for each square foot of floor area, or for removing the same amount and discharging it to the outside as a means of flushing the garage.[4]

Research

Research 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, Lawrence, Kans., in cooperation with the A.S.H.V.E. Research Laboratory, and at the A.S.H.V.E. Research Laboratory, has resulted in authoritative papers on the subject.

Some of the conclusions from work at the Laboratory are listed in the following statements:

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 is had with complete 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 cu ft per hour, with an average rate of 35 cu ft per hour.

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

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[4]Code for Heating and Ventilating Garages (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929, p. 355), (A.S.H.V.E. Reprint, January, 1935).

Airation Study of Garages by W. C. Randall and L. W. Leonhard (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 233).

A.S.H.V.E. RESEARCH REPORT No. 874—Carbon Monoxide Concentration in Garages, by A.S. Langsdorf and R. R. Tucker (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 511).

A.S.H.V.E. RESEARCH REPORT No. 935—Carbon Monoxide Distribution in Relation to the Ventilation of an Underground Ramp Garage, by F. C. Houghten and Paul McDermott (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 439).

A.S.H.V.E. RESEARCH REPORT No. 934—Carbon Monoxide Distribution in Relation to the Ventilation of a One-Floor Garage, by F. C. Houghten and Paul McDermott (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 424).

A.S.H.V.E. RESEARCH REPORT No. 967—Carbon Monoxide Distribution in Relation to the Heating and Ventilation of a One-Floor Garage, by F. C. Houghten and Paul McDermott (A.S.H.V.E. TRANSACTIONS, Vol. 39, 1933, p. 395).

Carbon Monoxide Surveys of Two Garages, by A. H. Sluss, E. K. Campbell and Louis M. Farber (A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934, p. 263).

Chapter 43

PIPE AND DUCT HEAT LOSSES

Heat Losses from Bare and Insulated Pipes, Low Temperature Pipe Insulation, Insulation of Pipes to Prevent Freezing, Economical Thickness of Pipe Insulation, Underground Pipe Insulation, Heat Losses from Ducts

THE heat transfer through uninsulated pipes and ducts may be of considerable magnitude if the temperature of the surrounding medium differs appreciably from that of the fluid conveyed. Careful consideration must, therefore, be given to this factor in a properly designed system and adequate insulation provided, if necessary.

HEAT LOSSES FROM BARE PIPES

Heat losses from horizontal bare steel pipes, based on tests at *Mellon Institute* and calculated from the fundamental radiation and convection equations (Chapter 3), are given in Table 1. Heat losses from horizontal copper tubes and pipes with bright, lacquered and tarnished surfaces, are given in Tables 2, 3 and 4[1].

The monetary values of the heat losses given in Tables 1, 2, 3 and 4 may be obtained by means of Fig. 1 for various heating system efficiencies, temperature differences, and calorific values, and costs of coal. This chart, however, is intended for heat losses greater than 2 Btu per linear foot per hour per degree Fahrenheit temperature difference. To solve a problem, select the proper heat loss coefficient from Tables 1, 2, 3 or 4 and locate this value on the upper left-hand margin of the chart. Then draw lines in the order indicated by the dotted lines, the dollar value of the heat loss per 100 linear feet of pipe per 1000 hours being given on the upper right-hand scale. In using the chart, the cost of coal should also include the labor for handling it, boiler room expense, etc.

The area in square feet per linear foot of pipe is given in Table 5 for various standard pipe sizes, and Table 6 for copper tubing, while Table 7 gives the area in square feet of flanges and fittings for various standard pipe sizes. These tables can be used to advantage in estimating the amount of insulating cement required for various equipment.

Very often, when pipes are insulated, flanges and fittings are left bare so as to allow for easy access to the fittings in case of repairs. The fact that a pair of 8-in. standard flanges having an area of 2.41 sq ft would

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[1]Heat Loss from Copper Piping, by R. H. Heilman (*Heating, Piping and Air Conditioning*, September, 1933, p. 458).