from one-fourth to two inches or more of water pressure to overcome the air friction.

The power required for such fans is proportional to the volume of the air moved, and to the pressure overcome. Centrifugal fans with radial or forward-curved blades require power proportional to the volume at constant speed and have a power increase as the cube of the speed. If the resistance is increased the air volume is reduced, and the power at constant speed is reduced. If the resistance is reduced the air volume is increased at constant speed, and the power demand will be increased.

Centrifugal fans with backward-curved blades and those with compound curves while following the same general laws as the fans with the forward-curved blades, have been developed to the extent that they have a self-limiting power demand at a certain peripheral velocity even though the resistance at that speed may be decreased.

It is no easy matter to pre-determine the exact resistance to be encountered by a fan, or having determined this resistance, to insure that no changes in construction or operation shall ensue which may increase air resistance, thus requiring more fan speed and power to deliver the required volume, or which may reduce air resistance, thus causing delivery of more air and a consequent increase of power even at constant speed.

It is recommended therefore for centrifugal type fans that the rated power to be supplied shall exceed the rated fan power by a liberal margin, depending on the type of blade, of from 10 per cent minimum, to about 50 per cent maximum.

Justification for liberal power provision exists also in the possibility of varying demand due to changes in ventilation requirements, intensity of occupation, weather conditions, etc.

Speed Control

Some method of volume control of fans usually is desirable. This may be done by varying the peripheral velocity, or by interposing resistance, as by throttling-dampers. Both methods since they reduce the volume of air, reduce the power required. In many installations adjustments of volume are desirable during varying hours of the day. In others an increased supply of air in summer over that needed for winter, is demanded. There is room for judgment in deciding whether speed-control or damper-control shall be used for specific cases. Where noise is a factor, it may be exceedingly desirable to reduce the speed at times, while on the other hand a centrifugal fan which has its normal speed reduced as much as 50 per cent without change in resistance will move so small a volume of air that operating the fan will be hardly worth while.

Electric Motors

Electric power is the almost universal solution for fan operation, and each type of motor and current has its advantages and disadvantages.

Direct-connected electric motors are usually very efficient for fan driving because there is no slippage due to belts, and no wear or noise due to chains or gears.

Unless the fan speeds are high enough to permit comparatively high

rotative speeds, however, direct connected motors must be unduly large and heavy and will be costly. If anything goes wrong with a direct-connected motor there may be a considerable delay in replacing or repairing it, and changes in speed are not always made easily with full efficiency. On the other hand, the non-direct connected motors have transmission subject to wear and slippage, and chains and gears may be noisy. With the latter type, however, changes in speed-ratio are easily made, and in case of a break-down a standard stock-motor may be substituted quickly.

There is no advantage as to mechanical or induction-noise, in the direct-connected slower speed motors over belted higher speed motors. In either case noise seems to result from obscure manufacturing causes, and generally can be controlled by proper sound-insulation in the foundations.

Kinds of Electric Current

In general if direct current is available, it is most satisfactory for fan operation because of the inexpensive and flexible speed-control which is inherent. Where motors are inaccessible or subject to dust, however, direct current motors with their commutators and brushes will generally cause undue up-keep expense, and polyphase induction motors are to be preferred.

Single phase electric motors are reasonably satisfactory for small sizes, say 10 horsepower and smaller. They require special starting devices, which are noisy and troublesome as compared with electric motors for direct current or polyphase current.

Polyphase electric motors are satisfactory from all standpoints except that of low speed and variable speed, these arrangements being rather expensive and difficult to secure.

Controllers for Electric Motors

Electric motors of 5 horsepower and smaller for constant speed, generally may be thrown directly on to the line. Larger sizes than these require starters, of which there is a wide choice, with a multitude of variations in service and a great range in price.

Arrangements can be made for remote control of fan motors, or for automatic control by influence of temperature. Remote control may be by pneumatic or by hydraulic manipulation as well as by electrical means.

It is easy to provide tell-tales to show the setting of remote electric controllers, as by miniature electric lamps.

Other Power Sources for Fans

In many large ventilating systems which have heating plants in connection, steam engines are used to operate fans. A medium-speed steam engine, exhausting at low pressure into the radiators which heat the building or which warm the air, is a very economical source of power, is nearly noiseless, and has a wide range of speed variation. The steam-economy of such an engine usually is of little importance, since the engine serves as an auxiliary to the pressure-reducing valve interposed in such cases between the boiler and the radiators.