No. 786

INFILTRATION THROUGH PLASTERED AND UNPLASTERED BRICK WALLS

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MEMBERS

INFILTRATION or leakage of air into buildings has been the subject of investigation at the Research Laboratory of the American Society of Heating and Ventilating Engineers since 1920. Several reports have appeared in The Journal of the Society containing data on leakage of air through cracks around windows and doors. One of these reports[3] included data on leakage of air through a 13-in. plastered brick wall, obtained from a single test on a wall in which a window was built. The main interest was in the leakage around the window and only one determination was made incidental thereto of air leaking through the wall itself. Leakage of 0.1 cu. ft. per minute per square foot of wall with a 15-mile wind was indicated, a value which seemed surprisingly large to those interested in heat loss from buildings.

As pointed out in the report referred to, the heat loss through each square foot of wall resulting from air leakage was about 20 per cent as great as the loss per square foot of weatherstripped windows. Considering the greater area of wall than windows in the ordinary building, the infiltration through the wall would appear to be greater than that through the windows. The heat loss through the wall by infiltration as indicated by this value is 43 per cent as great as the loss by transmission.

Upon renewing the investigation at the laboratory about a year ago, it was considered desirable to check the result of the single test reported and to determine the infiltration through various types of building construction.

Fig. 1 is a drawing and Fig. 2 a photograph of the apparatus developed at the laboratory for measuring the leakage of air through walls, windows and doors. A complete description of the apparatus and method of test appears in an earlier laboratory report. The wall to be tested is built in the apparatus between the pressure and collecting chambers. A pressure equal to that of a given wind velocity is produced in the first chamber and the air leaking through the wall is measured as it passes through a calibrated orifice from the collecting chamber.

Since the renewal of the investigation at the laboratory two brick walls have

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[3] Air Leakage through Openings in Buildings, by F. C. Houghten & C. C. Schrader, A.S.H.&V.E. Transactions, Vol. 30, 1924.

wall. One advantage of such a collector is the fact that infiltration through existing walls can be determined similar to the determination of heat flow through a wall by means of the heat meter. The method has the disadvantages of including a comparatively small section of wall and difficulty of air-tight application.

Fig. 8 shows the result of tests with such a collector on different sections of the

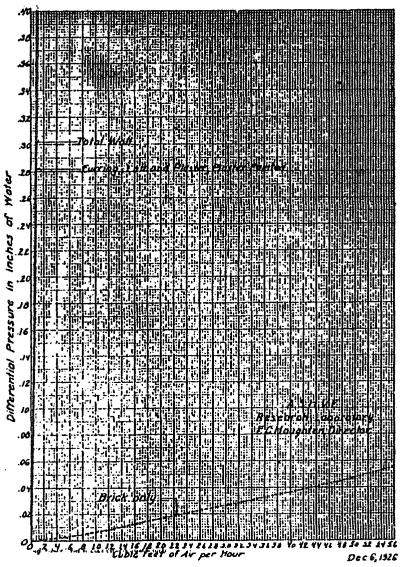


FIG. 6. PRESSURE DROP THROUGH PLASTER AND BRICK OF FURRED AND PLASTERED WALL AND ACCOMPANYING LEAKAGE

same wall. Curves showing the leakage through areas A, B, C and D are for sections of the wall picked at random. Curve, area E, shows the leakage through a section of wall in which there was a noticeable crack in the plaster. The leakage through the entire wall at approximately the same time as determined by the larger apparatus, is given by the curve for March 19, 1926. The difference between the curves for March 19 and November 23 shows the effect of aging on the leakage through the total plastered wall.

Table 1 gives the leakage through the various types of construction for various

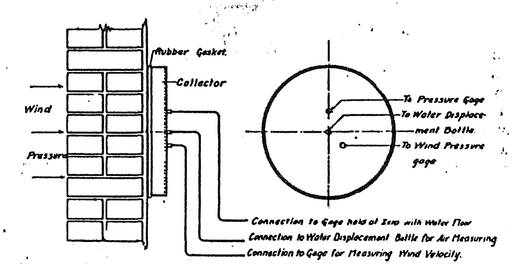


FIG. 7. COLLECTING CHAMBER TO DETERMINE RELATIVE LEAKAGE THROUGH DIFFERENT SECTIONS OF SAME WALL

wind velocities. Table 2 gives the heat loss in B.t.u. per hr. per sq. ft. per degree temperature difference of the air on the two sides of the wall by infiltration and transmission for a 15-mile wind. The table also gives the per cent which the heat loss by infiltration is of the total loss by infiltration and transmission and the per cent which the infiltration loss for any wall is of that for a similar unplastered brick wall. This table again emphasizes the fact that heat loss by infiltration is a very small factor for a plastered wall. The heat loss by infiltration for the plain $8^1/_2$-in. and 13-in. brick walls are, respectively, 33 and 39 per cent of the total heat loss for the wall, while the greatest heat loss by infiltration for any plastered wall tested is 2.4 per cent for the 13-in. wall with furring lath and plaster.

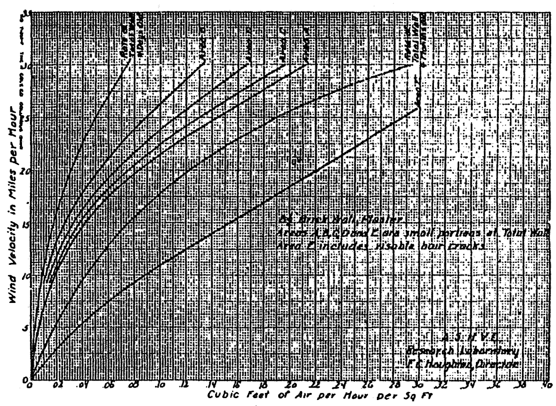


FIG. 8. INFILTRATION THROUGH PORTIONS OF A PLASTERED WALL

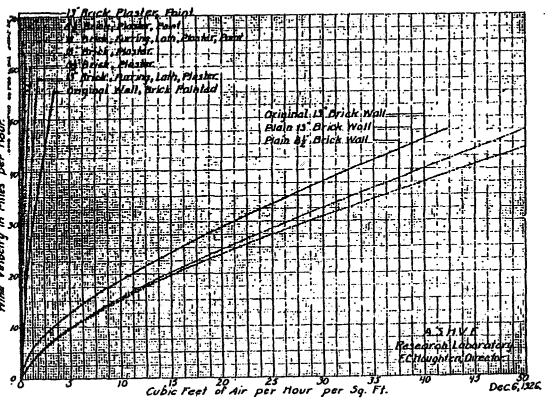


FIG. 3. INFILTRATION THROUGH BRICK WALLS

Painting the plaster considerably reduces the leakage through a plastered wall as indicated by the curves, however, it should be pointed out that while the percentage decreases in leakage through a plastered wall caused by painting is large, the actual saving in heat is relatively unimportant since heat loss by infiltration through a plastered wall is already comparatively small.

In order to demonstrate the relative effect of the brickwork and the plaster in

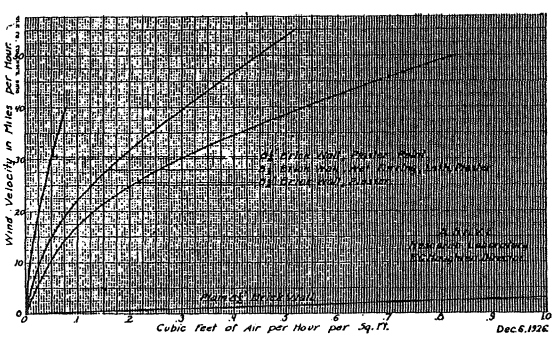


FIG. 4. INFILTRATION THROUGH 8½-IN. BRICK WALL

stopping leakage or the relative resistance of the two to air flow, a tube was connected into the furring space of the 8½-in. brick wall and the pressure drop through the brick and through the plaster was determined for various wind velocities. The curves, Fig. 6, show the relation between pressure drop and air leakage through the brick, plaster and total wall. It will be seen that the plaster offers by far the greater part of the resistance to infiltration.

In order to determine the relative leakage through different sections of the same wall, a small collecting chamber shown in Fig. 7, was developed. This consists of a small galvanized iron collector which can be clamped up against the wall and

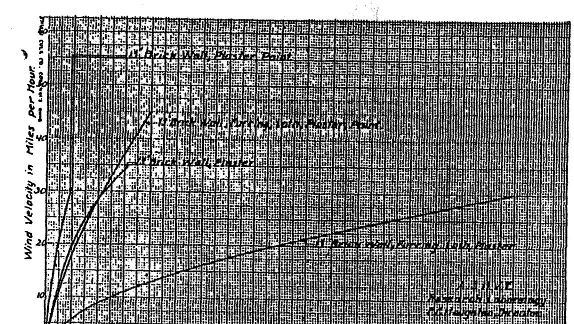


FIG. 5. INFILTRATION THROUGH 13-IN. BRICK WALL

made air-tight by the use of a gasket between its edge and the wall. This collector was clamped against the inside or plaster side of the wall, while a wind pressure was directed against the outer or brick side of the wall. Air was removed from the collector by means of water displacement just fast enough so that a differential pressure gage indicated the same pressure within and outside the collector. With the same pressure on the plaster side of the wall inside and outside of the collector, there was no tendency to distort the lines of air flow through the wall or for leakage into or out of the collector, therefore the air removed from the collector by water displacement represents the leakage for the given wind velocity through the portion of wall covered by the collector. This method of determining air leakage through the wall was quite successful and could be used to determine air leakage through an existing wall in a building under natural conditions.

The collector used in these tests was limited to 16 in. in diameter in order to pass through the man-hole in the present apparatus. The collector should be made considerably larger in order to cover a more nearly average section of the

been tested. Relation between infiltration and wind velocity has been determined for an $8^1/_2$-in. and a 13-in. brick wall each without plaster, with furring lath and plaster and plastered directly on the brick. The effect of painting plastered walls has also been determined.

In all cases the wall tested was 10 ft. high by 6 ft. wide, having a total area of 60 sq. ft. The edge of the wall where it joined the metal box was calked with a plastic calking compound in order to eliminate edge leaks. As soon as the mortar in, or the plaster on, any wall had hardened, tests were made and repeated

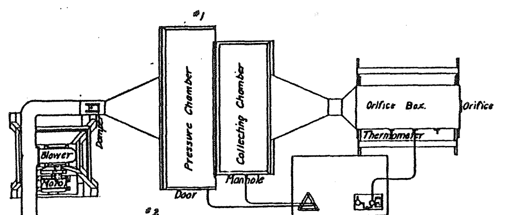


Fig. 1. Arrangement of Apparatus for Measuring Leakage of Air through Walls, Windows and Doors

at intervals as the wall dried and aged. With the plastered wall the leakage was found to increase for a period of 3 to 4 months after application of the plaster after which no measurable change could be noted. The time required for aging the walls until the leakage became constant was the most time consuming factor in the investigation.

The curves in Fig. 3 give the relation between the leakage through the different walls tested and wind velocities. The solid line curves give leakage through the 13-in. plastered wall previously reported and that for the same wall after the brick has been painted. It will be noted that the leakage previously reported for the 13-in. plastered wall is but little less than the leakage through the plain brick walls tested in the present investigation, and many times greater than the leakage through the present plastered walls. In considering this discrepancy it should be emphasized that the data previously reported were the result of a single test on a small section of wall and that after this leakage was once determined by eliminating it through painting the wall, it was impossible to recheck the value. In the present investigation the leakage was checked many times. A very plausible expla-

nation of the greater leakage indicated in the previous tests is the possibility that air after passing through the first or second course of brick flowed laterally through the bond to the window frame and thence out into the collecting chamber through a possible crack between the plaster and window frame. The crack between the brick and frame was calked to eliminate air entering the wall at this point. The perimeter of the wall where it joined the box was carefully calked on both the brick and the plaster sides of the wall, but it did not occur to those working on the problem that the joint between the plaster and the frame should be calked.

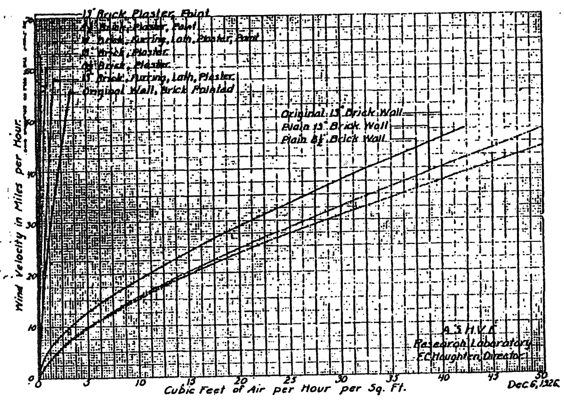
The curves also bring out the fact that the plaster is practically air-tight in com-

Fig. 2. Apparatus for Measuring Leakage of Air through Walls, Windows and Doors

parison to the brick and that as far as infiltration is concerned a 13-in. brick wall is not much better than an $8^1/_2$-in. wall.

In order to more closely study the effect of plaster and paint the data contained in the curves, Fig. 3, are replotted on a different scale in Figs. 4 and 5. The data on the $8^1/_2$-in. brick wall with furring, lath, and plaster cannot be accepted as representative of such a wall since the plaster which had appeared to be entirely dry a short while after application was found to be quite wet upon its removal. This was the first plastered wall tested and its early removal demonstrated the necessity of allowing a much greater length of time for a wall to age.

The curve for the 13-in. brick wall with furring, lath, and plaster is representative of the effect of this type of wall on leakage. The wall with furring, lath, and plaster shows a greater leakage than the same wall with plaster applied directly on the brick. This is as one would expect, since the furring space allows lateral flow of air between possible passageways through the brick and through the plaster.



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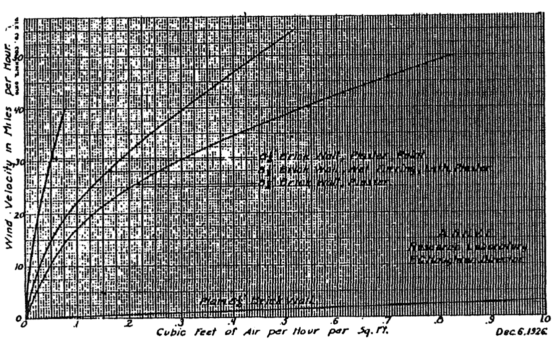

FIG. 4. INFILTRATION THROUGH $8^1/_2$-IN. BRICK WALL

stopping leakage or the relative resistance of the two to air flow, a tube was connected into the furring space of the $8^1/_2$-in. brick wall and the pressure drop through the brick and through the plaster was determined for various wind velocities. The curves, Fig. 6, show the relation between pressure drop and air leakage through the brick, plaster and total wall. It will be seen that the plaster offers by far the greater part of the resistance to infiltration.

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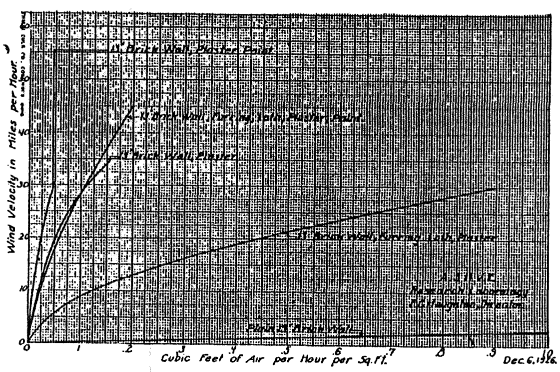

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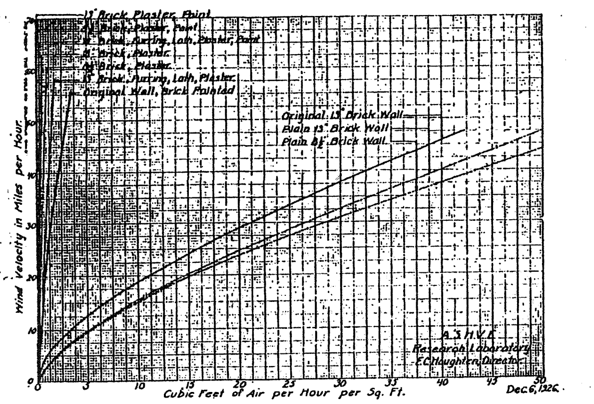

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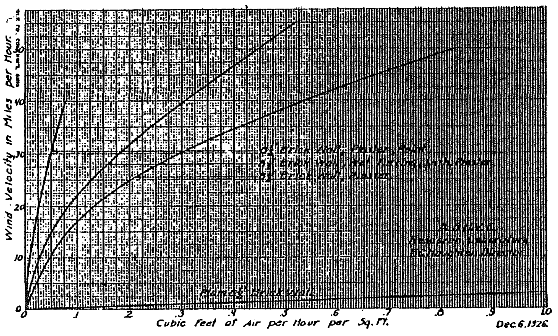

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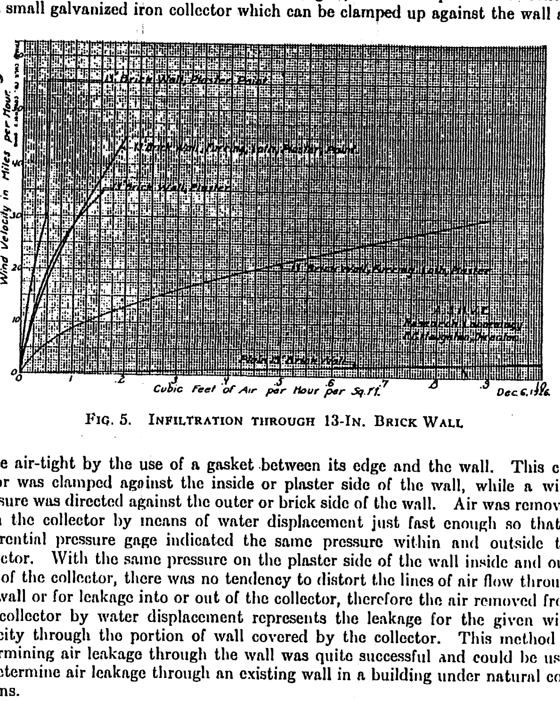

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The fourth column of Table 2 shows the effect which plaster and paint have on heat loss by infiltration. Paint is very effective in reducing leakage through a plastered brick wall, it is however only effective in reducing an already small value. While paint on a 13-in. brick wall with furring lath and plaster reduces heat loss by leakage through such an unpainted wall by about 85 per cent, this decrease is only about 2 per cent of the infiltration loss through the unplastered brick wall and only about 1 per cent of the total heat loss through the plain wall by infiltration and transmission.

Infiltration of cold air into a building takes place on the windward side while warm air leaks out on the leeward side. The pressure of the wind is the cause of both. The pressure drop through the leeward wall is at least partially the result of a pressure being built up inside the building; hence the total pressure of the wind will not be effective in producing infiltration on the windward side and the values given in Tables 1 and 2 are too high for actual conditions. In Tables 3 and 4, the values found in Tables 1 and 2 are reduced by 20 per cent to cover this factor and are recommended for practical use in most cases where more exact knowledge of such contingent factors is not available. This reduction in actual test values for practical use is in conformity with THE GUIDE.[1]

CONCLUSIONS

Infiltration is a large factor in the total heat loss through an unplastered brick wall. The infiltration loss amounts to from 30 to 40 per cent of the total heat loss through such a wall. Plaster either when applied directly on the brick or with furring, lath and plaster is very effective in reducing heat loss by infiltration. Paint will reduce infiltration through a plastered wall to a small per cent of its

TABLE 1. INFILTRATION IN CUBIC FEET PER HOUR PER SQUARE FOOT OF WALL

Actual Test Data

Wind Velocity in Miles per Hour	5	10	15	20	25	30	40
CONSTRUCTION							
8½″-Brick wall—plain	2.18	5.24	9.81	15.3	23.2	28.6	43.5
*8½″-Brick wall—furring, lath, 2 coats prepared gypsum plaster, plaster not dry	0.010	0.025	0.046	0.081	0.125	0.178	0.306
8½″-Brick wall, 2 coats prepared gypsum plaster on brick	0.021	0.046	0.083	0.134	0.201	0.295	0.543
Same, plaster painted, 1 coat sealer, 2 coats paint	0.004	0.011	0.019	0.027	0.036	0.050	0.077
13″-Brick wall—plain	1.80	4.90	9.35	14.5	20.3	25.5	39.75
13″-Brick wall—furring, lath, 2 coats prepared gypsum plaster	0.039	0.125	0.262	0.448	0.663	0.893	
Same—plaster painted, 1 coat sealer, 2 coats paint	0.010	0.023	0.039	0.059	0.082	0.109	0.166
13″-Brick wall—2 coats prepared gypsum plaster on brick	0.006	0.016	0.031	0.054	0.084	0.121	
Same—plaster painted, 1 coat sealer, 2 coats paint	0.004	0.011	0.019	0.027	0.036	0.050	

* Data on this wall was obtained before the plaster was dry which accounts for the low leakage values given. All other walls were dry.

[1] Heat Loss from Buildings, A. C. Willard, Chapter I, pp. 25–26, A.S.H.&V.E. GUIDE, 1926–27.

TABLE 2. HEAT LOSS IN B.T.U. PER HOUR PER SQUARE FOOT PER DEGREE TEMPERATURE DIFFERENCE BY INFILTRATION AND TRANSMISSION—WIND VELOCITY 15 MILES PER HOUR

Actual Test Data

CONSTRUCTION	Heat Loss by Infiltration	Heat Loss by Transmission	Infiltration in % of Total Heat Loss	Infiltration Loss in % of Plain Wall
8½″-Brick wall—plain	0.178	0.360	33.0	100.00
*8½″-Brick wall—furring, lath, 2 coats prepared gypsum plaster, plaster not dry	0.0008	0.220	0.4	0.45
8½″-Brick wall—2 coats prepared gypsum plaster on brick	0.0015	0.300	0.5	0.84
Same—plaster painted, 1 coat sealer, 2 coats paint	0.0003	0.300	0.1	0.17
13″-Brick wall—plain	0.169	0.27	39.0	100.00
13″-Brick wall—furring, lath, 2 coats prepared gypsum plaster	0.0046	0.19	2.4	2.72
Same—plaster painted, 1 coat sealer, 2 coats paint	0.0007	0.19	0.4	0.41
13″-Brick wall—2 coats prepared gypsum plaster on brick	0.0006	0.25	0.2	0.36
Same—plaster painted, 1 coat sealer, 2 coats paint	0.0003	0.25	0.1	0.18

* Data on this wall was obtained before the plaster was dry, which accounts for the low leakage values given. All other walls were dry.

TABLE 3. VALUES RECOMMENDED FOR PRACTICAL USE—INFILTRATION IN CUBIC FEET PER HOUR PER SQUARE FOOT OF WALL

Actual Test Data Reduced by 20 Per Cent to Allow for Building Up of Pressure in Room

Wind Velocity in Miles per Hour	5	10	15	20	25	30	40
CONSTRUCTION							
8½″-Brick wall—plain	1.75	4.20	7.85	12.2	18.6	22.9	34.8
8½″-Brick wall, 2 coats prepared gypsum plaster on brick	0.017	0.037	0.066	0.107	0.161	0.236	0.435
Same, plaster painted, 1 coat sealer, 2 coats paint	0.003	0.009	0.015	0.022	0.029	0.040	0.062
13″-Brick wall—plain	1.44	3.92	7.48	11.6	16.3	21.2	31.80
13″-Brick wall—furring, lath, 2 coats prepared gypsum plaster	0.031	0.100	0.210	0.359	0.530	0.715	
Same—plaster painted, 1 coat sealer, 2 coats paint	0.008	0.018	0.031	0.047	0.066	0.087	0.133
13″-Brick wall—2 coats prepared gypsum plaster on brick	0.005	0.013	0.025	0.043	0.067	0.097	
Same—plaster painted, 1 coat sealer, 2 coats paint	0.003	0.009	0.015	0.022	0.029	0.040	

original value, however, its effect in conserving heat is relatively unimportant since the heat loss through a plastered wall by infiltration is already only a small part of the total heat loss through such a wall.

TABLE 4. VALUES RECOMMENDED FOR PRACTICAL USE—HEAT LOSS IN B.T.U. PER HOUR PER SQUARE FOOT PER DEGREE TEMPERATURE DIFFERENCE BY INFILTRATION—WIND VELOCITY 15 MILES PER HOUR

Actual Test Data Reduced by 20 Per Cent to Allow for Building Up of Pressure in Room

CONSTRUCTION	Heat Loss by Infiltration
$8^1/_2$"-Brick wall—plain	0.142
$8^1/_2$"-Brick wall—2 coats prepared gypsum plaster on brick	0.0012
$8^1/_2$"-Brick wall—same, plaster painted, 1 coat sealer, 2 coats paint	0.0002
13"-Brick wall—plain	0.135
13"-Brick wall—furring, lath, 2 coats prepared gypsum plaster	0.0037
13"-Brick wall—same, plaster painted, 1 coat sealer, 2 coats paint	0.0006
13"-Brick wall—2 coats prepared gypsum plaster on brick	0.0005
Same, plaster painted, 1 coat sealer, 2 coats paint	0.0002

APPENDIX

Specifications of Walls Tested

The brick walls tested were built and the plaster was applied by Mr. Larkin, head instructor of masonry, Carnegie Institute of Technology. Instructions were that the walls and plastering should be of good average workmanship, representing as nearly as possible common practice in the industry and built in accordance with the following specifications:

Brick Wall

Brickwork: The brick used in these walls are to be a selected type of common brick. They must be well burned and uniform in size and shape. The walls are to be laid up in common bond (six stretcher courses between headers). Courses are to be laid straight and level and wall is to be kept plumb.

Mortar: The mortar is to be composed of one part Portland cement, one part hydrated lime, and six parts of clean sharp river sand. It is to be uniformly mixed and to be laid in one-half inch joints. All joints to be thoroughly filled and those on outside surface of wall are to be smoothly struck. Mortar which has partially set is not to be retempered and used.

Furring, Lath and Plaster Applied to above Brick Walls

Lathing: Thin strips, such as wood lath, are to be placed between every fifth and sixth course to furnish grounds for nailing furring strips. Furring strips are to be three-quarters inch thick and two inches wide, and spaced 16 inches on centers. Furring is to be well nailed to strips built in brick wall. Standard wood lath to be used and spaced three-eighths inch apart with broken joint every fifth lath.

Plastering: Prepared gypsum plaster to be used. First coat to be three-eighths inch in thickness and to be scratched or roughened so as to receive second coat. Second coat to be three-eighths inch thick and well floated to an even surface. Mortar is to be well tempered and uniformly mixed. Mortar which has partly set should not be retempered and used.

Plaster Applied to above Brick Wall

Plastering: The plaster is to be put directly on the brick wall. The brick wall to be made wet before plastering, in order to get a good bond. The first coat is to be composed of one part of Portland cement and two parts of clean river sand. It is to be put on three-eighths inch thick and roughened or scratched to receive second coat. The second coat is to be of same composition as that of first coat and is to be finished and floated to an even surface.