No. 704

AIR LEAKAGE AROUND WINDOW OPENINGS

By C. C. SCHRADER,[1] PITTSBURGH, PA.

MEMBER

THIS report is the second one dealing with the air leakage problem being investigated at the Research Laboratory. The first report, Air Leakage through the Openings in Buildings, was published in the February, 1924 JOURNAL and included a description of the apparatus and the method of procedure. The tests in both experiments followed the same general routine, and in each case the same frame was used with the same kind of sash, namely, double hung wooden sash, 2 ft. 8 in. by 5 ft. 2 in. by $1^3/_8$ in.

The principal facts brought out in the first report were that increasing the crack around the perimeter of a plain sash did not materially increase the leakage, and that weather-stripped sash, while permitting much less leakage, showed a small increase in leakage with increase in crack. These facts were established by making several hundred tests. The present report deals with the effect of increasing the width of the stile, that is, increasing the clearance.

Fig. 1 illustrates what is meant by crack and clearance. The crack around the sash perimeter is equal to one half the difference between the width of the frame and the width of the sash, that is, the crack is the same on each side of the sash. The clearance is the difference between the width of the stile and the thickness of the sash. These terms are chosen arbitrarily to distinguish the two principal air passages which are found in double hung windows, and they will be used frequently throughout the report and should not be confused.

In fitting the sash for these tests it was discovered that they were thicker than those used in the first tests, which led to an investigation as to the actual thickness of the sash in each case. All of the sashes were measured with calipers, and it was found that those used for the tests in the first report were $1^{21}/_{64}$ in. thick while those used in the new tests were $1^3/_8$ in. thick. The stile previously measured was $1^7/_{16}$ in. in width. In view of this information a statement made in the first report must be corrected, which was that the difference between the width of the stile and the thickness of the sash was $^1/_{16}$ in. when it was actually $^7/_{64}$ in. This difference in clearance is probably due to manufacturing practices, as some mills use the specified dimension for the thickness of the sash while others use it for the width of the stile.

---

[1] Research Engineer, A.S.H. & V.E. Laboratory.

Presented at the Semi-Annual meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Kansas City, Mo., June, 1924.

In order to test the effect of different clearances it was necessary to have stops that could be moved to any desired distance from the parting bead. Therefore the stops were removed and slots cut in them so that they could be screwed to the frame to give a maximum of $^1/_4$ in. clearance. Known clearances were obtained by strips of cold rolled steel of convenient thicknesses, and these strips were measured with a micrometer to determine their exact dimensions. A strip of a thickness equal to the desired clearance was inserted between the sash and the stop, the whole pressed firmly against the parting bead, and the stop screwed on in position. The strip was then removed, and in this manner any desired clearance was obtained. When weather stripping was used it held the sash against the parting bead, so that the clearances could be obtained in the same manner. The cracks around the stop were sealed to prevent leakage through them.

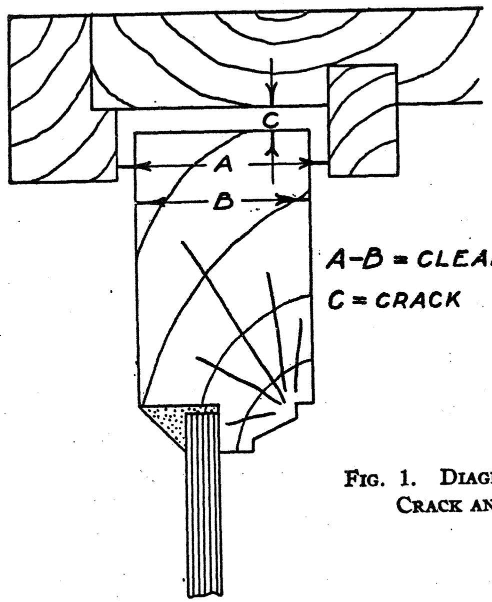

FIG. 1. DIAGRAM ILLUSTRATING CRACK AND CLEARANCE

Procedure

Four sets of sash were fitted with cracks of $^1/_{16}$, $^1/_8$, $^3/_{16}$ and $^1/_4$ in. Each set was tested with clearances varying from $^1/_{32}$ to $^1/_4$ in. Each test was repeated a number of times because no two tests gave exactly the same leakage, and it was necessary to obtain average results. Before duplicating any test the window was opened and closed, and the stops were removed and then returned to as nearly the same position as possible. The weather-stripped sashes were tested in the same way.

Plain Window

Fig. 2 gives the results of tests of a plain window with various clearances. The tests proved that the size of the crack around the perimeter of the sash has no appreciable effect on the leakage. Therefore the results apply to any window of the type tested with a crack of from $^1/_{16}$ to $^1/_4$ in. In practice most new sashes are fitted with the crack at least $^1/_{16}$ in., and this crack becomes greater as the sash dries out and shrinks. It should be clearly understood that each curve is the average obtained from a number of tests, and the results of any one test may vary from the given curve by four or five per cent. The figure shows that the leakage increases rapidly with increase in clearance.

Fig. 3 is obtained from curve 4 in Fig. 2 and is drawn to show the relation of leakage to wind velocity. The graph thus drawn shows a slight double curve, but it is seen that it varies but little from a straight line. In some cases the double

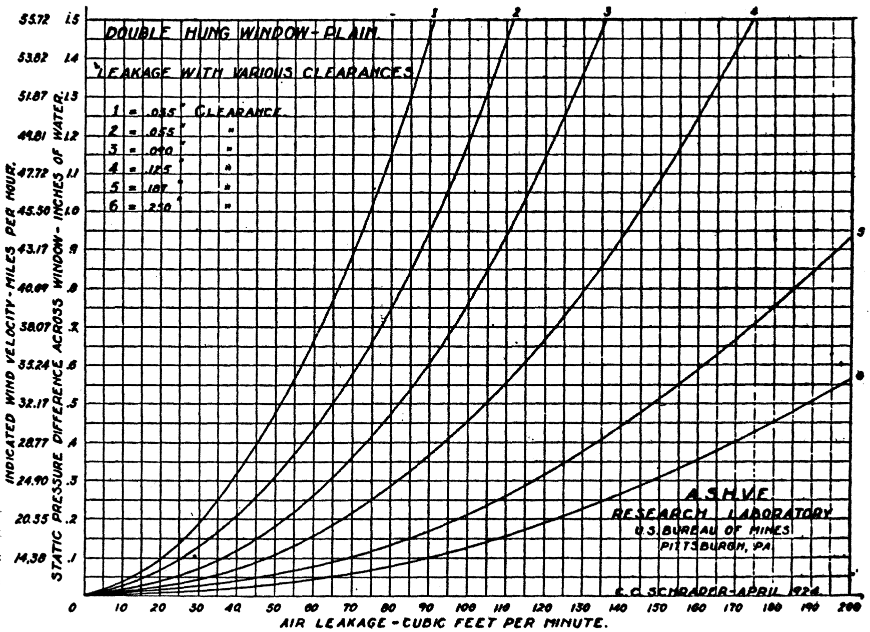

FIG. 2. LEAKAGE THROUGH PLAIN WINDOW WITH VARIOUS CLEARANCES

curve is more pronounced but the curve does not reverse until the velocity has reached twenty-five or thirty miles per hour. Hence no great error is introduced by taking any point on the leakage curve below thirty miles per hour, to determine the leakage per mile of wind velocity.

Since the velocity used in most calculations of window leakage is about fifteen miles per hour, or approximately $^1/_{10}$ in. water pressure, values at these points were taken from the curves in Fig. 2 and plotted against clearance. Fig. 4 was thus obtained. It is seen that a straight line passes close to all these points, and that the variation from the points plotted will be within the limits of the above variation of the original tests. The line drawn does not pass through zero leakage for zero clearance, and therefore the leakage will not vary in direct proportion to the clearance, which is to be expected because the surfaces of the window are not perfectly true, and regardless of how closely they are held together some leakage will always occur. If the sashes were not free to move with the pressure of the wind and were always held in the middle of the stile, a direct ratio of leakage to clearance would be expected. However the movement of the sash introduces a variable element, and it is difficult to determine its effect. It must be remembered also that the leakage at zero clearance is not the elsewhere leakage. The conditions for determining the elsewhere leakage require that certain openings around the sash be sealed so that no leakage will take place through them, whereas regardless

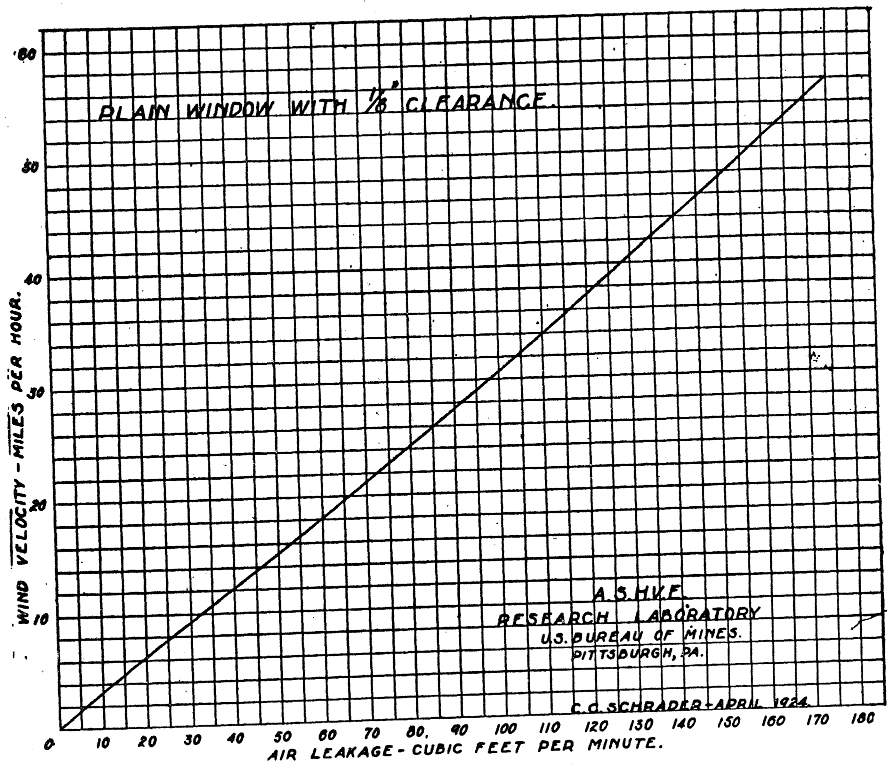

FIG. 3. RELATION OF LEAKAGE TO WIND VELOCITY

of how tightly the sash fits between the stops some leakage will occur through these openings due to the uneven surfaces caused by warping and so forth. (For determination of elsewhere leakage refer to first report mentioned above.) It is probable that the elsewhere leakage, particularly through the pulley holes, increases as the clearance is made greater, but the increase is too small to be differentiated from the variation that may take place in two tests of the same condition.

From the standpoint of the heating engineer the most convenient terms expressing infiltration are cubic feet per hour, per foot of crack, or per mile of wind velocity. Using these terms the infiltration for any room can be easily computed

by multiplying by a constant depending on the wind velocity and the number of feet of crack. Fig. 5 was obtained by expressing the values in Fig. 4 in these terms.

Weatherstripped Windows

In the first report it was shown that the leakage through a weather-stripped window increased as the crack was made larger. Fig. 6 shows what happens when the crack is kept constant and the clearance increased in a window with the interlocking type strip applied. The increase in leakage with increase in clearance is probably

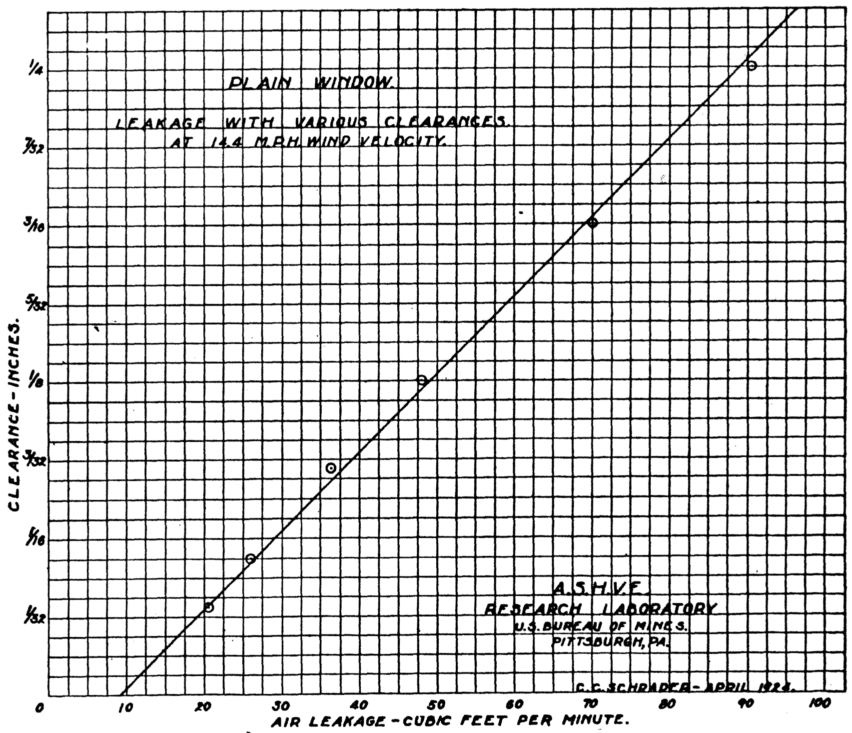

FIG. 4. RELATION OF TOTAL LEAKAGE TO CLEARANCE. PLAIN WINDOW

due to greater leakage through the pulley holes which is caused by decreased resistance in the path of the air to the pulley holes. This evidence supports further the statement previously made that the elsewhere leakage increases slightly as the clearance decreases. In fact, it is the only explanation that can be found for the increase in leakage since the sash is held against the parting bead in the same position by the weatherstripping, all other openings around the sash remaining the same. The increase in leakage is quite pronounced until the clearance becomes equal to the crack, after which the increase is not so rapid. Fig. 7 illustrating this point shows the leakage through windows with the interlocking type weatherstrip for all the cracks and clearances tested. Fig. 8 gives similar data for windows fitted with rib type weatherstrip. A comparison of the two figures brings out the greater consistency in results obtained with the interlocking type of strip, which is to be expected, as this type of weatherstrip holds the sash in the same position at all times. With the rib strip the sashes are free to move from

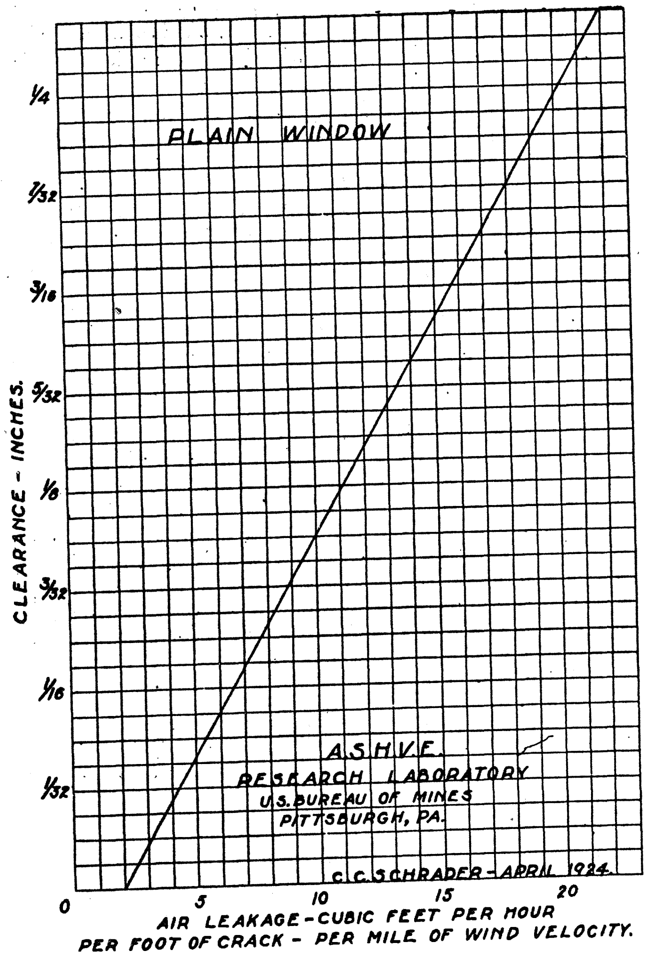

FIG. 5. RELATION OF LEAKAGE PER FOOT TO CLEARANCE. PLAIN WINDOW

side to side a distance depending on the size of the crack, and since it is impossible to return them to exactly the same position after each test the results become more varied. This change of position of the sash often causes the leakage with a small clearance to be greater than that with a larger clearance, for a slight change is sufficient to affect the difference. This fact is particularly true when the crack

is large and permits considerable divergence from the previous position of the sash.

It is not the purpose of this report to draw a comparison between the relative values of different types of weatherstripping. However, some explanation is necessary to understand thoroughly the conditions under which these tests were conducted so that comparison may be made with other data on the subject. Concerning the interlocking type of weatherstrip all that needs to be mentioned is

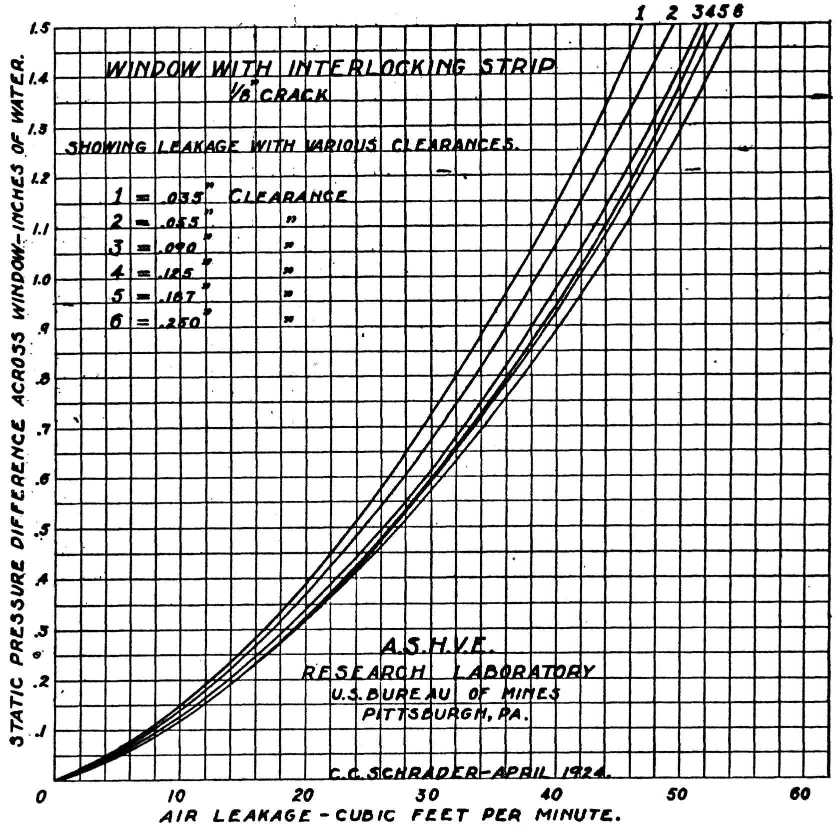

FIG. 6. LEAKAGE THROUGH WEATHERSTRIPPED WINDOW WITH VARIOUS CLEARANCES

that it has metal members on both the sash and the frame, and they are so constructed that one fits into the other. The rib type strip has one metal member fastened on the frame which fits into a groove ploughed in the sash by the carpenter applying the strip. The width of this groove in comparison with the width of the metal member may be the determining factor in the leakage through a window to which this type of strip is applied. In this instance the rib was $^1/_8$ in. wide and the groove $^1/_{32}$ in. wider. De Volson Wood (A.S.M.E. *Transactions*, Vol. 10) gives the lateral expansion of white pine as 2.6 per cent from dryness to saturation.

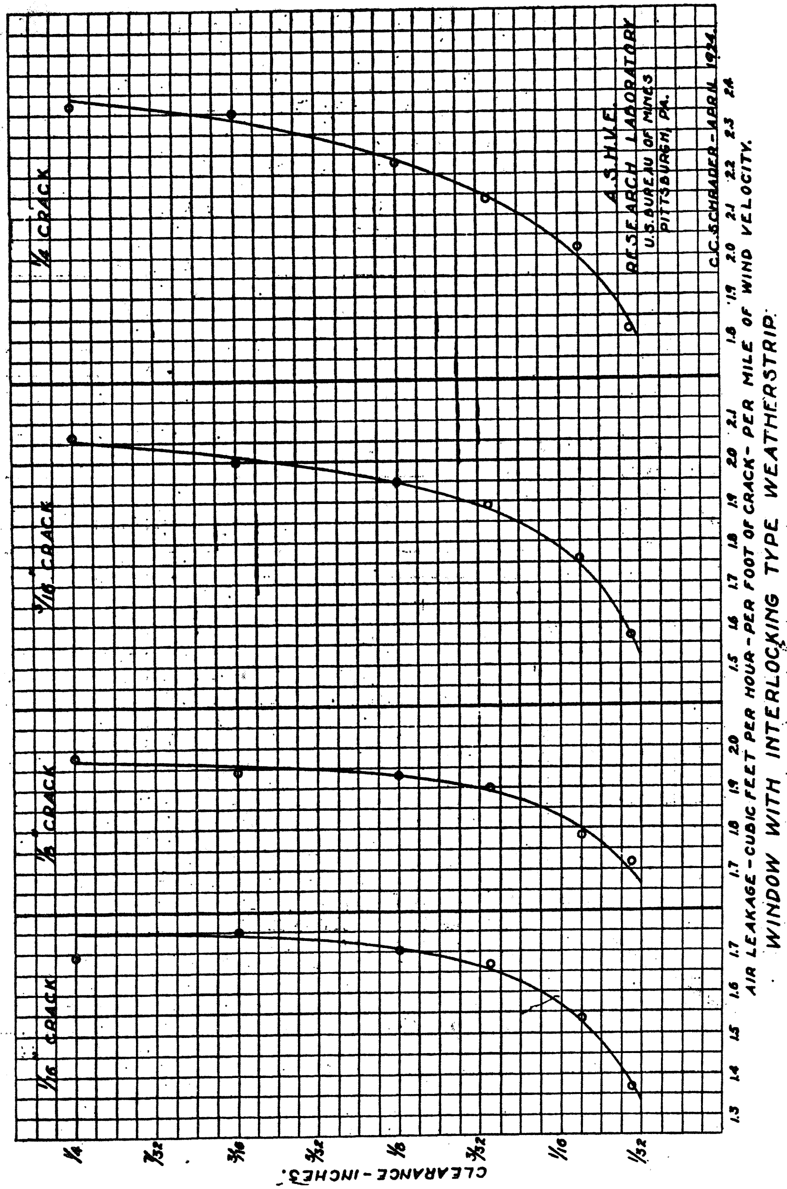

FIG. 7. LEAKAGE PER FOOT WITH VARIOUS CRACKS AND CLEARANCES. INTERLOCKING TYPE WEATHERSTRIP

With the groove 5/32 in. wide a variation of 0.004 in. in width is given from one extreme to the other. Though most sashes at the present time are made of some less expensive wood, such as cypress or spruce, it is probable that the expansion of either would not be much greater than white pine. Therefore the clearance allowed here would be ample in any case.

No tables of leakage are included in this report because any values desired can

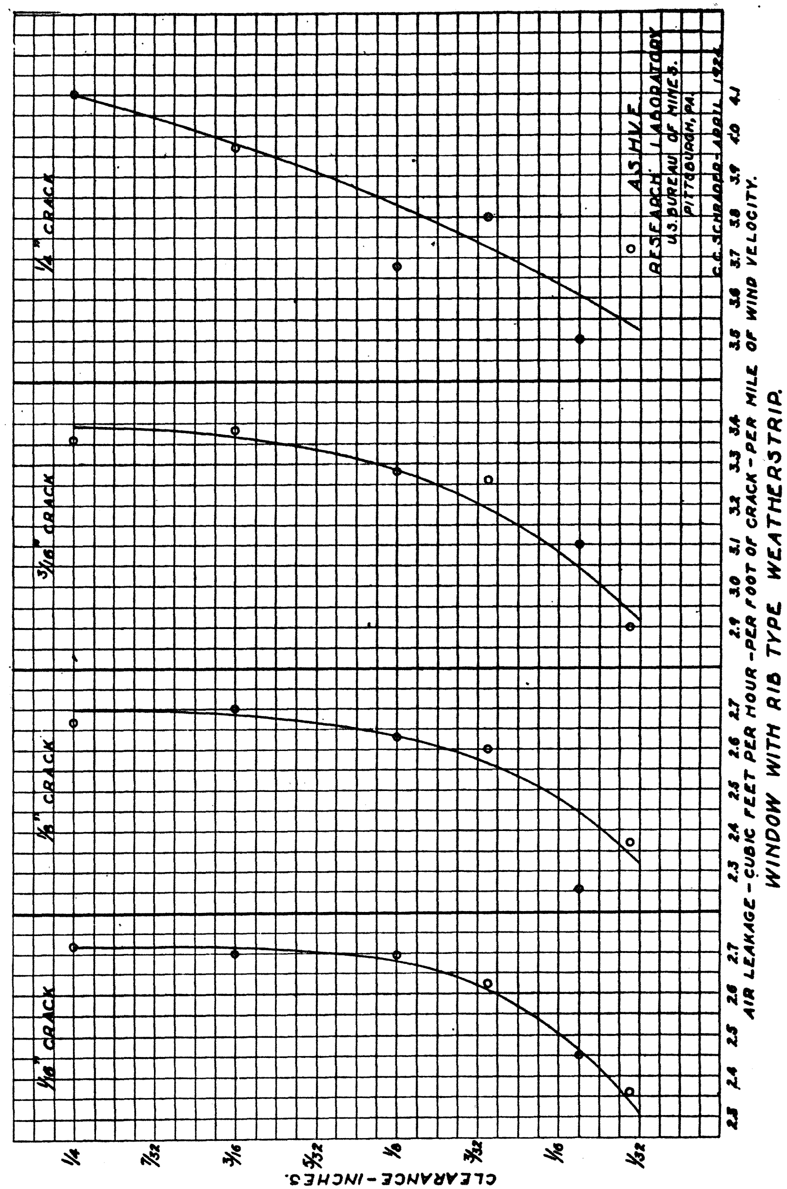

FIG. 8. LEAKAGE PER FOOT WITH VARIOUS CRACKS AND CLEARANCES. RIB TYPE WEATHERSTRIP

easily be found from the curves. Another reason is that the most important factor in the problem of infiltration has been the subject of much discussion and is not yet definitely determined. This factor is the clearance of the average window after it has been in service a sufficient length of time to have reached its final condition in regard to shrinkage which is a question for architects and heating engineers to decide. A simple solution to the problem can be obtained by actually measuring and then averaging the clearances of a sufficient number of windows in buildings which are at least five years old. Different results would probably be obtained for sashes of different thicknesses because, although most windows leave the mill with the same clearance, those made of heavier wood will shrink more. Data obtained from twenty large manufacturers of windows have shown that almost all sashes from $1^3/_8$ in. to $2^1/_2$ in. thick are allowed $^1/_{16}$ in. clearance. It remains to be decided what the final clearance will be when the sashes have thoroughly weathered and dried.

The importance of the increase in clearance is shown by the following example: The capacity of a room 14 x 12 x 10 ft. is 1680 cu. ft. With two windows such as those tested there would be 36.67 ft. of crack. From Fig. 5 the leakage for $^1/_{16}$ in. clearance is 6.6 c.f.m. per ft. of crack per mile of wind velocity. Assuming a 15 mile wind, the infiltration would be 6.6 x 36.67 x 15 or 3630 cu. ft. per hr., or $\frac{3630}{1680} = 2.16$ air changes per hr. If the clearance increases to $^1/_8$ in. the leakage increases to 11.2 cu. ft. per hr. per ft. of crack per mile of wind velocity. The infiltration would then be 11.2 x 36.67 x 15 or 6160 cu. ft. per hr., and the number of air changes would be increased to 3.66 per hr.

It must be remembered that in all these tests the crack between the frame and the setting was sealed, and this practice being easily done has become more and more common, and it has prevented considerable leakage, and thereby effected a saving in radiation surface and fuel.