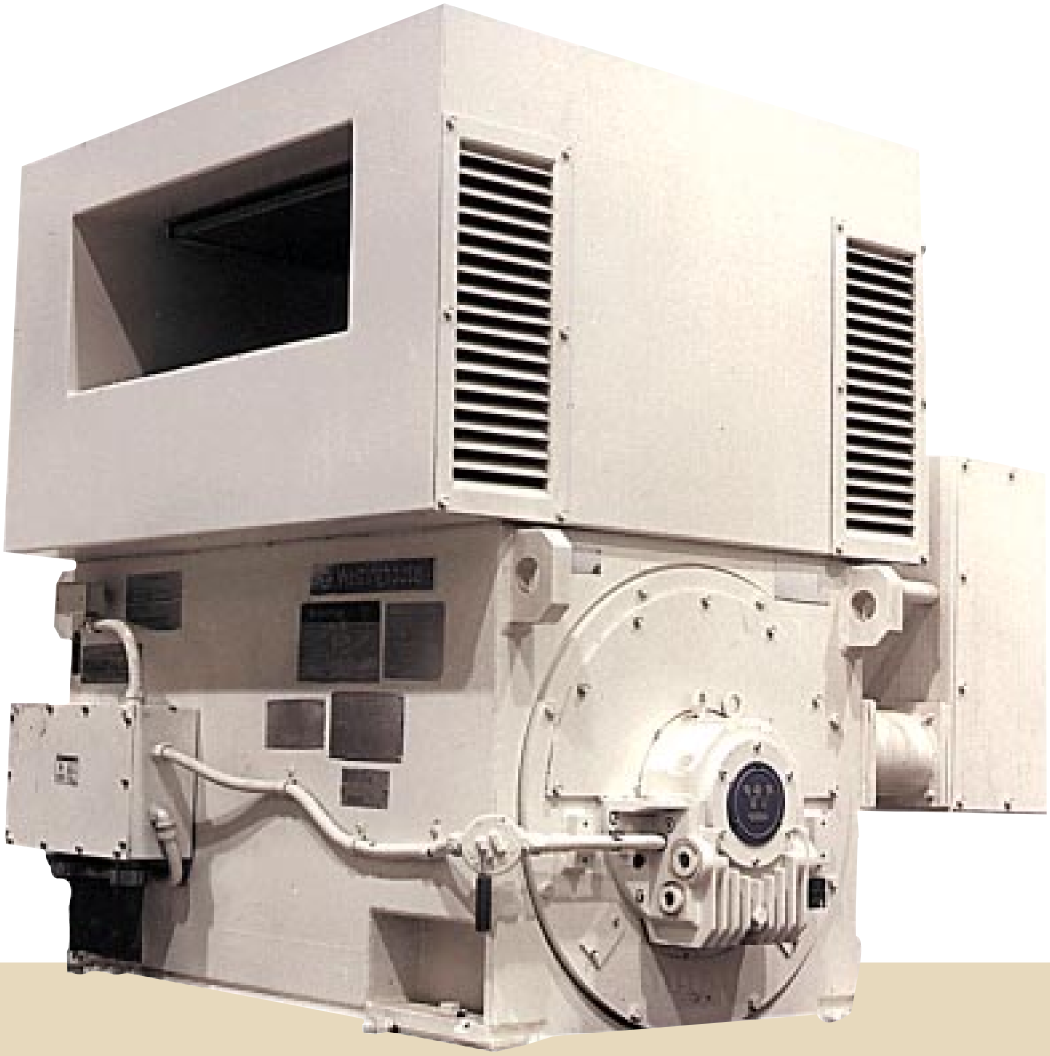
TECO-Westinghouse PAM Motor

An Economical Drive for Multi-Speed

Applications Through Pole Amplitude Modulation

The PAM Motor
Versatile and Efficient



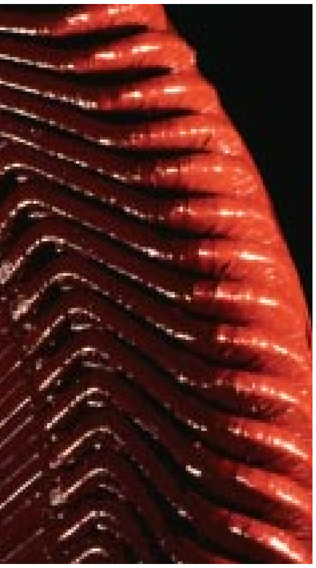
Known in the industry as the PAM motor, the TECO-Westinghouse Pole Amplitude Modulation motor is the world's most innovative AC induction motor. Although it is basically a single-winding, two-speed squirrel cage motor, the PAM motor features one outstanding characteristic that makes it versatile in application and efficient in operation, especially where less than peak load operation is desired: the PAM motor does not have to be engineered with a 2:1 ratio for its two speeds. It can be built with any number of speed ratios, such as 720/600, 900/720, 900/600, 600/514, 900/514, 277/180, 450/360, 1200/900 or 1800/1200 rpm, to name a few of the many possible combinations.

This availability of a great variety of two-speed combinations (relatively close together) gives the PAM motor a much wider range of application than that of conventional single-winding, two-speed motors where the ratio of one speed to the other must always be 2:1.

PAM Motor Benefits

- Power savings at reduced loads.
- A practical and effective means of driving a load where a change of speed can provide operating efficiency.
- Initial investment costs are lower than those of a comparable two-speed, two-winding motor.
- As a single-winding machine, the PAM motor is lighter, smaller and more efficient than a two-winding motor of a comparable rating and application.
- Inrush currents during starting are greatly reduced when low-speed starting is used.
- Using the PAM motor's low speed to start high inertia loads reduces rotor heating up to 40% and contributes to extended motor life.
- Reduced wear and erosion on the driven equipment (and less noise) during operation at low speed.
- Speeds are changed electronically, not mechanically, which means additional apparatus between the motor and the driven equipment is not required; there is no slip energy loss from speed adjusting couplings.

And, of course, the PAM motor is a TECO-Westinghouse motor. Westinghouse built the first PAM motor in 1968 and, on a horsepower basis, has sold well over half the PAM motors in operation today, worldwide.



Stator coils are double-braced by arch-lock supports between the coil end turns and by two insulated support rings which are tied and secured around the coils.

Construction Features of the TECO-Westinghouse PAM Motor

The same exceptional features that make TECO-Westinghouse induction motors universally accepted are also among the main reasons the TECO-Westinghouse PAM motor has become the industry choice for two-speed, single-winding induction motors.

Some of the construction features singled out for special consideration are the Thermalastic® epoxy insulation system, the use of copper/copper alloy rotor construction, the high-frequency induction-brazed rotor, the special coating for the laminations, the construction of the frame, and the top-hat ventilation enclosure.

Thermalastic Epoxy Insulation

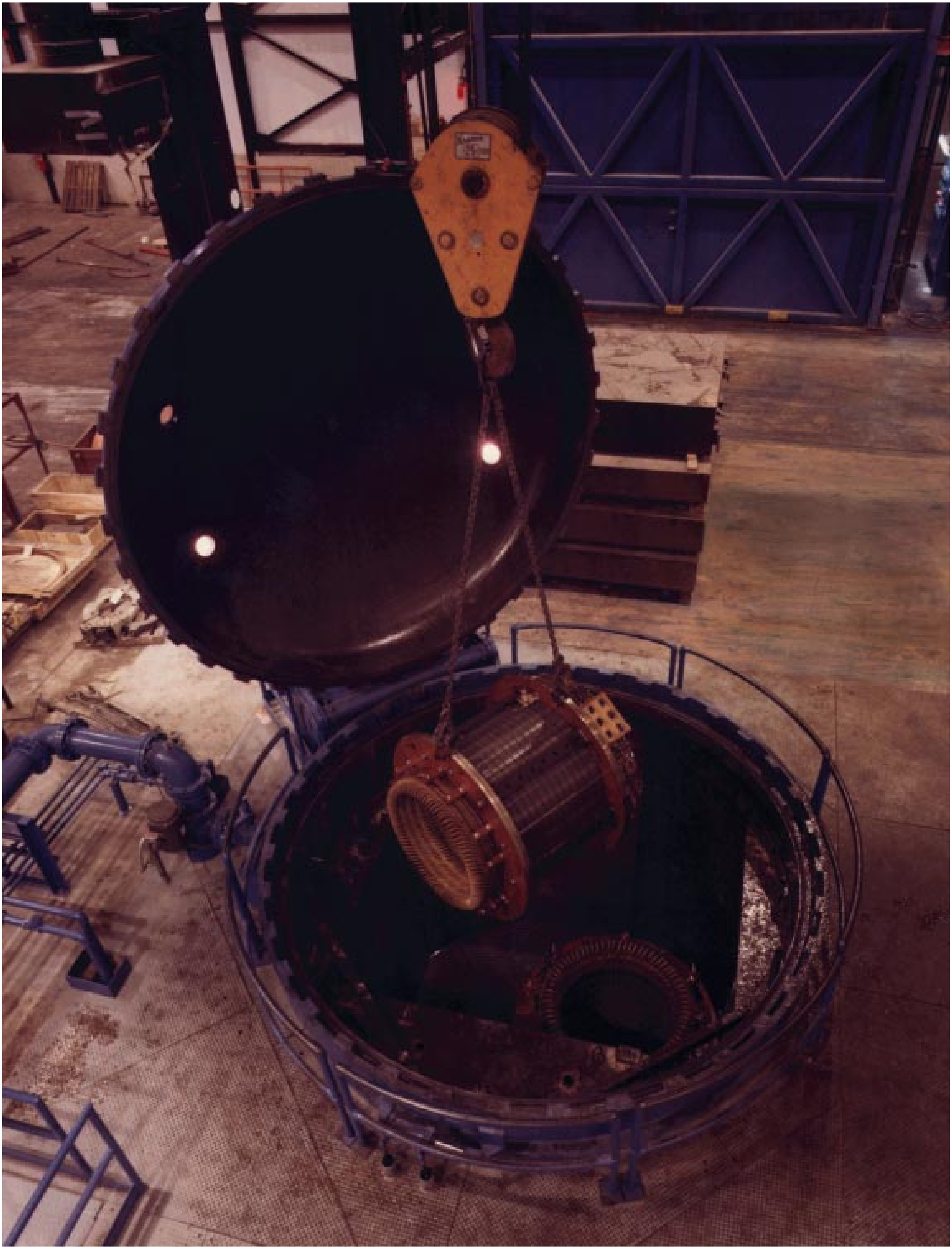
The standard insulation system for TECO-Westinghouse motors is the Thermalastic epoxy system, in which an insulation process is used to impregnate the completely wound and connected stator. Westinghouse developed this innovative process and has used it in motor production since 1960. No other manufacturer offers a vacuum pressure post-impregnation system that has been in service this long.

The Thermalastic insulation system is based on:

- Insulating tape or sheet containing mica—the dielectric material which is still the best-known insulator.
- Ground wall insulation of mica, applied at conservative voltage stress levels. Coils are wrapped with mica tape or sheets, and additional layers are applied in the slots where there will be more stress. Mica is also used on the end turns.
- Double-braced stator end turns provide extra support. Highly absorbent polyester pads are placed between the coil diamonds where, after resin impregnation and curing cycles, these pads harden into rigid arch-lock supports. The coils are tied to insulated support rings that attach to the outside diameter of the end turns to ensure a strong mechanical construction.
- Two vacuum pressure impregnation cycles make twice as sure that the entire stator winding is thoroughly saturated and impregnated with epoxy. For this manufacturing procedure, the stator is placed into an impregnation tank, where it is first put under vacuum to remove any air that may be trapped between the layers of tape. Then, under positive pressure, the entire stator is treated with epoxy resin to impregnate every possible surface. After the fully impregnated stator is baked in a curing oven, the epoxy hardens to the toughness of a reinforced laminate, acting as both a dielectric insulator and bonding agent. Between end turns, however, a sufficient amount of space remains to allow cooling air to pass through during motor operation.

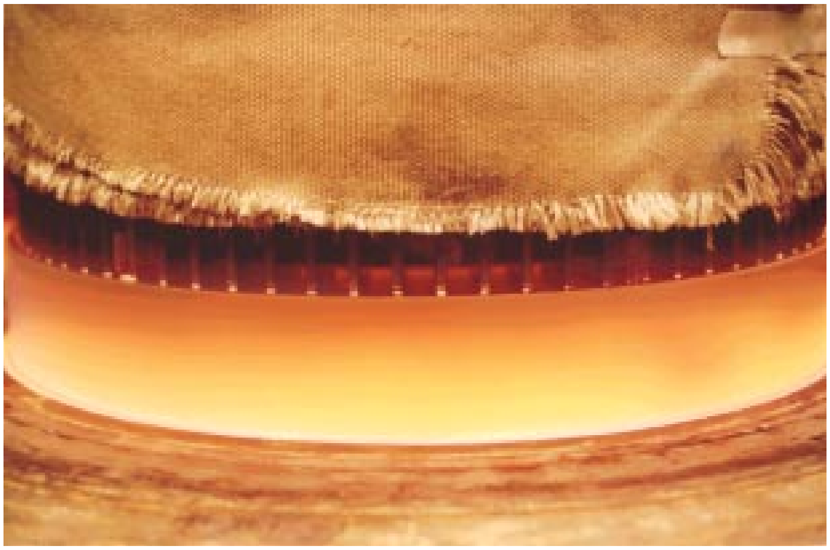
Mica tape is wrapped around coils as one step in the insulation process.

Opposite: Fully impregnated stator is lifted from vacuum pressure impregnation tank, ready for the curing oven.



Copper

For maximum reliability, TECO-Westinghouse has standardized the use of copper/copper alloy in rotor construction for all large motors.



Brazing operation shown in progress.

- Use of copper/copper alloy material for components such as rotor bars and end rings ensures minimum losses and maximum thermal conductivity.
- Copper and its alloys also offer superior mechanical characteristics, including a low coefficient of expansion and minimum creep.
- Design flexibility is enhanced by the use of copper. Rotor bars, for example, can be conservatively sized to allow compact motor dimensions.

Rotor Construction

- High-frequency induction brazing of the rotor bars to the end rings ensures mechanical integrity and results in uniform strength and electrical conductivity at the brazed joints. This has been the standard, proven TECO-Westinghouse manufacturing method since 1950 and is still being used for most rotor sizes.
- Swaged rotor bars minimize bar vibrations and ensure long motor life.
- End rings are centrifugally cast to ensure uniform, void-free, high-integrity construction.
- For most ratings, the rotor core is attached to the shaft stiffener bar construction through the use of a shrink fit. This procedure, together with the welded-on spider construction, assures stable operation under rotational and thermal forces encountered in service.

Frame

Overall mechanical rigidity minimizes movement, virtually eliminating the need for realignment and increasing the length of trouble-free, heavy-duty service.

- Heavy bulkheads and end plates provide solid support for the frame, giving it both lateral and torsional stability.
- Reinforced end brackets give the bearings rigid support and keep vibration to a minimum.
- The bearing housing, in line with the end of the frame, provides maximum bearing stiffness.

Top-Hat Enclosure

The uniform design concept of the top-hat ventilation enclosure combines efficient cooling with greatly reduced noise levels.

- All airflow for motor cooling takes place well above shaft level, thereby lessening intake of foreign matter from the surrounding area.
- Foot mounting dimensions are independent of the type of enclosure selected.

The PAM Motor Saves Energy

Many electric utility and industry customers have turned to the TECO-Westinghouse PAM motor to drive fans, pumps, compressors, Banbury mixers or any other equipment where changing speed provides significant benefits. Although the applications and the speed combinations are different, the underlying reason for choosing the PAM motor is always the same: for applications where a change of speed can offer operating economies, the PAM motor is less costly to install and more efficient to operate than two-winding motors, two-motor arrangements or motors with any kind of hydraulic coupling or VFD.

TWMC rotors are composed of copper/copper alloy.

For example, the PAM motor is an efficient power drive for fan applications where either short or extended periods of operation at less than maximum capacity are required.

Cost Comparison Demonstrates Value

An accurate projection of application economics was made using our PAM Motor Evaluation Program. The result, based on computer analysis, is a cost comparison covering a 35-year operating period. In five-year increments, this projection provides such cost-related data as operating schedules, fixed costs, energy costs and operating savings–including comparisons between the dollar investment and the resultant savings for a particular PAM motor.

The results show that a PAM motor, although initially more expensive than a single-speed motor of comparable rating, typically earns back its investment within one to three years.

Speed Change Advantages

The PAM motor saves energy costs with its ability to switch speeds as operating conditions dictate changes in flow rates.

In fan and pump applications, for example, it is this speed change, accomplished without use of outlet dampers or valves, that is the key to this motor's usefulness.

To illustrate the greater efficiency of the PAM motor over other means of accomodating variable flow rates, let us look at the three most popular methods: outlet damper control, inlet vane control and speed control.

The simplest way to change the flow rate is to throttle the system by using inlet vanes or outlet dampers on fans and suction or discharge valves on pumps. When such devices are used, the output of the fan or pump is reduced by the additional pressure drop of the throttling device involved.

For example, a fan with outlet damper control will require 50 percent of rated power input at 30 percent flow, as shown in the top curve of Figure 1.

When using inlet vane control, 30 percent of rated horsepower will produce 30 percent of rated flow, as shown in the middle curve of Figure 1.

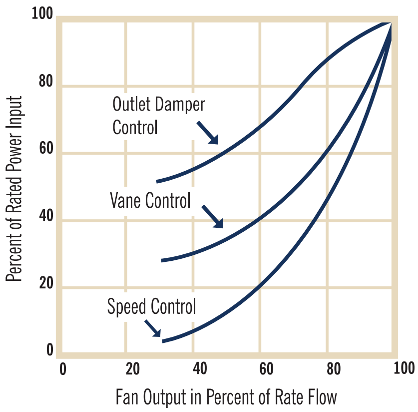


Figure 1: Typical Power Input Requirements for Fans

The most efficient method of varying the capacity of fans or pumps is to vary their speed, as can be seen in the lower curve on Figure 1, because both the pressure and the flow are reduced. Using this method, the input power to the fan can be reduced to approximately 3 percent of rated horsepower to get 30 percent of output flow. The PAM motor design enables users to take advantage of this principle.

Although a 70 percent variation in flow may seem extreme, it does illustrate the fundamental point that controlling flow by varying the speed of the motor is more efficient than throttling at all flow rates.

Speed control is actually more efficient if there is a wide range in the fluctuation of the flow or if a motor must operate at reduced load for considerable periods of time. A related advantage of the PAM motor is that its capability to change speeds allows it to easily accomodate any future contingencies when the load may have to be changed.

Efficiency Up 20% In Typical Application

A graphic comparison (Figure 2) of four methods used to drive a forced draft fan shows that the PAM motor is most efficient at the maximum continuous rating (MCR) point of the fan:

First, compare a one-speed, 900 rpm motor where the fan has vane control (Curve 1) with a similar motor that uses a hydraulic coupling (Curve 2). We see that the first combination is more efficient than the hydraulic coupling control at all points above 75 percent. Although the hydraulic coupling is more efficient below 75 percent, base load generating stations are not likely to operate in this range.

However, at the probable operating point of 75 percent flow, the PAM motor design (a two-speed, 900/720 rpm motor where the fan has vane control) results in an efficiency of about 80 percent (Curve 3) compared to only 60 percent for either of the other two arrangements. A fan operating at this higher efficiency for a number of years will give you considerable savings in energy costs. Also, the elimination of the hydraulic coupling with its high initial investment costs, decreased maintenance costs and use of less floor space will result in additional savings.

Curve 4 shows how a conventional two-speed motor with a 2:1 speed ratio would perform under similar flow conditions. The dotted line indicates a speed change.

This kind of comparison becomes especially meaningful when one considers that fan-type loads are usually operated at 80 percent of output, and in a single-winding configuration, only the PAM motor can operate at 720 rpm (the most efficient speed for loads in that range) and then switch to the 900 rpm speed whenever required. The capability is available when it is needed.

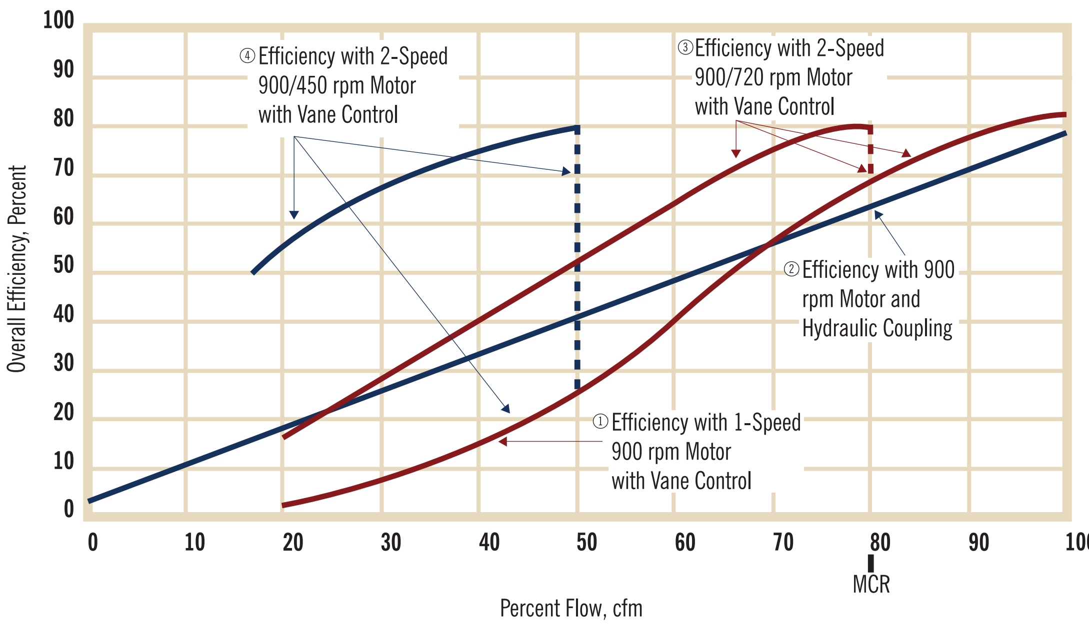


Figure 2: Combined Efficiency of Fan and Motor vs. Output Volume

How the PAM Motor Works

The PAM motor works on a very simple principle: Superimposing one alternating frequency on another alternating frequency produces both the sum and the difference of those frequencies.

For example: A 900 rpm induction motor will have an eight-pole fluctuating magnetic wave in the air gap between the rotor and the stator. So, by doubling up connections on specific coils, sequenced according to the desired second speed, a second magnetic field will be produced—in this case, a two-pole field. This superimposition of a two-pole on an eight-pole field could result in both the sum and the difference of those two fields, namely a mixture of a ten-pole and a six-pole field. In the PAM motor, however, we suppress the resultant six-pole field and keep the original eight-pole field together with the ten-pole field.

The end product of this "Pole Amplitude Modulation" is an AC induction motor with two predetermined and distinct speeds (900 and 720 rpm in our example). The PAM motor, in fact, differs from conventional AC induction motors only in its winding design. Actual motor construction details are identical.

One Winding Does the Job of Two

The PAM motor is not an adjustable speed drive. It is designed to operate at only two distinct, fixed speeds. While on the one hand, a conventional single-winding motor can operate at two fixed speeds, the ratio of the speeds must always be 2:1, which has proven to be practically useless in driving "fan-type" loads. On the other hand, any two distinct speeds, regardless of ratio, can always be obtained, but two windings are necessary to accomplish this, unless the PAM concept is applied.

The advantages related to the PAM motor's single winding versus two winding machines are:
- Only one winding is needed; it is energized the entire time the motor is in operation.
- The single-winding design results in an inherently more efficient motor.
- The PAM motor is up to 25 percent lighter and smaller.

The Speed Changing Switch

The most widely accepted speed changing device for the PAM motor is the oil-filled, five-pole, motor-operated speed changing switch. It is typically installed close to the motor to minimize cable requirements. There are six leads (three for each speed) on a PAM motor installation. A schematic diagram of this type of switch is shown in Figure 3.

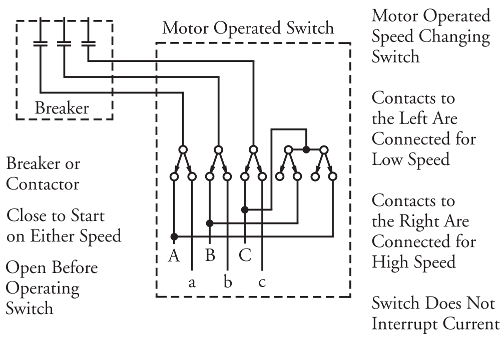


Figure 3: Settings of Motor-Operated Speed Changing Switch for High and Low-Speed Operation

The PAM motor should be started on its low-speed winding to limit the inrush current. This prolongs motor life by keeping rotor and core temperatures to a minimum. Starting on the low speed is also more desirable for driven equipment considerations.

When starting the motor with the speed changing switch at the low-speed setting, the main breaker is closed. To change speed once the motor is operating, the main breaker must be opened, the switch transferred to the other three leads, and the main breaker closed again. It is important, however, to allow the magnetic flux in the air gap to decay before finally closing the main breaker. This pause will usually take about one to two seconds, depending on motor size.

Motor-operated speed changing switch

Strong on Service

During the project planning stage, detailed motor information specifically tailored to the customer's need is essential. We take this step seriously and give you all the help we can—product information, quotation assistance, computer studies, and engineering support. We apply our wide range of resources and capabilities to your requirements.

The planning process requires accurate inputs, and we realize that time is a major consideration. We pride ourselves on being prompt in providing you with all necessary information during each phase of the planning process. And when you have determined what your needs are, we move quickly to design, produce and deliver the motor of your choice.

To assist you further in taking good care of your equipment and giving it long life, TECO-Westinghouse has a worldwide service network with the capability of providing you with fast and dependable motor service. Our field service engineers are on call 24 hours a day for assignments anywhere in the world. They are ready to help you with your motor repair and service needs, as well as to provide you with complete maintenance services.

TECO-Westinghouse exists specifically to satisfy your requirements for large motors. We have the people, the technology and the on-site service capability to produce the best quality products, get them to you on time and service them when and where needed.

TECO–Westinghouse
MOTOR COMPANY

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