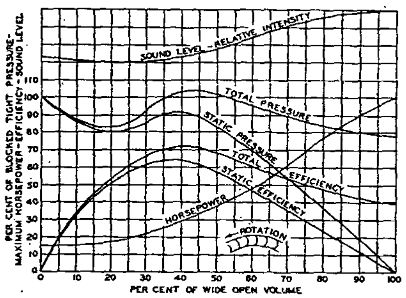

Fig. 2 .... Percentage Performance Curves of a Forward-Curved Blade Centrifugal Fan

livery. The horsepower reflects the energy-velocity relationship by rising to a maximum value as the capacity increases, and then decreasing with further increase in capacity to give a self-limiting horsepower characteristic. The maximum horsepower coincides approximately with the maximum efficiency. The sound is again a minimum near maximum efficiency, but is little or no higher at free delivery than at low capacities.

Between the extremes of forward and full-backward-curved blades, there exists a number of intermediate designs which show varying degrees of similarity to the curves in Figs. 2 and 3. A common variation is a fan having modified backward, single, or double-curved blades and equipped with fixed inlet vanes. Such vanes applied to a partially backward-curved impeller give the steep, constantly rising pressure characteristic, and the self-limiting horsepower feature of the full-backward-curve impeller. They also stabilize the flow entering the impeller when adverse flow conditions exist in the approach to the inlet.

Axial-flow fans develop none of their static pressure by centrifugal force, but all from the change in velocity in passing through the impeller, and its conversion into static pressure. They are thus inherently high-velocity fans, and are very dependent on blade conformation for good characteristics. For that reason, an air-foil section, such as developed in wind tunnels for aircraft work[6] is frequently used. Since any shape of blade can only be correct for a narrow range of capacity at constant speed, the performance curves for any blade show definite characteristics. To absorb energy, the air must be given a tangential motion in passing the impeller,[7] and when operating against higher pressures, must have guide vanes (see vaneaxial fans) to obtain best efficiencies.

While *axial-flow fans* are inherently a higher capacity type than centrifugal fans, they, too, may be designed with widely varying characteristics. As with a centrifugal fan, the pressure rises generally from free delivery to no delivery, but tubeaxial and vaneaxial fans may have a drop in pressure when the capacity decreases below a certain volume, a condition also found in the case of the centrifugal fan having forward-curved blades. The pressure drop is caused by the same condition for both fans, i.e., the static pressure is largely dependent on conversion of velocity pressure, and velocity pressure is small at low capacity. Tubeaxial and vaneaxial fans may also have performance curves resembling somewhat those of a centrifugal fan with backward-curved blades. Fig. 4 shows the performance curves for a typical design.

The horsepower curve may be flat with a self-limiting characteristic as in a backward-curved blade centrifugal fan, or it may have a generally downward trend from no delivery to free delivery with the maximum at no delivery, contrary to that of a centrifugal fan. The type of guide vanes in a vaneaxial fan has a distinct bearing on the shape of the horsepower curve. The maximum efficiency tends to occur at a percentage of free delivery capacity higher than for a centrifugal fan.

The sound curve, which may have a minimum value comparable to centrifugal fans, is again lowest near maximum efficiency, but has a characteristic rise when the fan is operating at low capacities and the *stall* point of the blade section is reached.

Since *propeller fans* are designed for operation near free delivery, less attention is given the regaining of velocity to static pressure, and the pressure curve rises constantly from free delivery to no delivery. The horsepower is highest at no delivery, and decreases toward free delivery, in contrast to a centrifugal fan. Maximum total efficiency is obtained at a higher percentage of free delivery than for other types.

SYSTEM CHARACTERISTICS

Any ventilating system consisting of ductwork, heaters, air washers, filters, etc., has a system characteristic which is individual to that system, and is independent of any fan which may be applied to the system. This characteristic may be expressed in curve form in exactly the same manner that fan characteristics may be shown. Typical system characteristic curves are shown as *A*, *B*, and *C* in Fig. 5. These curves are drawn to follow the simple parabolic law in which the static pressure or resistance to flow of air varies as the square of the volume flowing through the system. Heating and ventilating systems follow this law very closely and no serious error is introduced by its use.

When the characteristic curve of a constant-speed fan of a given size is superimposed upon a system characteristic curve, the relation between the two is at once apparent. The only point common to the two curves is the point at the intersection of the system characteristic curve and the fan characteristic curve, and it is at this point that the combination will operate. In Fig. 5, system characteristic curves *A*, *B*, and *C* cross the fan characteristic curve at points *X*, *Y*, and *Z*. The fan whose curve is shown, when applied to systems having characteristic curves *A*, *B*, and *C*, will deliver 10,000, 13,000 or 16,400 cfm, respectively.

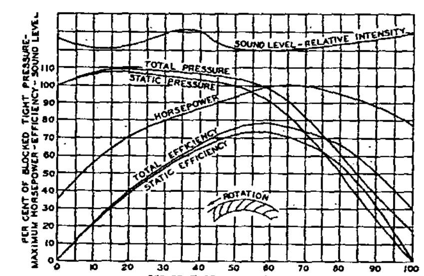

Fig. 3 .... Percentage Performance Curves of a Backward-Curved Blade Centrifugal Fan

The curves in Fig. 5 also illustrate the effect of errors that may be made in calculating the resistance of a ventilating system. For instance, if a given system requires 13,000 cfm, and the resistance to flow of the system has been computed as 1.25 in. static pressure, such a system would be represented by system characteristic curve *B* in Fig. 5. If a 100 percent error had been made and the resistance were 2.5 in. instead of 1.25 in., then the system characteristic would be as shown in curve *A*, and would cross the fan curve at 10,000 cfm. Such an error would cause the flow of air to be decreased from a design volume of 13,000 cfm to 10,000 cfm. If the resistance to flow had been overestimated and the resistance actually were 0.625 in., the system characteristic curve would be as shown in curve *C*, and the fan would deliver 16,400 cfm to the system instead of the design volume of 13,000 cfm.

In this example, extreme errors have been selected to emphasize the effect the square function of the system characteristic has in maintaining the fan performance within comparatively narrow limits. In the first example, a system estimated at half what it should have been, resulted in a drop of 23 percent in volume; and in the second example, a system estimated at twice what it should have been resulted in an increase of 26 percent in volume.

In some instances fans may be applied to variable-flow systems. In such cases, the limiting systems may be plotted and the effect on fan performance examined. For instance, a system might have a characteristic curve between *A*, shown in Fig. 5, as one limit, and *B* as the other limit. The fan performance will then fall between points *X* and *Y* on the fan curve at a point determined by the system characteristics at that particular time. If *A* and *B* are the limiting characteristic curves of the systems, the fan performance will never be outside the points *X* or *Y*.

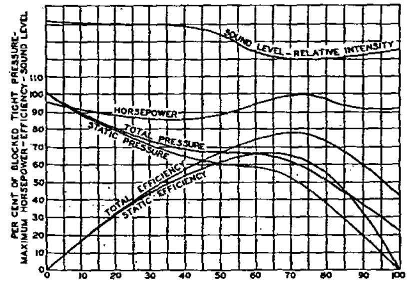

Fig. 4 .... Percentage Performance Curves of an Axial-Flow Fan

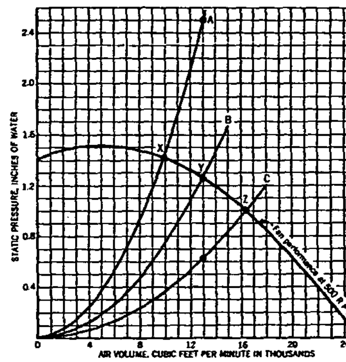

Fig. 5 .... Parabolic System Characteristic Curves

FAN ARRANGEMENTS

Centrifugal fan arrangements have been standardized by the Air Moving and Conditioning Association. Figs. 6, 7, and 8 show the accepted designation as to arrangement of drive, rotation, discharge, and motor position, for belt drive. Axial-flow fans are either belt driven or direct connected, in accordance with individual manufacturer's arrangements. Usually a choice of antifriction or sleeve bearings is available.

FAN CONTROL

In some heating and ventilating systems it is desirable to vary the volume of air handled by the fan. This may be accomplished by a number of methods. Where the change is made infrequently, the pulley or sheave on the driving motor or fan may be changed to vary the speed of the fan and alter the air volume. Dampers may be placed in the duct system to vary the volume. Variable-speed pulleys or transmissions, such as fan belt change boxes, or electric or hydraulic couplings, may be used to vary the fan speed. Variable-speed motors and variable inlet vanes on fans may also be used to adjust the fan volume. All of these methods will give control. From a power consumption consideration, a reduction of fan speed is most efficient. Inlet vanes save some power, while dampers save the least. From consideration of first cost, dampers usually are the lowest in cost. In some installations, adjustments of volume are desirable at various times during the day, or continuously. In others, an increased supply of air in summer, over that needed in winter, is demanded. The demands in each case will dictate which type of control is most desirable. Where noise is a factor, a lowering of fan speed, if possible, is preferred as a control means, because of the resulting reduction in sound level.

In addition to the above types of control, *tubeaxial* and *vaneaxial* fans are sometimes made with adjustable blades to permit balancing of the fan against the system, or making seasonal adjustment.