raised enough to give the desired area, and be fitted with baffle boards to direct the air straight and upward.

In houses less than 20 ft in width, all inlets may be on one side. In wider houses, a rather uniform distribution of inlets is essential.

GARAGE VENTILATION

Because of hazards resulting from carbon monoxide and other physiologically harmful or combustible gases or vapors in garages, the importance of proper ventilation of these buildings cannot be over-emphasized. During the warm months of the year, garages are usually ventilated adequately because the doors and windows are kept open. The A.S.H.V.E. Code of Minimum Requirements for Heating and Ventilating Garages,[11] adopted in 1935, specifies that openings for natural ventilation shall be distributed as uniformly as possible in at least two outside walls, and that the total area of such openings shall be equivalent to at least 5 percent of the floor area. The code further states that where it is impracticable to operate such a system of natural ventilation, a mechanical system shall be used, and shall provide for either the supply of 1 cfm of outdoor air for each square foot of floor area, or for exhaust of the same amount of air, discharging it to the outside as a means of flushing the garage.

Cooperative research[11] on garage ventilation, undertaken by the A.S.H.V.E. Committee on Research at *Washington University*, St. Louis, Mo., and at the *University of Kansas*, and tests conducted at the A.S.H.V.E. Research Laboratory, have resulted in authoritative papers on the subject.

Some of the conclusions based on work at these laboratories are:

1. Upward ventilation results in a lower concentration of carbon monoxide at the breathing line and a lower temperature above the breathing line, than does downward ventilation for the same rate of carbon monoxide production, air change, and the same temperature at the 30-in. level.

2. A lower rate of air change and a smaller heating load are required with upward than with downward ventilation.

3. In the average case, upward ventilation results in a lower concentration of carbon monoxide in the occupied portion of a garage, than that obtained with mixing of the exhaust gases and the air supplied. However, the variations in concentration from point to point, together with the possible failure of the advantages of upward ventilation to accrue, suggest the basing of garage ventilation on complete mixing and an air change sufficient to dilute the exhaust gases to the allowable concentration of carbon monoxide.

4. The rate of carbon monoxide production by an idling car is shown to vary from 25 to 50 cfh, with an average rate of 35 cfh.

5. An air change of 350,000 cfh per idling car is required to keep the carbon monoxide concentration down to one part in 10,000 parts of air.

Individual Exhaust Ducts

Motor vehicle servicing areas may be provided with underground or overhead exhaust systems discharging outdoors. Each service location should be provided with a flexible branch duct, the inlet end of which is sized to slip over the tail pipe of the engine, or over any deflector attached to the tail pipe. The minimum branch size and ventilation rate for the largest class of vehicle regularly serviced at each location are shown in Table 4.

Where each tail pipe exhaust branch is provided with an automatic device to close the branch inlet when it is not in use, the capacity of the fan for the system should be based on the maximum number of branches in simultaneous use. Where the branch inlets are open when not in use, the system capacity should be based on the total number of branches connected to the main.

TABLE 4. MINIMUM TAIL PIPE CONNECTION SIZE AND VENTILATION RATE

CLASS OF VEHICLE	TAIL PIPE DIAMETER, IN.	VENTILATION RATE, CFM	FLEXIBLE PIPE, DIAM, IN.	DIAMETER OF RIGID BRANCH CONNECTION TO FLEXIBLE PIPE, IN.
Auto	Under 2	100	3	4
Truck	2 to 3	150	4	4½
Bus	3 and over	250	4½	5½

Individual straight lengths of gas tight duct, not over 20 feet in length, terminating outdoors, may be provided where exhaust systems are not installed. The duct should fit tightly over the tail pipe and be of a diameter not less than the diameter of the tail pipe.

REFERENCES

[1] A.S.H.V.E. RESEARCH REPORT No. 786—Infiltration Through Plastered and Unplastered Brick Walls, by F. C. Houghten and Margaret Ingels (A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927, p. 377). No. 826—Air Infiltration Through Various Types of Brick Wall Construction, by G. L. Larson, D. W. Nelson and C. Braatz (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929, p. 183). No. 851—Air Infiltration Through Various Types of Brick Wall Construction, by G. L. Larson, D. W. Nelson and C. Braatz (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 99). No. 868—Air Infiltration Through Various Types of Wood Frame Construction, by G. L. Larson, D. W. Nelson and C. Braatz (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 397).

[2] A.S.H.V.E. RESEARCH REPORTS No. 686—Air Leakage, by F. C. Houghten and C. C. Schrader (A.S.H.V.E. TRANSACTIONS, Vol. 30, 1924, p. 105). No. 704—Air Leakage Around Window Openings, by C. C. Schrader (A.S.H.V.E. TRANSACTIONS, Vol. 30, 1924, p. 313). No. 803—Air Leakage on Metal Windows in a Modern Office Building, by F. C. Houghten and M. E. O'Connell (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928, p. 321). No. 815—Air Leakage Through a Pivoted Metal Window, by F. C. Houghten and M. E. O'Connell (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928, p. 519). No. 817—Effect of Frame Calking and Storm Sash on Infiltration Around and Through Windows, by W. M. Richtmann and C. Braatz (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928, p. 547). No. 909—Air Infiltration Through Double-Hung Wood Windows, by G. L. Larson, D. W. Nelson and R. W. Kubasta (A.S.H.V.E. TRANSACTIONS, Vol. 37, 1931, p. 571). The Weathertightness of Rolled Section Steel Windows, by J. E. Emswiler and W. C. Randall (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928, p. 527). Pressure Differences Across Windows in Relation to Wind Velocity, by J. E. Emswiler and W. C. Randall (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 83). Air Infiltration Through Steel Framed Windows, by D. O. Rusk, V. H. Cherry and L. Boelter (A.S.H.V.E. TRANSACTIONS, Vol. 39, 1933, p. 169).

[3] Fuel Saving Resulting from the Use of Storm Windows and Doors, by A. P. Kratz and S. Konzo (A.S.H.V.E. TRANSACTIONS, Vol. 42, 1936, p. 87).

[4] The Infiltration Problem of Multiple Entrances, by A. M. Simpson and K. B. Atkinson (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, June, 1936, p. 345). Infiltration Characteristics of Entrance Doors, by A. M. Simpson (*Refrigerating Engineering*, June, 1936).

[5] Indices of Air Change and Air Distribution, by F. C. Houghten and J. L. Blackshaw (A.S.H.V.E. TRANSACTIONS, Vol. 39, 1933, p. 261).

[6] A.S.H.V.E. RESEARCH REPORTS No. 994—Wind Velocities Near a Building and Their Effect on Heat Loss, by F. C. Houghten, J. L. Blackshaw and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934, p. 387). No. 1069—Heating Requirements of an Office Building as Influenced by the Stack Effect, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 43, 1937, p. 437). Flue Action in High Buildings, by H. L. Alt (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, May, 1932, p. 376). Influence of Stack Effect on the Heat Loss in Tall Buildings, by Axel Marin (A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934, p. 377).

[7] Neutral Zone in Ventilation, by J. E. Emswiler (A.S.H.V.E. TRANSACTIONS, Vol. 32, 1926, p. 59).