used in water-tightness tests on windows, the Technical Centre for Wood made inquiries at the Meteorological Service for the Paris region.

Precipitation measurements could be obtained for various large cities of France, but these measurements were expressed in different ways: total annual precipitation, distribution according to months of the year, etc. Usually this information is of very little interest for a water-tightness test when the rain lasts 15 minutes, for example.

The highest average precipitation lasting 15 minutes was sought over a ten year period. For three different cities in France, the maximum values obtained indicated the following flows (in 1/min. per m^2 at ground level) corresponding to rains lasting 15 min:

1. Paris Montsouris (from pluviometric observations over 60 years)

   Record: 2 1 16/min/m^2
   Average over ten years: 1 1.76 for 15 min. (i.e. 100 1/m^2/hr.).

2. Lyon (from observations made over 15 years)

   Record: 1 1 17/min/m^2
   Average over ten years: 1 1. for 15 min. (i.e. 60 1/m^2/hr.).

3. Nantes

   Record: 1 1 00/min/m^2
   Average over ten years: 0 1.78 for 15 min. (i.e. 46 1/m^2/hr.).

The record values are obviously exceptional and are not attained every year; nevertheless, in laboratory experiments it would not be abnormal to require values based at least on the ten-year averages. There is nothing wrong with requiring test conditions which are slightly worse than reality.

Appendix II

Various coatings have been tested, including fast-drying oils, phenolic oil varnish, glycerophthalate varnish, various paints with pigments such as aluminium, mica, etc.

It is usually agreed that the waterproofing efficiency of a layer of these various products decreases very rapidly in a humid atmosphere. (the most important effect). In most cases it is reduced to zero at the end of ten days. On the other hand, a very marked increase is noted in the waterproofing efficiency of 2 layers; it is almost doubled. The increase is small in going from 2 to 3 layers.

For water the growth is slight in going from 1 to 2 layers during the initial hours, but the efficiency is almost doubled over 48 hours.

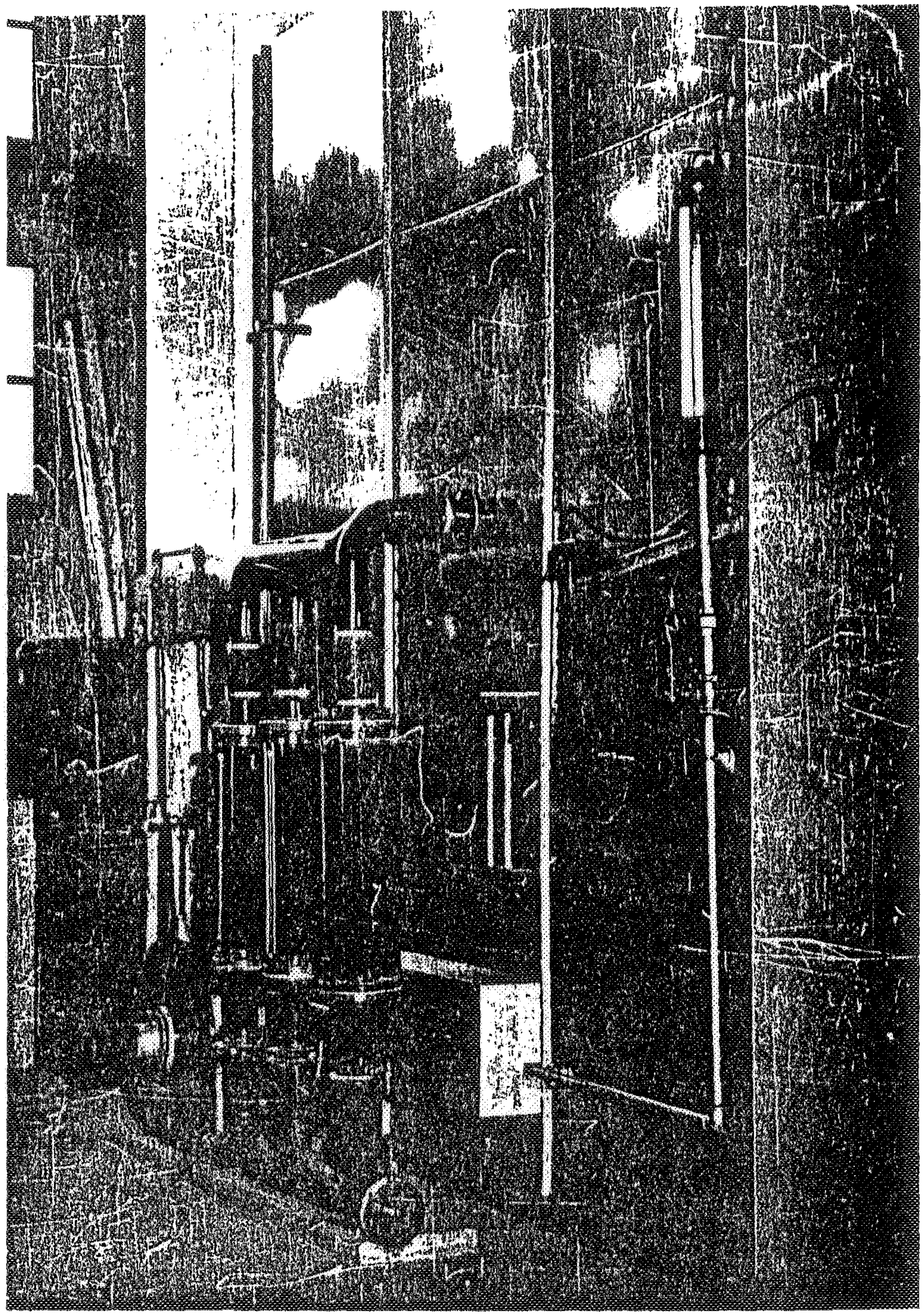
Out of the various products tested up to the present, the best results were obtained with:

- varnish: of the glycerophthalate and the phenolic oil type

- paints: with quantities of aluminium and mica.

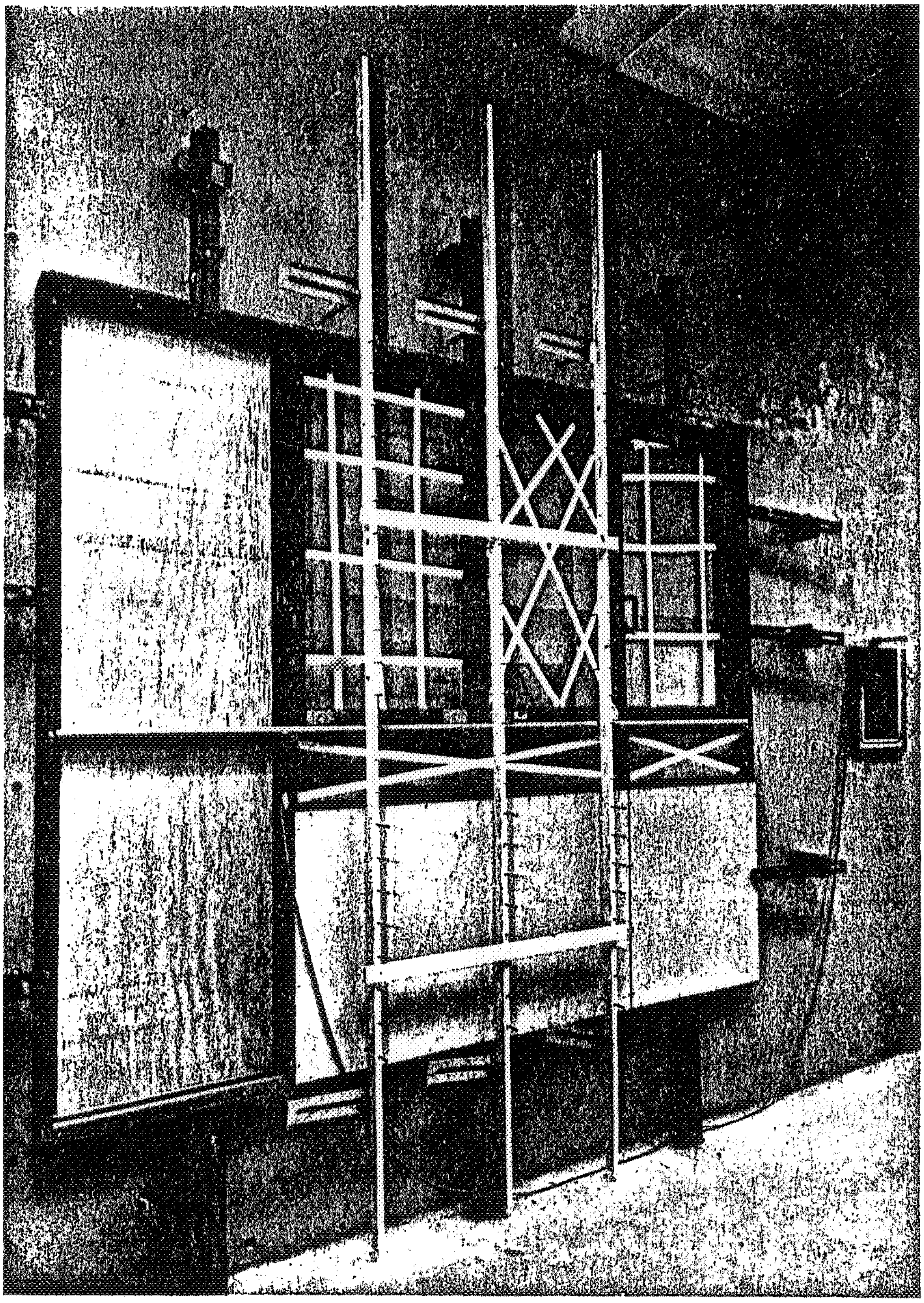
TEST CAISSON

Front view



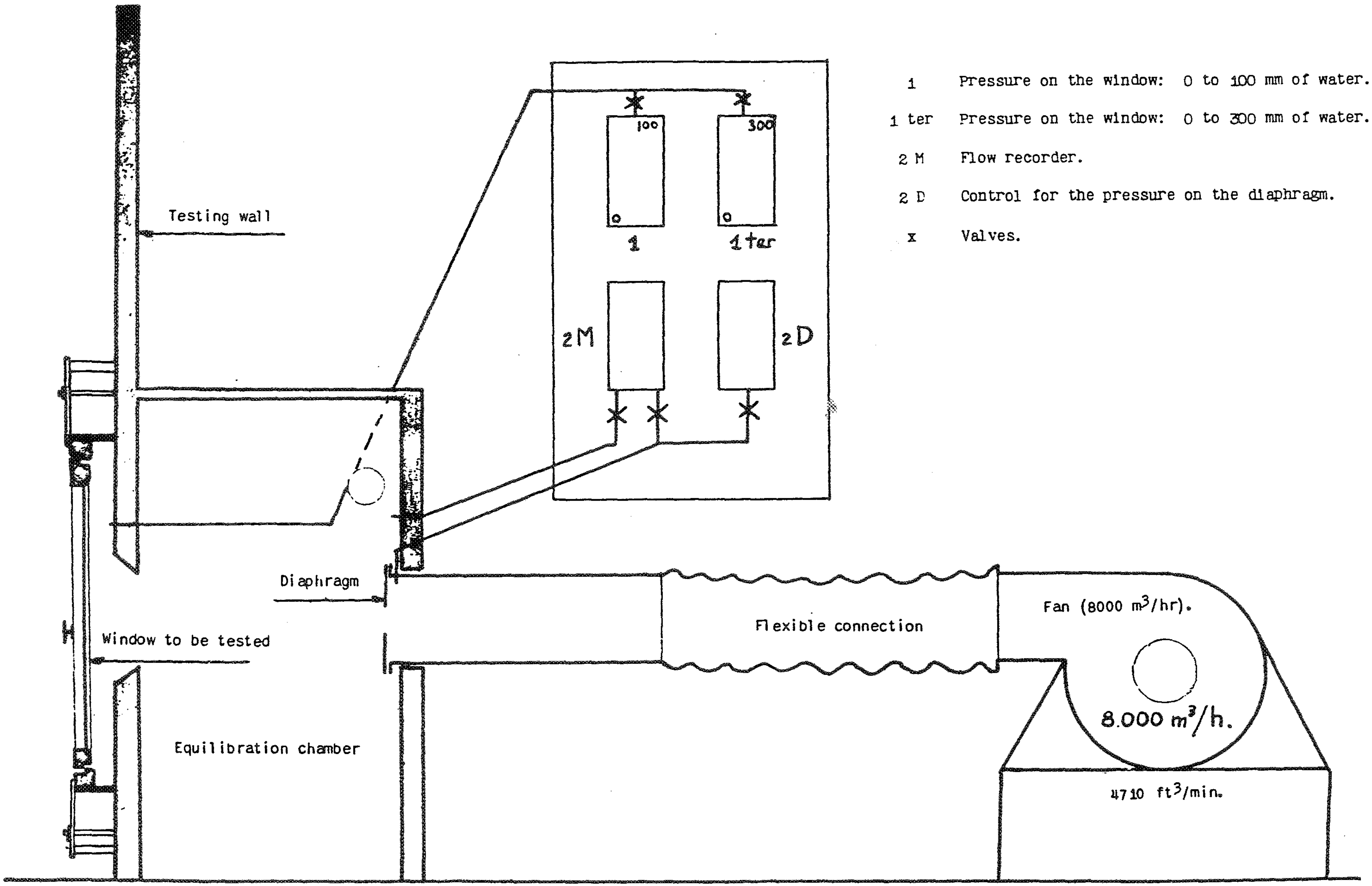
TEST CAISSON

Rear view: Fan
Rotameters
Manometer
Flow meter



TESTING WALL

Front view



SCHEMATIC DIAGRAM OF THE TESTING WALL