distribution, cannot be predicted with certainty, and refinement in calculations is not justified; consequently, a simplified method can be used. This may be done by using the equations and calculating the flows produced by each force separately, under conditions of openings best suited for coordination of the forces. Then, by determining the ratio of the flow produced by temperature difference to the sum of the two flows, the actual flow due to the combined forces can be approximated from Fig. 4.

Example 1: Assume a drop forge shop, 200 ft long, 100 ft wide, and 30 ft high. The cubical content is 600,000 cu ft, and the height of the air outlet over that of the inlet is 30 ft. Oil fuel of 18,000 Btu per lb is used in this shop at the rate of 15 gph (7.75 lb per gal). Desired summer temperature difference is 10 deg, and the prevailing wind is 8 mph perpendicular to the long dimension. What is the necessary area for the inlets and outlets, and what is the rate of air flow through the building?

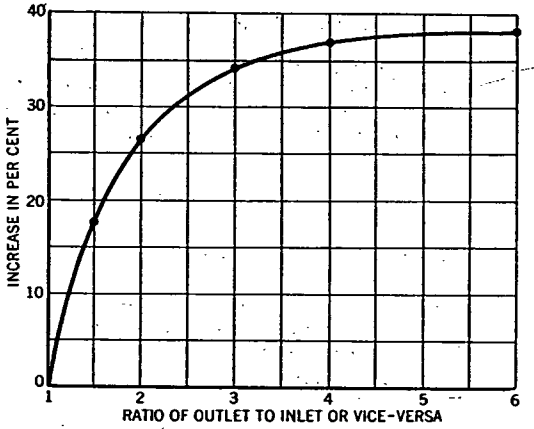

FIG. 3. INCREASE IN FLOW CAUSED BY EXCESS OF ONE OPENING OVER ANOTHER

Solution for Temperature Difference Only: The heat $H = 15 \times 7.75 \times 18{,}000 = 2{,}092{,}500$ Btu per hr.

By Equation 5, the air flow required to remove this heat with an average temperature difference of 10 deg is

$$Q = \frac{H}{1.08(t_i - t_o)} = \frac{2{,}092{,}500}{1.08 \times 10} = 193{,}750 \text{ cfm.}$$

This is equal to about 20 air changes per hour. From Equation 4, the inlet (or outlet) opening area should be

$$A = \frac{Q}{9.4\sqrt{h(t_i - t_o)}} = \frac{193{,}750}{9.4\sqrt{30 \times 10}} = 1190 \text{ sq ft.}$$

The flow per square foot of inlet or outlet would be 193,750 ÷ 1190 = 162.5 cfm, with all windows open.

Solution for Wind Only: With 1,190 sq ft of inlet openings distributed around the sidewalls, there will be about 400 sq ft in each long side and 195 sq ft in each end. The outlet area will be equally distributed on the two sides of the monitor, or 595 sq ft on each side. With the wind perpendicular to the long side, there will be 400 sq

ft of opening in its path for inflow, and 595 in the lee side of the monitor for outflow with the windward side closed. The air flow, as calculated by Equation 3, will be:

$$Q = 0.60 \times 400 \times 704 = 168{,}960 \text{ cfm.}$$

This gives 16.9 air changes per hour, which should be more than ample when there is no heat to be removed.

Solution for Combined Heads: Since the windward side of the monitor is closed when the wind is blowing, the flow due to temperature difference must be calculated for this condition, using Fig. 3. This chart shows that, when inlets are twice the size of the outlets, in this case 1,190 sq ft in the sidewalls and 595 sq ft in the monitor, the flow will be increased 26.5 percent over that produced by equal openings. Using

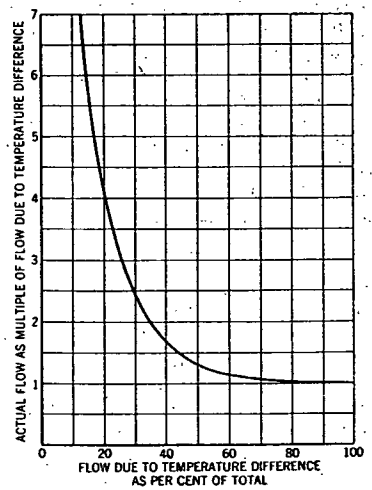

FIG. 4. DETERMINATION OF FLOW CAUSED BY COMBINED FORCES OF WIND AND TEMPERATURE DIFFERENCE

the smaller opening and the flow per square foot obtained previously, the calculated amount for this condition will be

$$595 \times 163 \times 1.265 = 122{,}700 \text{ cfm.}$$

Adding the two computed flows:

Temperature Difference	= 122,700	= 42 percent.
Wind	= 168,960	= 58 percent.
Total	291,660	= 100 percent.

From Fig. 4 it is determined that, when the flow due to temperature difference is 42 percent of the total, the actual flow due to the combined forces, will be about 1.6 times that calculated for temperature difference alone, or 196,300 cfm.

The original flow due to temperature difference alone was 193,750 cfm with all openings in use. The effect of the wind is to increase this to 196,300 cfm, even though half of the outlets are closed.

A factor of judgment is necessary in the location of the openings in a building, especially those in the roof, where heat, smoke, and fumes are to be removed. Usually, windward monitor openings should be closed, but if