poorly fitted window. *All* of the figures for double-hung wood windows are for the *unlocked* condition. Just how a window is closed, or fits when it is closed, has considerable influence on the leakage. The leakage will be high if the sash are short, if the meeting rail members are warped, or if the frame and sash are not fitted squarely to each other. It is possible to have a window with approximately the average crack and clearance that will have a leakage at least double that of the figures shown. Values for the average double-hung wood window in Table 2 are considered to be easily obtainable figures, provided the workmanship on the window is good. Should it be known that the windows under consideration are poorly fitted, the larger leakage values should be used. Locking a window generally decreases its leakage, but in some cases may push the meeting rail members apart and increase the leakage. On windows with large clearances, locking will usually reduce the leakage.

Wood casement windows may be assumed to have the same unit leakage as for the average double-hung wood window when properly fitted. Locking, a normal operation in the closing of this type of window, maintains the crack at a low value.

For a metal pivoted sash, the length of crack is the total perimeter of the movable or ventilating sections. Frame leakage on steel windows may be neglected when they are properly grouted with cement mortar into brick work or concrete. When they are not properly sealed, the linear feet of sash section in contact with steel work at mullions should be figured at 25 percent of the values given in Table 2 for industrial pivoted windows.

When storm sash are applied to well fitted windows, some reduction in infiltration is secured; the application of the sash provides an air space which reduces the heat transmission and helps prevent the frosting of the windows.[12] By applying storm sash to poorly fitted windows, a reduction in leakage of 50 percent may be obtained, the effect, so far as air leakage is concerned, being roughly equivalent to that obtained by the installation of weatherstrips.

Air Leakage Through Walls

Data on infiltration through brick and frame walls are given in Table 3.[12] The brick walls listed in this table are walls that show poor workmanship, and which are constructed of porous brick and lime mortar. For good workmanship, the leakage through hard brick walls with cement-lime mortar does not exceed one-third the values given. These tests indicate that plastering reduces the leakage by about 96 percent; a heavy coat of cold water paint, 50 percent; and three coats of oil paint carefully applied, 28 percent. The infiltration through walls ranges from 6 to 25 percent of that through windows and doors in a 10-story office building, with imperfect sealing of plaster at the baseboards of the rooms. With perfect sealing the range is from 0.5 to 2.7 percent; or a practically negligible quantity, which indicates the importance of good workmanship for proper sealing at the baseboard. It will be noted from Table 3 that the infiltration through properly plastered walls can be neglected.

The value of building paper, when applied between sheathing and shingles, is indicated by curve 3D–7D, Fig. 4, which represents the effects on outside construction only, without lath and plaster. The effectiveness of plaster properly applied is no justification for the use of low grade building paper, or of the poor construction of the wall containing it. Not only is it difficult to secure and maintain the full effectiveness of the plaster, but also it is highly desirable to have two points of high resistance to air flow

Table 3 .... Infiltration Through Walls[a]
Expressed in cubic feet per (square foot) (hour)

Type of Wall	Wind Velocity, Miles per Hour					
	5	10	15	20	25	30
Brick Wall[b]						
8½ in. Plain	2	4	8	12	19	23
Plastered[c]	0.02	0.04	0.07	0.11	0.16	0.24
13 in. Plain	1	4	7	12	16	21
Plastered[c]	0.01	0.01	0.03	0.04	0.07	0.10
Plastered[d]	0.03	0.10	0.21	0.36	0.53	0.72
Frame Wall, lath and plaster[e]	0.03	0.07	0.13	0.18	0.23	0.26

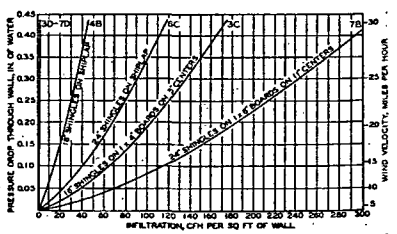
[a] The values given in this table are 20 percent less than test values to allow for building up of pressure in rooms, and are based on test data reported in the papers listed in chapter footnotes.
[b] Constructed of porous brick and lime mortar—workmanship poor.
[c] Two coats prepared gypsum plaster on brick.
[d] Furring, lath, and two coats prepared gypsum plaster on brick.
[e] Wall construction: bevel siding painted or cedar shingles, sheathing, building paper, wood lath, and three coats gypsum plaster.

with an air space between them. The infiltration indicated in Fig. 4 is that determined in the laboratory, and *should be multiplied by the factor* 0.80 to give values consistent with Table 3. In order to find air leakage rates from Table 3 resulting from pressure due to stack action the procedure outlined under Air Leakage Through Windows can be followed.

Published data are not available for air leakage rates through modern curtain wall constructions. These no doubt vary considerably in initial tightness as well as in tightness in years following construction. Maximum air leakage rates may be specified by architects in the design of large commercial buildings.

Air Leakage Through Doors

Infiltration through doors must be considered in relation to the type of door and room or building involved. For residences and small buildings where doors are used infrequently, infiltration can be based on the air leakage through cracks between door and frame. Such doors vary greatly in fit because of their tendency to warp. For a well fitted door, the leakage values for a poorly fitted double-hung wood window may be used. If poorly fitted, twice this figure should be



3D-7D: 3-D-16 inch shingles on 1 x 4 inch boards on 5 inch centers with paper, 7-D-16 inch shingles, shiplap and paper.

Fig. 4 .... Infiltration Through Various Types of Shingle Construction

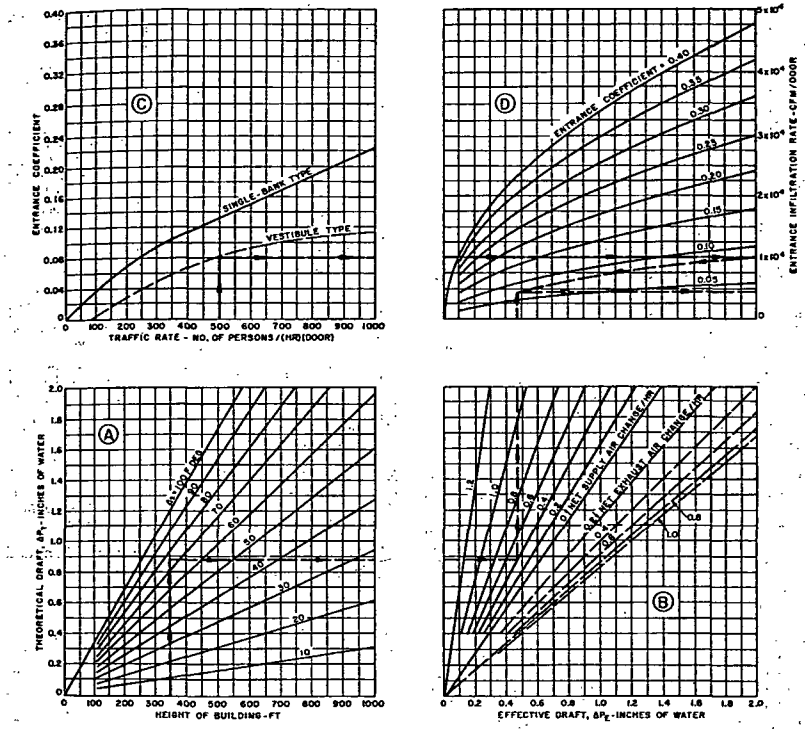


Fig. 5 .... Design Chart for Evaluating Air Infiltration Rate Through Swinging Door Entrances Under Winter Heating Conditions

used. If weatherstripped, the values may be reduced one-half. A single door that is frequently opened, as might be the case in a small store, should have a value applied three times that for a well fitted door. This extra allowance is for opening and closing losses, and is kept from being greater by the fact that doors are not used as much in the coldest and windiest weather. Large rates of leakage can occur with doors in use and this must be taken into account in commercial establishments where high traffic rates are expected. Information on the infiltration characteristics of swinging and revolving doors has been quite limited[14] and predictions for purposes of load calculations generally have been a matter of engineering judgement.[15] A recent program of Society research has provided comprehensive data on the air leakage characteristics of swinging door entrances[3] and similar data on revolving doors.[16] Complementary data on pressure differences across entrances of tall buildings[3] have also been provided.

Swinging Door Entrances

Air leakage through swinging door entrances is complicated by the opening and closing of doors and other variables related to the entrance. Based on a recent research[3] a simplified chart[17] for design purpose is shown in Fig. 5 The infiltration can be evaluated by following the flow diagram if height of building, inside-outside temperature difference, net supply or exhaust air change, type of entrance and traffic rate are known. *Example* 1 illustrates the use of the chart.

Example 1: A conventional building 350 ft high has a net cubage of 4,200,000 cu ft. Fresh air fans supply outside air at the rate of 80,000 cfm and exhaust fans discharge 50,000 cfm. The building has a vestibule-type entrance having four 3 × 7 ft doors and the indoor temperature is maintained at 75°F. Find the infiltration rate through the entrance at a time when the traffic rate is 2000 persons per hour. Outdoor temperature is 0°F.

Solution: From Fig. 5A; the theoretical draft for a 350 ft