study as this ought to be based upon conditions prevailing during a single day of maximum or extreme conditions, or whether it should be based, as we have suggested here, upon a total of several hours during which the wind velocity was up to or above a certain selected level, that is an important question. If you consider the situation from the standpoint of performance, it would seem that you would have to base it upon some such arbitrary factor or time, as we have chosen. If you would want to examine an actual system that is already in operation, then it would be perfectly logical, of course, to observe during that day when the extremes prevailed.

In answer to Professor Larson's question, we have a record of the outside temperature along with wind velocity, but there seemed to be no obvious relation between the two. Of course, with the lower temperature and the same velocity, the inertia or impact effect of the wind is greater. The amount of infiltration, however, is not different with the lower temperature and therefore higher density, but, of course, the weight of air is somewhat different. We did not think this would make a great deal of difference.

The tube used was simply pushed through a hole in the wood strip under the sash, the end of the tube being flush with the outside surface of the board, so that it collected, so to speak, the dynamic pressure that was produced by the wind. It did not of itself produce or result in any localized static pressure as a result of the wind blowing across it, or at same angle to it. It simply, as I see it, collected the static pressure that existed at the exterior of this window due to the dynamic effect of the wind blowing, together with any natural static pressure that prevailed there.

In answer to Miss Ingels' question, we took no measurements of the quantity of air flowing through the gravity flues. We simply took a record of pressure differences as they existed in the two rooms and, these gravity flues would readily account for the displacement of those two pressure difference curves in relation to the wind. They would account for the fact that at zero velocity we found no vacuum on the outside with respect to that inside.

Again, referring to Mr. Nicholl's question, there has already been done a very extensive amount of laboratory work in the determination of the amount of infiltration that will take place through openings or cracks in windows and doors, with certain specified pressure differences applying, and curves and tables present the relation between the quantity of infiltration and the pressure differences. However, I do not see how in any way you could in the laboratory decide upon the question as to what wind velocity you were going to use in applying or making use of the tabular values resulting from the laboratory experiments. It seems to me that must be obtained from statistical data with respect to the observatory records.

MR. NICHOLLS: You have to do some intelligent guessing, you mean?

PROFESSOR EMSWILER: Mr. Lewis and Mr. Harding presented very interesting phases of this same question and I am sure that we all look forward with anticipation to the results that are available when they have been finished. However, the only record which we were interested in was the pressure difference across the window. We are continuing this experiment and possibly may have some more to present at some later time.

No. 851

AIR INFILTRATION THROUGH VARIOUS TYPES OF BRICK WALL CONSTRUCTION[1]

By G. L. LARSON[2] (*MEMBER*), D. W. NELSON[3] (*MEMBER*), *and* C. BRAATZ[4] (*NON-MEMBER*), MADISON, WIS.

The results of cooperative research between the University of Wisconsin and the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

INTRODUCTION

SINCE the fall of 1927, a program of cooperative research concerning air-infiltration through various types of brick wall construction, sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the University of Wisconsin, has been in progress. The first results of this research appeared as a paper entitled, Effect of Frame Calking and Storm Windows on Infiltration Around and Through Windows, which was presented at the Semi-Annual Meeting of the Society in June, 1928. Preliminary to the report contained herein, a second paper entitled Air Infiltration Through Various Types of Brick Wall Construction, was presented at the Annual Meeting of the Society in January, 1929.

This report is in conclusion to the latter paper and contains results obtained on plain, plastered, and painted brick walls.

DESCRIPTION OF APPARATUS

The test equipment used to determine air leakage or infiltration is shown in Figs. 1 and 2. Briefly, it consists of the following: The pressure chamber, *A*, and the collecting chamber, *B*, between which the wall is placed. The joints between the steel channel frames, in which the walls are constructed, and the chambers *A* and *B*, were made air tight by clamping a rubber gasket between the flange of each chamber and the corresponding flange of the steel frame, in a manner which is shown in Fig. 2. To facilitate setting up a wall for testing, the collecting chamber side of the machine is mounted on a small four-wheel truck which can be moved back about 10 ft from the pressure chamber on a narrow gage track.

Artificial wind pressure is produced by a small motor-driven blower, shown

[1] Final report on Brick Wall Construction, preliminary report of which is published in A. S. H. V. E. TRANSACTIONS, 1929.
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at the extreme left of Fig. 2. The pressure drop through the wall was controlled by means of a damper on the intake of the blower, a relief damper, *D*, and a sliding damper, *E*, located in the connection between the blower and the pressure chamber, at right angles to the flow of air. The pressure drop through the wall, from which the corresponding wind velocity was computed, was measured with an inclined draft gage *F*.

The amount of air which filtered through a wall was measured by interchangeable orifices mounted at the end of orifice box, *C*, and ranging in size from $\frac{3}{8}$ in. to $1\frac{3}{4}$ in. in diameter, accurately machined in accordance with Durley's[5] specifications. A coefficient of 0.6 was applied to all orifices, in conformity with Durley's results. The accuracy of the small size orifices was checked by means of a gas meter. A Wahlen gage, *G*, was used to determine the

FIG. 1. GENERAL LAYOUT OF TEST EQUIPMENT

pressure difference existing between the orifice box and the atmosphere, into which the measured air was discharged.

GENERAL DESCRIPTION OF WALLS

All walls were built into frames constructed of 15 in., 33 lb steel channels as shown in Fig. 2. The A-shaped frame which appears in the foreground, together with a single roller jack arrangement, attached to the other end of the wall, provides a convenient means of transporting the walls between the test machine and the storage rack, shown in Fig. 1.

Two types of brick were used in the construction of these walls—a hard face brick and a more porous type, commonly known as Chicago clay brick. Water absorption tests were conducted on samples of each type of brick by the National Bureau of Standards, the results of which are tabulated in Table 1. The average dimensions of the hard brick in inches, in the order: Length, width and thickness, were $8\frac{1}{8}$, $3\frac{3}{4}$, $2\frac{11}{32}$, and for the porous type, $8\frac{1}{16}$, $3\frac{9}{16}$, $2\frac{5}{16}$. The average thickness of the vertical and horizontal mortar joints for all of the walls was approximately $\frac{1}{4}$ and $\frac{1}{2}$ in. respectively.

Three of the walls were slushed with cement-lime mortar; the others with

[5] On the Measurement of Air Flowing into the Atmosphere Through Circular Orifices in Thin Plates and Under Small Differences of Pressure, by R. J. Durley. Volume 27. *Transactions, A. S. M. E.*

lime mortar. The walls were constructed such as to differentiate between good and poor workmanship. Each of these terms is defined as follows:

Cement-lime mortar: One of cement, one of lime and six of sand by volume, and enough water to make the mixture workable.

Lime mortar: One of lime and three of sand by volume and enough water to make the mixture workable.

Workmanship: Good workmanship is distinguishable from poor workmanship only in the manner of using the mortar. In good workmanship, the spaces between the bricks are completely filled with mortar throughout the thickness of the wall, resulting in a wall which is practically free from voids. In poor workmanship, very little mortar is used between the two outside faces of the wall. The outside appearance of these walls is the same. Fig. 3 is intended to show this difference in workmanship. The poorer wall appears in the foreground.

The walls were constructed by bricklayers from the Service Department of the University of Wisconsin in a manner comparable to actual building construction practice. Prior to their construction, which took place during the month of February, the bricks were stored out-of-doors. In the opinion of the bricklayers, the brick contained the proper amount of moisture, and the addition of more moisture by soaking was deemed unnecessary.

With the exception of Wall No. 2, the mortar joint between the bricks and the steel channel frame was completely calked with a plastic calking compound, on both sides of all walls. Fig. 4 shows the effect of calking one or both sides of this joint for Wall No. 2. The net area of each wall, excepting No. 7, was 50 sq ft.

PROCEDURE

Each of the walls was subjected to wind pressures corresponding to wind velocities ranging from about 5 to 30 mph. With the exception of Wall No. 7, which stood for eight months before testing, the original tests of all plain brick walls were made after an aging period of five months. These tests were repeated at the end of two additional months.

Walls No. 4 and No. 5 were later plastered, on metal lath and furring space, for further testing. After removal of the plaster, Walls No. 4 and No. 5 were used for the determination of the effectiveness of several kinds of paint on infiltration.

Wall No. 6 was also re-tested with an application of plaster directly on the brick, without lath.

Wall No. 7 was used only to determine the effectiveness of plaster, no tests being made on the plain brick wall.

A more detailed description of the conditions under which these tests were conducted relative to plaster composition, nature of paint, aging or drying periods, etc., is to be found in the section on Addition of Plaster and Paint to Plain Brick Walls.

DISCUSSION OF RESULTS ON PLAIN BRICK WALLS

Fig. 5 shows the results of the tests on the plain brick walls. The infiltration in cubic feet per hour per square foot of wall surface is plotted against

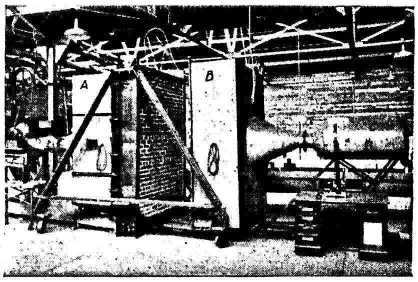

FIG. 2. MACHINE OPEN WITH TEST WALL IN PLACE

the pressure drop through the wall in inches of water. Each curve was determined from the points of two series of tests; one set of points from the original tests made five months after construction and the other from the check tests made two months later. The difference in values of the original and check tests was found to be less than one per cent for Walls 3, 4 and 6. The check tests on Wall 2 showed 7.1 per cent less infiltration than did the original tests and the check tests on Wall 5 resulted in 2.6 per cent more infiltration than did the original tests. This seems to show that there is no correlation between infiltration and the aging of the walls between the time of the original and check tests. Further, there seems to be no correlation between the humidity at the time of testing and the variation in test results. This comparison is given in Table 2.

The test results in cubic feet per hour per square foot of wall as shown in Fig. 5 are replotted in Fig. 6 against a uniform scale of velocity in miles per hour instead of against a uniform scale of pressure drop in inches of water.

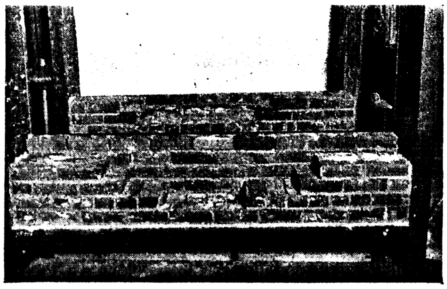

FIG. 3. BRICK WALLS UNDER CONSTRUCTION

When plotted in this way, the results show how rapidly infiltration increases with increase in wind velocity.

Table 3 gives the infiltration through the various plain brick walls for the range of pressures used in the tests and the corresponding wind velocities ranging from 5 mph to 30 mph. This table also shows a summary of the workmanship, mortar and brick for each of the walls.

The results show that Wall 6 is considerably poorer from the infiltration standpoint than the other walls. Wall 6 was constructed of porous brick and lime mortar applied with poor workmanship. By improving the workman-

TABLE 1. WATER ABSORPTION TESTS OF BRICKS

WATER ABSORPTION (TOTAL IMMERSION) AS PER CENT OF DRY WEIGHT

		1 hr cold	5 hr cold	24 hr cold	48 hr cold	5 hr boiling
Red (Hard) Brick........ 10 specimens..............	Ave.	13.1	13.7	14.3	14.8	16.9
	Max.	14.7	15.3	15.9	16.7	18.8
	Min.	10.0	10.3	10.9	11.3	13.4
White (Porous) Brick.... 10 specimens.............	Ave.	15.0	16.4	17.7	18.2	21.4
	Max.	19.9	21.0	22.0	22.6	24.5
	Min.	11.2	12.8	13.9	14.7	18.3

PENETRABILITY OF BRICK EXPRESSED AS PER CENT OF DRY WEIGHT ABSORBED IN 1 HOUR WHEN IN ⅛-IN. CONTACT WITH WATER

Per Cent Absorption					Time to Wet Through	
		End	Face	Flat	End Face	Flat
Red Brick...... 10 specimens....	Ave.	4.7	8.8	13.6	Greater than 1 hr..	33 m
	Max.	5.3	10.1	15.2	Greater than 1 hr..	50 m
	Min.	3.6	6.1	10.4	Greater than 1 hr..	28 m
White Brick.... 10 specimens....	Ave.	6.3	9.6	13.7	Greater than 1 hr..	Greater than 1 hr
	Max.	8.4	13.8	19.1	Greater than 1 hr..	
	Min.	3.8	4.8	10.4	Greater than 1 hr..	40 m

ship and using cement-lime mortar rather than lime mortar in Wall 4, the infiltration loss is cut to a little less than 50 per cent. In the case of the hard brick walls, Wall 5, the poorest, allows the passage of 37 per cent as much air as does the poorest wall built of porous brick. The best wall built of hard brick, Wall 2, allows the passage of about 70 per cent as much air as does the poorest wall built of hard brick, Wall 5. The comparison given here between the poorest and best walls for each type of brick is not strictly true, since the poorest of the two hard brick walls had cement-lime mortar as against lime mortar for the poorer porous brick wall.

Had a wall been built of hard brick, lime mortar and poor workmanship, its probable leakage would have been 4.59 cu ft per hour per square foot at 15 mph. This figure is arrived at by adding to the leakage through Wall 5 which was built of hard brick, with cement-lime mortar and poor workmanship, the difference between the leakage of lime mortar and cement-lime mortar as applied to hard brick Walls 2 and 3 (3.85 + 0.74 = 4.59). The true comparison then between the poorest and best hard brick walls would be that the best hard brick wall would have a leakage value a little less than 60 per cent of that of the poorest hard brick wall. The corresponding comparison for porous brick walls was slightly less than 50 per cent. At 15 mph, the difference between the best and poorest of the hard brick walls would be 4.59—2.71 = 1.88 cu ft per hour per square foot of wall, and for the porous brick walls would be 10.35 — 5.05 = 5.30 cu ft per hour per square foot of wall.

This comparison shows that there is a greater variation in infiltration between the best and the poorest walls built of porous brick than between those

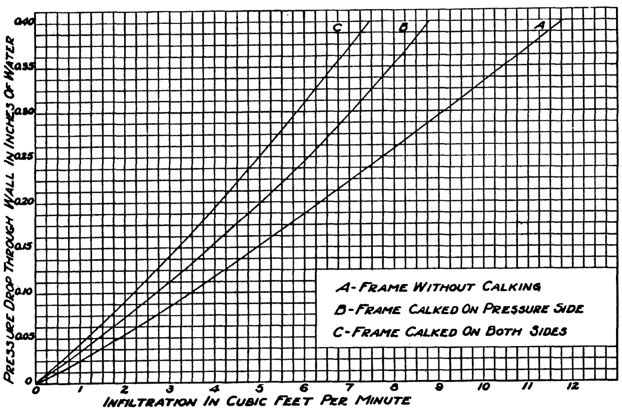

FIG. 4. EFFECT OF CALKING THE MORTAR JOINT BETWEEN THE CHANNEL FRAME AND WALL NO. 2

built of hard brick. This may be due to one of several causes. One possible cause is the variation due to chance. Were a similar set of walls to be built, the results likely would not check exactly the results of this series of tests because of a variation in materials and workmanship. Also, there is a possible cause in the psychology of good materials. A workman instructed to do equally poor work on two walls, one built of hard brick and the other of porous brick, might unconsciously do better work with the better material, the hard brick. It also seems logical to believe that two walls of good workmanship are more likely to be on a comparable basis from a workmanship standpoint than would two walls of poor workmanship, inasmuch as a completely slushed wall is more easily duplicated.

Since poor workmanship consists mainly in leaving voids between the bricks in the interior of the wall, and since the porous brick is likely to be much less uniform in density, it may be that poor workmanship allows passageways

for air through short distances from the face of the porous brick to the voids, and then out on the other face of the wall through a short distance of brick. This explanation would require that the hard brick wall passes most of the total infiltration through the mortar joints.

Another probable cause for this greater variation between the best and poorest of porous brick walls as compared to the best and poorest of hard brick walls is in the effect of the porosity of the brick on the proper setting of the mortar. It is likely that the porous brick draws the water from the

TABLE 2. COMPARISON OF HUMIDITY AND TEST RESULTS VARIATIONS

Wall No.	Av. Humidity Original Tests	Av. Humidity Check Tests	Change in Humidity Expressed in Per Cent	Variation in Test Results Per Cent
2	74.3	40.5	— 45.4	— 7.07
3	55.9	63.4	+ 13.4	— 0.27
4	77.2	58.8	— 23.8	— 0.14
5	65.4	31.7	— 51.6	+ 2.62
6	67.1	36.6	— 45.5	— 0.24

TABLE 3. INFILTRATION IN CUBIC FEET PER HOUR PER SQUARE FOOT OF PLAIN WALL

Drop in Pressure Inches of Water	Wind Vel. mph	Wall No. 2	Wall No. 3	Wall No. 4	Wall No. 5	Wall No. 6
0.012	5	0.34	0.46	0.71	0.51	1.60
0.048	10	1.30	1.64	2.36	1.83	5.30
0.108	15	2.71	3.45	5.05	3.85	10.35
0.192	20	4.59	5.76	8.31	6.34	16.28
0.300	25	6.85	8.38	12.03	9.22	23.05
0.431	30	9.31	11.30	16.00	12.40	30.80

Wall No.	Kind of Workmanship	Kind of Mortar	Kind of Brick
2	Good	Cement-lime	Hard
3	Good	Lime	Hard
4	Good	Cement-lime	Porous
5	Poor	Cement-lime	Hard
6	Poor	Lime	Porous

mortar before it has time to set and consequently causes an opening of pores and a shrinking away of the mortar from the brick surfaces. The bricks, both hard and porous, were considered by the mason to contain the proper amount of moisture for the proper laying up in the walls.

Table 1 shows the water absorption characteristics of the two kinds of brick used. It seems that the absorption test giving the best indication of the drying out effect of the bricks on the mortar would be the total immersion test in cold water for 24 hours, since the bricks are about five-sixths immersed in the mortar and 24 hours is near to the time required for proper setting of the mortar. For total immersion for 24 hours in cold water, a comparison of the figures in Table 1 shows that the hard bricks absorb 81 per cent as much water as the porous bricks. In the absorption tests, the bricks are dry to start with; in building the test walls, the bricks come in contact with mortar when they are somewhere between the dry and saturated condition. Also one face is exposed to the air. Under these altered conditions, it is not known whether the ratio of absorption for the two types of bricks would remain the same as under the absorption test conditions. The tests on air infiltration seem to indicate a greater difference in leakage through mortar applied to hard and porous bricks than the absorption tests would indicate.

The hard brick wall, with lime mortar and poor workmanship synthesized from Wall 5 and a comparison of Walls 2 and 3 would have a probable

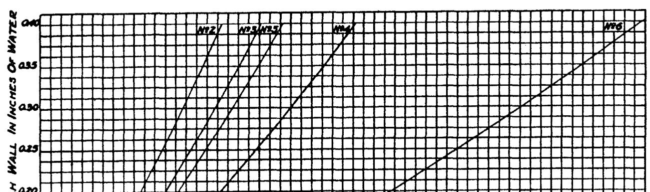

Fig. 5. Results of Infiltration Tests on the 13-Inch Plain Brick Walls

leakage of 4.59 cu ft per hour per square foot at 15 mph. This would be a wall built to the same specifications as Wall 6, except for the difference in brick. Wall 6 had a leakage of 10.35 cu ft per hour per square foot at 15 mph. The poorest hard brick wall would then have a leakage of 44 per cent as great as that through the poorest porous brick wall.

The substitution of cement-lime mortar for lime mortar in this poorest hard brick wall would reduce the leakage by 0.74 cu ft per hour per square foot of wall at 15 mph, or a saving of 16 per cent. The difference in leakage of Walls 5 and 2 gives the comparison of good and poor workmanship for hard brick walls. The saving in using the better mortar is 1.14 cu ft per hour per square foot, or a saving of about 25 per cent. The total reduction in infiltration by using the cement-lime mortar applied with good workmanship in place of lime mortar applied with poor workmanship is 1.88 cu ft per hour per square foot for hard brick walls, or a reduction of 41 per cent.

The same comparison of mortar and workmanship cannot be made separately for porous brick walls, since only two walls were tested. However, the best porous brick wall on which cement-lime mortar was applied with good workmanship has a leakage of 5.30 cu ft per hour per square foot less than does the poorest porous brick wall, which uses lime mortar applied with poor workmanship, or the reduction is 51 per cent. For hard brick, this reduction was 41 per cent. This seems to indicate that it is more important to use the best mortar and workmanship on porous brick walls than on hard brick walls. This is indicated both by the greater saving in cubic feet of infiltration and by the percentage saving. In actual construction, the item of cost would also enter in choosing material and workmanship. The hard brick is more expensive and the added cost of cement-lime mortar over lime mortar, and good workmanship over poor, would result in a smaller percentage increase in the wall cost than in the case of porous brick walls.

A hard brick wall with lime mortar applied with poor workmanship, it was found, would have a leakage of 4.59 cu ft. The porous brick wall with cement-lime mortar and good workmanship has a leakage of 5.05 cu ft. Then the poorest hard brick wall has a leakage 91 per cent as large as that of the best porous brick wall.

Addition of Plaster and Paint to Plain Brick Walls

With the completion of the original and check tests on the plain brick walls, the results of which are shown in Table 3, plaster and paint were applied to some of the walls. The walls used for these additional tests were numbers 4, 5 and 6, and were selected because of their relatively high leakage as plain walls. The same wall was used for both plastering and painting in the case of Walls 4 and 5. The work was done by plasterers and painters from the Service Department of the University of Wisconsin.

The first step taken with Walls 4 and 5 was the application of metal lath and plaster with a furring space. The thickness of the plaster was ¾ in. and the furring space was about the same. The plaster used was a gypsum plaster applied in three coats. The scratch coat consisted of two parts of sand to one part of plaster with hair. The brown coat was proportioned two and one-half parts of sand to one part of plaster with hair. The sand finish coat was made of equal parts of sand and plaster without hair. On Wall 6, three coats of gypsum plaster were applied directly to the brick. The total thickness of the plaster and the composition of the coats were the same as for Walls 4 and 5, except that the brown coat was proportioned three parts of sand to one part of plaster with hair. The walls were allowed to stand three weeks or longer after plastering before testing. The joint between the steel frame and the plaster was sealed with roofing cement.

After the tests of Walls 4 and 5 with the plaster applied were completed, the walls were stripped of the furring, lath and plaster, so that they were in their original plain condition except for the nail holes remaining in the mortar joints from the nailing of furring strips. The walls were re-tested for air infiltration and paint was then applied. All painting was done with a brush.

Three coats of exterior white lead and oil paint were applied to Wall 4 directly on the bricks. This paint was mixed in the proportions of 100 lb of white lead paste to 4 gal of linseed oil and ½ gal of turpentine. The wall was tested after the application of each coat. The first and second coats were applied with just ordinary care with no attempt to fill all crevices. The wall appeared well painted after the application of the first two coats. The third coat was put on with special effort to seal all pores and crevices. This coat was applied with much more than ordinary care. A drying period of one week was allowed after each coat before testing.

One heavy coat of cold water paint was applied directly to the bricks of Wall 5 upon removal of the furring strips, metal lath and plaster. The wall was tested after a drying period of three weeks. After the wall was tested, this coat was washed off as completely as possible with a stiff brush and water; first by hard scrubbing to loosen the paint, and then by flushing off with water.

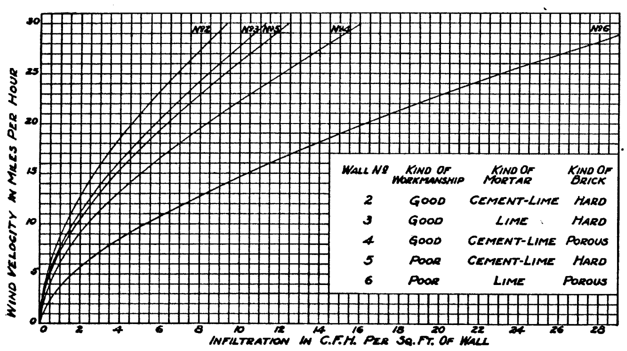

FIG. 6. CHART SHOWING HOW INFILTRATION INCREASES WITH INCREASED WIND VELOCITY THROUGH 13-INCH PLAIN BRICK WALLS

An effort was made to remove it from the mortar joints. The wall was then tested again after standing one month.

Wall 5 was then given two coats of a prepared linseed oil paint containing barium sulphate and zinc sulphide mixed with turpentine for interior use. A test was made after the application of each coat. The first coat dried for two and one-half weeks before testing; the second, five days.

No tests were made of paint applied to plaster.

The results of the plaster and paint tests are shown in Table 4 for Wall 4, Table 5 for Wall 5 and Table 6 for Wall 6. The results are shown graphically in Fig. 7 for Wall 4, Fig. 8 for Wall 5, and in Fig. 9 for Wall 6. The plain wall results before plaster was applied and after plaster was removed have been included in these tables and on the curve sheets for comparison. The one exception to this was in the case of Wall 4, where the plain wall results before plastering were left out, since the curve was almost identical to *C*, the curve for one coat of white lead and oil.

The results show that in each case plastering reduced the infiltration to a very low value. At 15 mph, plastering reduced the leakage through Wall 4 by 94 per cent, through Wall 5 by 96 per cent, and through Wall 6 by 98 per cent. It is to be expected that plaster applied directly to the brick would be more effective in preventing infiltration than plaster applied on lath with a furring space, since the furring space acts as a distributing chamber for

TABLE 4. RESULTS OF TESTS ON WALL 4

Wind Vel. mph	Drop in Pressure Inches of Water	Plain Wall	Furring Metal Lath Plaster	Plaster Removed	1 Coat White Lead and Oil	2 Coats White Lead and Oil	3 Coats White Lead and Oil
5	0.012	0.71	0.05	0.65	0.61	0.61	0.52
10	0.048	2.36	0.14	2.52	2.38	2.31	1.87
15	0.108	5.05	0.28	5.22	4.97	4.76	3.75
20	0.192	8.31	0.47	8.64	8.31	7.78	6.08
25	0.300	12.03	0.68	12.55	12.07	11.27	8.69
30	0.431	16.00	0.92	16.87	16.03	15.18	11.62

TABLE 5. RESULTS OF TESTS ON WALL 5

Wind Vel. mph	Drop in Pressure inches of Water	Plain Before Plastering	Furring Metal Lath and Plaster	Plain After Plaster was Removed	1 Coat Cold Water Paint	Cold Water Paint Washed Off	1 Coat White Oil Paint	2 Coats White Oil Paint
5	0.012	0.51	0.02	0.65	0.27	0.27	0.27	0.27
10	0.048	1.83	0.07	2.30	1.03	1.03	1.03	1.03
15	0.108	3.85	0.15	4.61	2.22	2.17	2.13	2.03
20	0.192	6.34	0.25	7.45	3.77	3.37	3.27	3.08
25	0.300	9.22	0.34	10.87	5.58	4.54	4.40	4.12
30	0.431	12.40	0.42	14.86	7.67	5.77	5.61	5.19

TABLE 6. RESULTS OF TESTS ON WALL 6

Wind Vel. mph	Drop in Pressure Inches of Water	Plain Wall	Plastered Directly on Brick
5	0.012	1.60	0.03
10	0.048	5.30	0.09
15	0.108	10.35	0.18
20	0.192	16.28	0.29
25	0.300	23.05	0.40
30	0.431	30.80	0.52

air coming through passageways in the brick and mortar. Plaster applied directly, it seems, would tend to close the passageways in the brick and mortar. The percentage figures given above seem to indicate that this is true, since the percentage reduction was the greatest (98 per cent) for Wall 6 which had plaster applied directly. Not too much reliance can be placed on the difference in these percentage reductions because of the small quantity of air being measured in the tests of plastered walls. For example, at 15 mph for Wall 5, a reduction in leakage of 0.03 cu ft per hour per square foot of wall would change the percentage reduction by one per cent. It would seem that the most difficult condition in which to secure a large reduction in leakage would be by plastering on the wall having the greatest leakage as a plain wall. Wall 6 had considerably the highest leakage as a plain wall, which seems to indicate that the greater per cent reduction for plaster applied directly to the brick is real. In service, however, a furred wall would probably have less tendency to crack from any settling occurring in the brick wall and would, therefore, better maintain its resistance to air leakage.

The application of one coat of interior cold water paint reduced the leakage at 15 mph of Wall 5 by 52 per cent. The wall face was completely covered by this coat and no second coat was applied. The reduction in leakage on

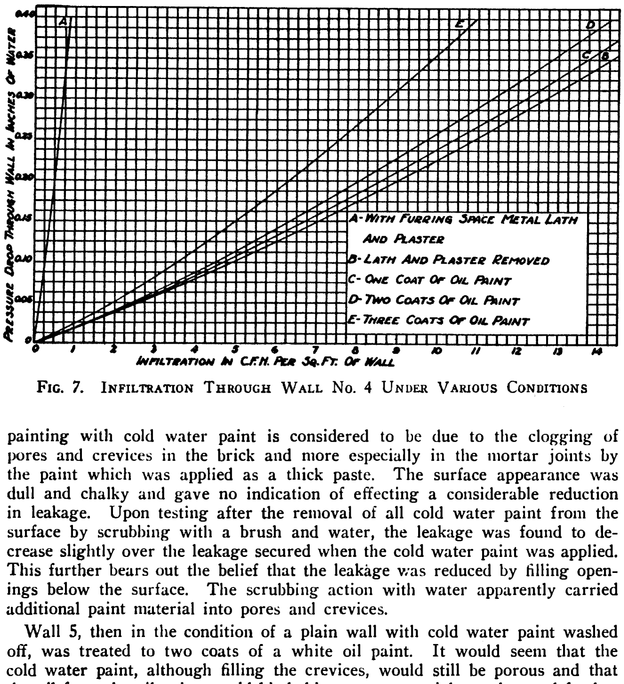

Fig. 7. Infiltration Through Wall No. 4 Under Various Conditions

painting with cold water paint is considered to be due to the clogging of pores and crevices in the brick and more especially in the mortar joints by the paint which was applied as a thick paste. The surface appearance was dull and chalky and gave no indication of effecting a considerable reduction in leakage. Upon testing after the removal of all cold water paint from the surface by scrubbing with a brush and water, the leakage was found to decrease slightly over the leakage secured when the cold water paint was applied. This further bears out the belief that the leakage was reduced by filling openings below the surface. The scrubbing action with water apparently carried additional paint material into pores and crevices.

Wall 5, then in the condition of a plain wall with cold water paint washed off, was treated to two coats of a white oil paint. It would seem that the cold water paint, although filling the crevices, would still be porous and that the oil from the oil paint would bind this porous material together and further reduce the leakage considerably. The first coat gave a reduction in leakage at 15 mph of only 2 per cent and the second coat an additional 4.5 per cent, or

a total reduction of 6.5 per cent. The application of two coats to the hard brick seemed to give a smooth and finished surface. The surface was less perfect on the mortar and it would seem that the oil paint was incapable of stopping the leakage through pores and crevices that the cold water paint had not already filled and stopped completely. White lead and oil paint applied to the bare brick surface of Wall 4 after the furring strips, metal lath and plaster were removed gave a reduction measured at 15 mph of 5 per cent for one coat and 9 per cent for two coats. The brick of this wall was a porous brick and it was observable that two coats did not cover all the imperfections in the brick, although the appearance of the surface was excellent from a

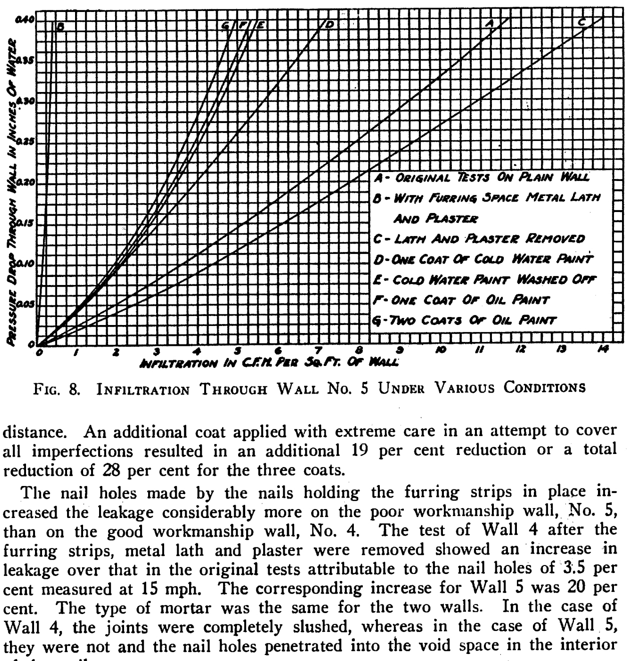

Fig. 8. Infiltration Through Wall No. 5 Under Various Conditions

distance. An additional coat applied with extreme care in an attempt to cover all imperfections resulted in an additional 19 per cent reduction or a total reduction of 28 per cent for the three coats.

The nail holes made by the nails holding the furring strips in place increased the leakage considerably more on the poor workmanship wall, No. 5, than on the good workmanship wall, No. 4. The test of Wall 4 after the furring strips, metal lath and plaster were removed showed an increase in leakage over that in the original tests attributable to the nail holes of 3.5 per cent measured at 15 mph. The corresponding increase for Wall 5 was 20 per cent. The type of mortar was the same for the two walls. In the case of Wall 4, the joints were completely slushed, whereas in the case of Wall 5, they were not and the nail holes penetrated into the void space in the interior of the wall.

Importance of Sealing Plaster

The tests show that plaster is very effective in reducing leakage to a negligible value. The condition of the plastered walls tested was most favorable to low leakage. No cracks existed in the plaster, and the perimeter against the steel frame channel members was completely sealed. In ordinary building construction, it was doubtful if the full efficiency of the plaster in stopping leakage is ever realized. There is opportunity in the case of a furred wall for the air to travel in the furring space to edges of the plaster sheet and enter the room at the edge of the wood trim such as baseboards, and also to get into the floor construction and enter the room through the flooring joints or through openings made in it such as are made for heating pipes. To obtain the full efficiency of the plaster in stopping air leakage, the plaster sheet should be sealed at all edges. At the baseboard, this would mean the

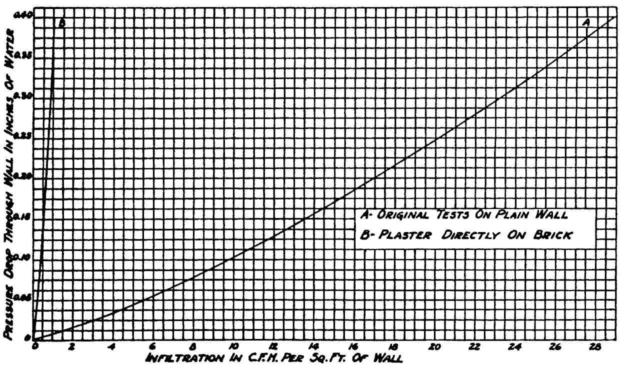

FIG. 9. INFILTRATION THROUGH WALL NO. 6—PLAIN AND PLASTERED

running of the plaster coats down to the rough floor and also filling the space between the plaster sheet and the brick wall surface with plaster. Any cracks or imperfections due to uneven settling of the building would tend to destroy the effectiveness of the plaster in stopping air infiltration.

To study the effect of imperfect sealing at the baseboard, Wall 7 was plastered and equipped with an 8-in. baseboard. The wall was built of porous brick, lime mortar and poor workmanship and was equipped with a window opening. Gypsum plaster in $\frac{3}{4}$-in. thickness was applied on metal lath in three coats, and a furring space of about the same thickness was provided. The plaster coats were stopped irregularly within an inch or two of the bottom channel, which corresponds to the floor level in building construction. The baseboard was then applied in the usual manner, except it was screwed to the grounds instead of nailed. The wall was allowed to dry one week before testing. Fig. 10 shows Wall 7 after plastering.

Three tests were made of the plastered wall equipped with the baseboard. In test run *A*, the baseboard was fitted as closely as could be against the sand

finished plaster. In this case, the end and bottom joints between the baseboard and wall were completely sealed. The baseboard was routed out or relieved in the center so that the bearing on the wall was over a width of $1\frac{1}{4}$ in. at the top and bottom. In test run *A*, the fit to the wall was such

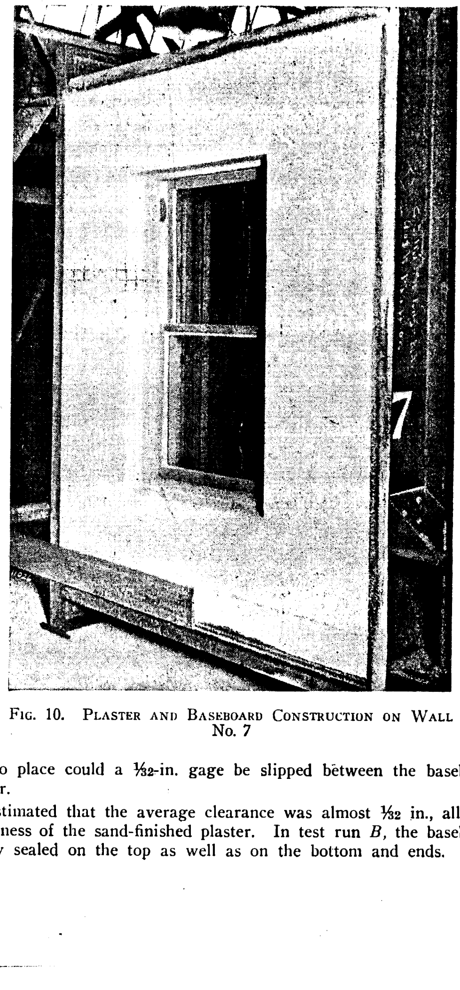

FIG. 10. PLASTER AND BASEBOARD CONSTRUCTION ON WALL No. 7

that at no place could a $\frac{1}{32}$-in. gage be slipped between the baseboard and the plaster.

It is estimated that the average clearance was almost $\frac{1}{32}$ in., allowing for the roughness of the sand-finished plaster. In test run *B*, the baseboard was completely sealed on the top as well as on the bottom and ends. This corresponds then fairly closely to a test of the wall when completely plastered and sealed at the joint against the steel frame members. In test run C, the baseboard was removed completely and the furring space was open to the collecting chamber or room side of the testing machine through the inch or two of irregular space at the bottom of the plaster sheet. This run then corresponds to a test of the plain wall not plastered, since all parts of the brick and mortar surface have access to the furring space.

Fig. 11 shows the results of these three test runs in graphical form. The results are given in total infiltration through the wall in cubic feet per minute.

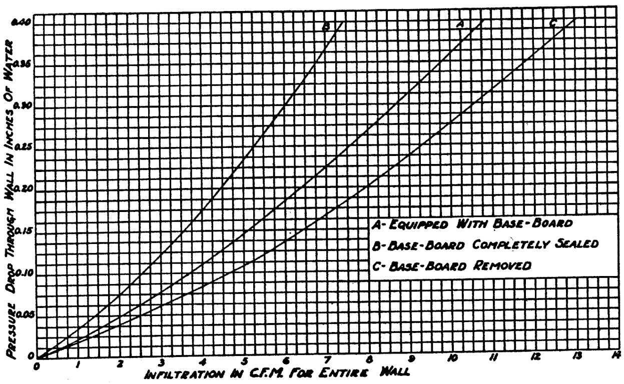

FIG. 11. INFILTRATION THROUGH WALL NO. 7 UNDER VARIOUS CONDITIONS

The difference between the values on Curves C and B gives the reduction in leakage that is due to plastering completely, allowing no leakage around the baseboard. The difference between the values on curves C and A shows the reduction in leakage occurring when the plaster is not perfectly sealed at the bottom and a baseboard is applied. The reduction in leakage for plastering completely (C-B) is 2.27 cfm at 15 mph for the entire wall. The reduction in leakage over that of the plain brick wall for the condition where the plaster is not perfectly sealed at the baseboard is $C - A$, equal to 1.06 cfm at 15 mph for the entire wall. The effectiveness of the imperfectly sealed plaster and baseboard is then measured by the ratio of $\frac{C-A}{C-B}$, which is about 47 per cent. Then, the plaster and baseboard as built reduced the leakage roughly one-half as much as would the best plaster coat. This seems to bear out the importance of sealing the edges of the plaster sheet as at the baseboard, if the value of plaster in stopping air infiltration is to be realized in building construction.

To study the relative importance of infiltration through brick walls as compared to other factors involved in heat loss calculations, the following example has been worked out. The comparison was made on a ten-story office building omitting the basement. The total boiler load figured 12,200 sq ft of direct radiation for a temperature difference of 70 deg and an emissivity of 240. The wall area, exclusive of window and door openings, was 37,860 sq ft and in this example was considered as all 13-in. brick wall with furring space, metal lath and ¾-in. plaster. The infiltration factors used on the windows and doors averaged about 110 Btu per hour per foot of crack.

An effectiveness of plaster of 50 per cent was used in accordance with the baseboard tests on Wall 7 included in this paper. For Wall 4, this would be an infiltration value of 8.46 cu ft per square foot per hour, or a heat loss factor of 10.7 Btu per square foot per hour for 70 deg temperature difference at 15 mph. For Wall 5, the corresponding values are 2.00 cu ft and 2.5 Btu. Assuming one-half of the wall area exposed to wind at one time, the calculated radiation to overcome infiltration through the brick on Wall 4 would be 926 sq ft or 7.6 per cent of the total calculated radiation, and for Wall 5 would be 220 sq ft, or 1.8 per cent of the total calculated radiation.

The infiltration heat loss through the brick, based on the results of tests on Wall 4, was 25 per cent of the infiltration through windows and doors, and the corresponding figure for Wall 5 is 6 per cent.

The comparisons probably represent conditions in a building where care has not been taken in sealing the plaster sheets at the baseboards and other wood trim. For a case where the sealing of the plaster is perfect, the amount of infiltration through the walls would be greatly reduced.

Based on the test results for Wall 4, the heat loss due to the infiltration through the walls would be 2.7 per cent of the infiltration loss through the windows and doors and the corresponding loss using the results of Wall 5 would be 0.5 per cent. Expressed in terms of the total heat losses for the building, the heat loss due to infiltration through the walls would be 0.8 per cent for the type of construction corresponding to Wall 4 and 0.14 per cent for Wall 5.

This indicates the importance of reducing infiltration for brick walls furred and plastered by the proper sealing of the plaster sheet at the baseboard and other wood trim.

CONCLUSIONS

Plain brick walls vary greatly with respect to air infiltration. Of the three factors—brick, mortar and workmanship—workmanship seems to be of most importance, the composition of the mortar as to cement and lime content next in importance, and the brick the least important. The infiltration for the 13-in. plain brick walls tested ranged from 2.71 to 10.35 cu ft per hour per square foot of walls.

Gypsum plaster, when properly applied, stops almost all infiltration. The results show that plastering stopped about 96 per cent of the leakage of the plain brick wall. Plastering directly on brick seemed to be slightly better than on metal lath with a furring space. The difference is small and the saving due to plastering directly on the brick would be negligible as compared to the saving in heat transmission effected by the furring space in the other construction.

The effectiveness of plaster in stopping infiltration in actual building construction is probably much less than that found in these tests. Cracking of the plaster, imperfect sealing of the plaster sheet at the wood trim, such as at the baseboard, would decrease the effectiveness greatly. A test made of a baseboard equipped wall, with a furring space, showed an effectiveness of only 50 per cent of that obtained with a perfectly sealed plaster wall.

Two ordinary coats of a linseed oil paint applied directly to the surface of a porous brick wall reduced the leakage by 9 per cent. A third coat applied with extreme care made the total reduction in infiltration 28 per cent.

One heavy coat of cold water paint applied directly to the surface of a hard brick wall reduced the leakage by 50 per cent.

A study made on a typical 10-story office building, considering all walls to be 13-in. brick with furring space, metal lath and plaster, indicates that the infiltration heat loss through the brick would range from 6 to 25 per cent of the infiltration heat loss through the windows and doors where the plaster is not properly sealed. For perfect sealing of the plaster, these percentages would be reduced to 0.5 to 2.7 respectively. This would indicate that the infiltration loss through brick walls with properly sealed plaster at the baseboard and other wood trim is negligible in making calculations for heat loss.

DISCUSSION

EDWIN C. EVANS (WRITTEN): This entire matter of building wall leakage is so vitally important to all human beings, affecting as it does the majority of building trades and manufacturers of building materials, I hope the Committee on Research will request a continuation of this investigation by Professor Larson.

Porosity is a natural enemy of practically all of the engineering professions and Professor Larson has shown how far-reaching is the porosity of 13-in. brick walls and he, no doubt, intends to further investigate a simple means or method of eliminating it, perhaps by applying common lead or zinc paint pigment, with special attention paid to the application of the first and second coats; that is, the first coat should be thinned with turpentine and applied without driers to assure penetration of the paint pigment to some given depth below the surface. The second coat should be applied with less turpentine, a little linseed oil and very little drier, while the third coat should be of the proper consistency with the addition of the correct amount of turpentine, linseed oil, and drier, well-known to the trade. This treatment is equally adaptable to concrete and has frequently been used with success to prevent loss with pressures below ½ lb per sq in.

Professor Larson describes his method of application and kind of paint together with the proportions of oil and turpentine, and in Table 4, results are shown that would not justify the use of oil and lead paint to kill porosity. However, if a further study of the application of oil and lead paint can be made, it will be found that painting in this manner will be far cheaper than plaster with even better results than are shown in Fig. 8. In the case of the water paint, porosity of the water paint itself, is very readily detected (see Table 5) but water paint could have been made to serve its purpose with better results, had the first coat been sufficiently diluted to permit it to flow into the outer surface of the wall.

In the foregoing, I have assumed that all the walls were treated with both paint and plaster on the pressure side without the fan in operation. This point should be brought out, as the pigment or plaster would have the backing of the wall which, in the case of some pigment materials, could readily be judged as ineffective for the purpose intended.

Applied to brick pent house walls, Professor Larson's paper should be very closely studied by architects and heating and ventilating engineers, some of whom, I regret to say, continue to use the pent house room as an exhaust chamber with a housed fan operating as an exhauster at a pressure of ½ in. of water and higher which, due to wall leakage, makes impossible either a reasonable close heat and humidity control or a clean air system. Such pent house designs should be discarded, especially so when studying the tables of air leakage shown by Professor Larson even though he has used wind pressures only up to and including 30 mph, whereas many of us have frequently had to work with pressures equal to wind velocities as high as 85 mph.

Professor Larson has shown the effectiveness of furred lath and plaster wall protection against porosity but only, of course, of gypsum plaster and these values, very likely, will not hold if soft acoustic plasters are used.

Where both the architect and engineer are called upon to contend with air leakage through the wall itself and acoustics within the room or rooms themselves, the reason for further research is apparent and to date, we have only the work of Professor Larson's laboratory to thank for the best known progress. Especially valuable are the results shown in Fig. 11 as regards sealing the baseboard, also his description for the benefit of the architect and trade of running the plaster down to the floor.

The brick mason must use water, and the Bureau of Standards table, shown as Table 1, gives plenty of room for thought on the part of the heating and ventilating engineer and especially the heating contractor who, in an 8 room residence built of 13-in. brick walls, must contend with excess water contained in the bricks and mortar joints. Then the plasterer comes along with a considerable amount of additional water and, while this point is not new to any heating engineer or heating contractor, one must at least be partially surprised when reading the figures on the amount of water that such a residence starts out with. Evaporation of this water, due to outside wind pressure and radiant heat from the sun, will always be an unknown quantity but after a fashion, this job is finally licked with salamanders or some kind of temporary heat.

How often do we hear complaints against a heating system in a new building which proves to be entirely satisfactory after the building is dried out to normal water content. The heating engineer should bear this point in mind and protect the heating contractor when this matter of building water is overlooked in the complaint of the architect or owner.

I want to commend Professor Larson and his co-workers on this very valuable and interesting paper which shows the results of a tremendous amount of work, time and study, and I am sure that all who have studied the charts, tables and descriptions will join me in this commendation and hope for a continuation of this research.

Were the test walls weighed when first built and at the time they were under test? If so, what was the loss of water weight and what was the additional loss of weight at the end of the test?

Were the paint and plaster applied to the front or pressure side of the wall?

What were the dry-bulb and wet-bulb temperatures of the air entering the fan from the room?

Will tests be run with higher wind pressures up to 60 mph, or say—1¾ in. of water?

L. B. LENT (WRITTEN): If any discussion of this excellent paper is warranted, it may be worth while to call attention to some of the points which might, in my opinion, be worthy of special emphasis.

I think we should bear in mind that a total of only seven walls were built and tested and that each of these seven walls were purposely built to represent a certain set of conditions. It is important to remember that all brick are not alike, but there are many grades varying over a considerable range in physical properties, and there are also many grades of brickwork.

It is quite impossible to construct brick masonry so that what might be called average conditions are represented in a single wall. Average values can only be obtained by averaging the results of the tests of many walls.

In a discussion of a former paper on this subject presented at the annual meeting in Chicago, I offered some information which came from investigations on the same subject made in Germany, and in which it was shown that the amount of air passing through a mortared wall is far in excess of that which one calculates from the data on a single brick; the ratio being approximately 380 to 1. In other words, the amount of air which could be actually forced through a single brick, or through all of the bricks constituting a wall construction, would probably be very much less than that which passes through the mortar joints. Hence, the physical properties of the brick which constitute the wall may be assumed to be of minor importance.

In this paper the average absorption of the hard brick, measured by a 48-hour immersion, was 14.8 per cent and that of the more porous brick measured by the same method, 18.2 per cent. The percentage of absorption for the hard brick is relatively high as compared with that for other hard bricks from other parts of the country.

I am of the opinion that, in any case, absorption percentage has little or no significance in the amount of air which may pass through the bricks, but that it may influence the adhesion of bricks and mortar and, therefore, the tightness of the mortar joint.

Without discussing the results stated in the paper, it would appear, as might be expected, that joint filling and adhesion of mortar to bricks are the important factors affecting the infiltration of air through any brick wall.

Since only one wall of each kind was tested, the results reported may well be considered as indicative rather than conclusive, for reasons already stated. It is also sometimes dangerous to deduce other results than those observed by mathematical calculations, for the actual phenomena may be different from those imagined.

To me, an important conclusion given in the paper is that the tests show that plaster is very effective in reducing leakage to a negligible value. This is important because it would seem to be always desirable to plaster the surface of any brick wall in any structure where heating costs are of any considerable amount. The cost of a plaster coating should much more than offset the cost of any heating equipment plus the annual fuel bill. One can hardly imagine a case where a plaster coating would not be more than justified.

The experience of other research workers in the field of masonry wall strengths, sound resistance, and heat transmission, indicates that much care should be exercised in using the results of tests from *only one sample* of wall construction.

If the results of this investigation are published in THE GUIDE for the information of designers, I think a word of caution should be inserted to the effect that they represent the result of only a single test and, therefore, are not conclusive.

JUDSON VOGDES: We of the Brick Association have been conducting a lot of tests on subjects very closely allied with the infiltration of air through brick walls. This is covered mainly in our investigation of leakage of moisture through walls. We have found that it is very hard to duplicate conditions by taking the same materials and the same workmen and building two walls. There are many factors which enter into the leakage, and I believe it also applies to leakage of air through these walls. As far as the passing of air or water through the individual bricks is concerned, I do not believe that it is a very important consideration, but that workmanship, kind of mortar, are of great importance. We are constantly trying to educate the masons and contractors to build better walls and I believe when they do that there will be less infiltration of air through those walls.

L. A. HARDING: There is one sentence in Mr. Lent's comments on Professor Larson's paper which I question and that is to the effect that one might infer from Professor Larson's paper that all brick walls in buildings which are to be heated should be plastered. I doubt very much whether that is so, particularly in the case of a single story factory building having a large percentage of the wall surface constituted of glass. The outside curtain walls are on the average 42 in. high. The infiltration can only take place on the windward side of the building and, as the infiltration through the wall is an exceedingly small percentage of the total heat loss of building I doubt very much the economic soundness of applying a plaster finish under those conditions. Of course, it is not customary practice.

F. D. MENSING: Professor Larson calls attention to the loss that is likely to result through poor baseboard construction. I think there is a possibility of connection with the *Fire Underwriters*. They are vitally interested in the travel of air from basements up to upper stories. They find a great deal of that is caused by a lack of sealing of vertical construction at the floor lines. I know of many instances where poor construction has happened, and I guess others have also come in contact with it. The Society might make a note of this to make a contact with the *Fire Underwriters'* Laboratories.

E. K. CAMPBELL: It has been pointed out a good many times in the discussions at these meetings that there is apt to be a considerable difference between laboratory conditions and field conditions. Professor Larson has pointed out the importance of sealing the joints between the wall section and the steel frame, also the importance of sealing the furring at the floor line by means of a baseboard or other means. That has brought to my mind an experience that I had a number of years ago. I was called on a large building that was some 25 or 30 years old. The heating plant was in pretty fair condition but was not giving satisfactory service. The windows were in bad shape, as far as the window construction itself was concerned; but the biggest thing that I did to help out the condition in that building was to put a half a bale of cotton in the joints between the wood frames and the brick due to the shrinkage of the wood frames in that time. So that very frequently in the field conditions you will find a condition that may not have existed when the building was erected, and the importance of it, I think, is pointed out very clearly by Professor Larson's mention of those two things.

H. M. NOBIS: Professor Larson ought to be congratulated on the common sense manner in which he handled a practical subject. I would like to know if it would be possible to ascertain at some time if the wall, after it is plastered, be covered with tinfoil.

C. C. HARTPENCE: Some years ago while building some gas purifying boxes, I decided to build them of brick and I used two coats of neat cement wash on the faces of the 8-in. brick walls. I used cement mortar, two parts of sand and one part of cement, but was very careful to see that the joints were entirely filled. There was no odor of gas in the room and apparently no leakage of gas through the walls of the purifying boxes, though they were under several inches of water pressure. The gas had been cleaned of water and oil mist, but had high relative humidity.

W. C. RANDALL: The point brought out by Mr. Larson that the amount of air coming through the brick wall, particularly if plastered, is negligible, is slightly beside the point in a lot of buildings which are being built today of walls less than 12-in. thick, of a type of workmanship that I think is poorer than the type of workmanship which Professor Larson calls poor workmanship. It is particularly apparent not in the leakage of air but in the leakage of water directly through the face of the building, especially in the multi-story type of buildings. In some of the taller buildings in New York, I find a tendency to go to thinner walls than the 8-in. brick wall, practically only some form of a filler to get an appearance on the outside of the brick. I hope that while Professor Larson has indicated that his tests are about through the discussion that has been made today will stimulate further work along this line.

J. D. CASSELL: In that respect, might I suggest that if you conduct these tests any further you will include wall plastering on the inside, probably waterproofed, and then plastered directly against the brick, not furred. There is a very considerable amount of that character of construction being done, and when the workmanship is poor, as I have had occasion to see in our own work, there will be spots of dampness on a panel, dotted all over, where the moisture drives directly through. A test of that kind would be very beneficial along the line that has been explained here today.

J. E. EMSWILER: I want to congratulate Professor Larson on this very fine piece of work, together with his associates. I know that the paper must represent an enormous amount of tedious experimental work behind it.

S. R. LEWIS: Do not forget the chimney in the outside wall. I was called in on a tall, cooperative apartment building in which they built their fireplace flues into the masonry of the outside wall. The fireplaces served by these chimneys consistently had a backdraft whenever they happened to be on the windward side. The owner installed the biggest fans he could get, with the biggest motors he could put on, up in the attic but could not overcome the trouble. The next apartment like this that I built, I had them build the outside wall; then do things to that outside wall that were paramount to putting plaster on; and then build the chimney inside the wall. We had no trouble due to unauthorized chimney leakage on the windward side when we did this.

G. L. LARSON: I do not know whether I got all these points. Mr. Evans asked some direct questions that I cannot answer. He asked whether the walls were weighed before and after testing. I will say that we did not weigh the walls. The walls were allowed to stand for five months before the tests were made and then check tests were run again two months after the first tests and the difference between the check tests and the previous ones, with an interval of two months between, showed no direct correlation of changes one way or the other. In some cases the leakage was more and in some cases the leakage was less. So we couldn't find any direct correlation there. Apparently, all the drying out had taken place before the tests were made.

We took records, of course, of the wet- and dry-bulb temperatures during all of the tests, but made no attempt whatever to keep these at any constant quantity. They averaged up and down day after day. So we have no relation there. In fact, we could find no relation between the results and the wet- and dry-bulb temperatures that we got during these particular tests. I believe that if the walls were maintained under a certain condition of humidity for certain periods of time we probably would find some difference, but these walls stand there and take the changes as they come and that may vary a great deal over a period of two months.

MR. EVANS: You would then expect more leakage?

PROFESSOR LARSON: Well, I can not say what might happen. Of course, there is one test that we have not been able to perform yet and that is to expose one side of these walls to the outside weather conditions and then test them after a few months of that kind of exposure. We may get into that later but that is not on our program at the present time because we are not equipped to do it.

There was another question on higher wind pressure tests, etc. We have not planned on going to higher wind velocities. In fact the last time we reported on this work, it was suggested we keep down to about 25 mph because it was felt that it was not necessary to go beyond that.

MR. EVANS: That has to do with pent house work?

PROFESSOR LARSON: Yes. I will take it up with our committee and we will be very glad to go to higher wind pressures, if there is a definite request for that. I can see it is of great importance in the work you have mentioned. I also think we can follow out your other suggestion, Mr. Evans, of trying different methods of painting the wall. What we did was just to take an ordinary paint and paint the wall as is done in common practice.

MR. NICHOLLS: One coat?

PROFESSOR LARSON: We tried three coats. A great deal may be brought to light as to how walls should be painted by trying other methods and cleaning out the paint, as you have suggested. We will be very glad to consider that question also.

The other suggestion about waterproofing the wall by Mr. Cassell—I think that is a good suggestion and we are very glad to get it. We want to get any suggestions that will be of any value in bringing out important points in the construction of buildings.