Some fan systems have changing air requirement during operation, such as variable air volume systems, while others have changing pressure requirements; both airflow and pressure are often altered during operation. To accommodate these changes, some form of fan performance modulation is required:

The type of modulation typically used in ducted application are:

(a) Scroll volume control
(b) Inlet dampers
(c) Discharge dampers
(d) Inlet vanes
(e) Speed modulation
(f) Fan blade pitch variation

Fig. 48 Type of Modulation for Centrifugal Fan
Scroll Volume Control
This is discussed under “System Surge, Fan Surge, and Paralleling.”. Scroll volume dampers are sometimes used on small, single-fan utility sets as a means of quickly adjusting the air delivery. However, it is not regarded as a good means of capacity control. Efficiency is reduced and the very nature of outlet volume control makes it difficult to operate automatically off a static pressure sensing device. Thus, while the scroll volume damper serves a useful purpose in controlling the paralleling of fans, it is not recommended for capacity modulation.

Inlet Dampers
The primary purpose of inlet dampers, or face dampers, as they are better known in central station units, is for the prevention of backdraft and air circulation when the unit is shut down. Inlet dampers merely add resistance to the system and cause a corresponding change in the static pressure at the fan to vary the air flow.

There are two basic drawbacks to inlet dampers. First, they allow little capacity modulation without forcing the fan to operate in an unstable part of its performance range. Secondly, since they are frequently mounted in front of an outside air opening or in front of a coil bank, they are much larger in size than the fan inlet. Thus, the static pressure differential across the damper is spread over a large area.

Because of this second drawback, care must be taken to make sure that the fan is not capable of producing a static pressure sufficient to warp or cave-in the dampers. Static pressure differential across most face dampers used on central station air-handling units should not exceed 1000 Pa, total. If the fan is capable of developing more than this static pressure at the operating RPM, care must be taken to insure that the face dampers cannot be closed while the fan is operating. If the dampers are used for trimming the system, a manual stop can be put in the damper linkage to prevent them from closing completely. For an on-off shutoff to prevent air circulation, damper motors should be installed to close the dampers only after the fan motors has shut off; conversely, the fan motor should not start until these dampers are at least partly opened. This can be done by an end switch on the dampers, which precludes fan motor operation when the dampers are completely closed and will permit fan operation only when the dampers are sufficiently opened to avert high suction static pressure.

Discharge Dampers
Discharge dampers are a method of varying the air flow over a rather narrow performance range. Since discharge dampers are typically mounted on the fan discharge, the area of the
dampers is relatively small. Thus, there is generally no need to worry about excessive static pressure, damaging the dampers. They will operate satisfactorily at block-tight conditions unless fan static pressure exceeds the structural capability of the dampers. Normally, the damper strength should withstand at least 1000 Pa of static pressure.

Fig.49 shows fan performance with discharge dampers. These dampers increase system static pressure to modulate the airflow. Discharge dampers do not change the unstable area of the fan. Thus, they should not be used for the airflow modulation with AF centrifugal fans below about 50% of wide open CMS, as this figure indicates.

Neither discharge dampers nor inlet dampers have much effect on the system noise level in the wide open position on low- and medium-pressure applications. However, they do increase the noise level as they near a closed position. The magnitude of the increase is a function of the air velocity and static pressure differential.

Fig. 49 Discharge damper performance for airofoil fan
Inlet Vanes

Inlet vanes are sometimes given the misnomer of vortex dampers. Actually, these vanes are not dampers; their sole purpose is to impart a swirl to the air in the direction of rotation as it enters the fan. The resulting vorticity results in a reduction in airflow, static pressure, and brake horsepower. Moreover, for every position of the inlet vanes, separate curves for static pressure and brake horsepower versus air flow are generated.

As these vanes are modulated, the brake horsepower curve generated is lower than the brake horsepower curve with the vanes wide open. Therefore, inlet vanes do provide some operating cost savings. The magnitude of these savings is generally about 20 to 30%, if the vanes are operated a majority of the time in the range of 60 to 80% of design CMS. Since inlet vanes cost two to three times as much as parallel-blade discharge dampers, it doesn’t pay to use them unless capacity reduction is at least 50% for long periods of time, since its horsepower savings over parallel and opposed blade dampers average about 25% under these conditions.

Quite apart from economics, inlet vanes are useful for capacity reduction on large centrifugal fans requiring more than 100 BHP, which are equipped with direct drive. This result from the difficulty of using vee-belt, variable-speed drives on such large fans. There are three drawbacks in using inlet vanes for capacity modulations: First, the fan can be forced to operate in an unstable range with inlet vanes. This is most likely to occur when the vanes are used to modulate a constant static pressure system. The resultant noise and vibration has been known to shake an entire floor.

Secondly, capacity reduction also occurs when the inlet blades are in the wideopen position. Construction of the vanes with the hub and turning mechanism located in the center creates a pressure drop, the magnitude of which is a function of the fan size. For very small fans, the hub is a relatively large percentage of the total inlet area. Thus, the capacity reduction is substantial. On the other hand, with very large fans, the hub area is a very small percentage of the total and the reduction is negligible. With belt drive applications, this does not present any particular problem since the fan speed can be readily increased to compensate. However, brake horsepower also goes up.

For example, the RPM must be increased approximately 3% with a 900 mm diameter wheel to achieve full load capacity with inlet vanes in the wide-open position. This increases the brake horsepower approximately 9.3% which could be a problem if the brake horsepower is very close to the nameplate motor horsepower.

In direct drive unit, however, the use of inlet vanes becomes more of a problem. Fairly accurate means must be available for estimating the capacity reduction for various size fans. Thirdly, inlet vanes will increase the fan’s noise level, even at wide open position. Because test data is limited, a good rule to follow is to add 5 dB to the fan noise level when using inlet vanes.
Before using inlet vanes, the fan manufacturer should be consulted for information regarding the unstable range of operation, the capacity reduction due to inlet area restriction, and the resultant noise levels.

**Speed Modulation**

Speed variation in fans can be accomplished in a number of ways, including: multi-speed motors; fluid drives; mechanical speed reducers; and solid-state devices. Speed modulation is not generally used in air conditioning application and will not be discussed in detail. Typically, the cost is greater and requires more elaborate control. Solid state devices have some merit on fractional horsepower motors and smaller integral horsepower motors. However, the control must be closely matched with the motor to operate properly.

All of these devices affect the fan performance in accordance with the following fan laws:

\[
\frac{Q_2}{Q_1} = \left( \frac{N_2}{N_1} \right)
\]

\[
\frac{Q_i^2}{Q_i} = \left( \frac{N_2}{N_1} \right)^2
\]

\[
\frac{W_2}{W_1} = \left( \frac{N_2}{N_1} \right)^3
\]

Care must be exercised in using this type of modulation in systems requiring constant static pressure either at the fan or at remote distribution boxes, as the static pressure at the fan reduces proportionally to the square of the RPM reduction.

**Fan Blade Pitch Variation**

Axial fans are available with adjustable pitch blades to permit varying the fan’s performance. This may be used to increase or decrease system capacity on direct drive fans, depending upon the original selection. On belt-driven fans it may allow some increase in efficiency if the static pressure was grossly overestimated when the original selection was made. This form of capacity modulation will generally reduce brake horsepower more than any of the previous methods for the given air flow and static pressure. It also obviates the vee-belt drive problem for larger fans requiring more than 100 BHP, since control
modulation can be accomplished fairly easily. One method of fan-blade pitch variation allows for a change in pitch while the fan is in operation. This makes the fan very adaptable for such application as automatic static pressure control for variable air volume systems.