



ADJUSTABLE FREQUENCY DRIVES

FLOW CONTROL
APPLICATION GUIDE



Cutler-Hammer

EATON

AFFINITY LAWS

THREE INTERRELATED AFFINITY LAWS COVERING CENTRIFUGAL LOADS ARE ILLUSTRATED BELOW.

IF YOU REDUCE MOTOR SPEED BY 20%, YOU REDUCE THE PRESSURE CREATED TO 64% (.80 X .80) OF WHAT IT WAS AT FULL SPEED, AND THE POWER REQUIRED TO 51% (.80 X .80 X .80) OF THE FULL-SPEED REQUIREMENT.

Energy Efficiency Through Motor Speed Control.

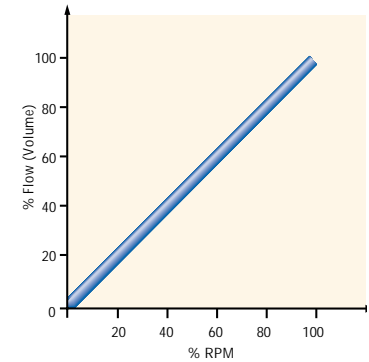


FIGURE A: ILLUSTRATES REDUCED SPEED REDUCES FLOW OR VOLUME PROPORTIONALLY.

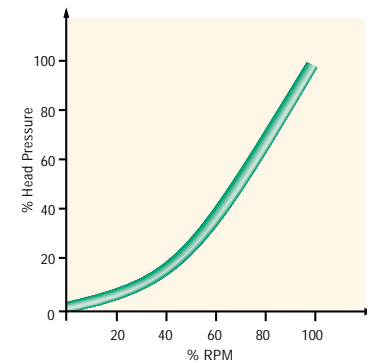


FIGURE B: SHOWS HOW PRESSURE OR HEAD VARIES AS THE SQUARE OF SPEED.

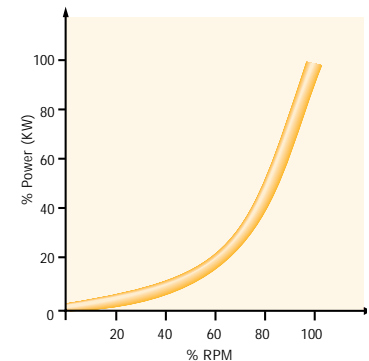


FIGURE C: ILLUSTRATES HOW POWER REQUIREMENTS VARY AS THE CUBE OF SPEED.

Sixty-five percent of all electrical energy used in the United States operates centrifugal or flow loads such as pumps, fans, blowers and compressors—most of which are powered by constant-speed induction motors. Conservative estimates indicate that centrifugal load applications consume one-third as much energy as all the passenger cars in the United States.

Often, output requirements fluctuate, so an external means of adjustment is necessary when they are driven by constant speed motors. Commonly used methods for obtaining flow control include throttling or restrictive devices such as valves, outlet dampers, inlet vanes and diffusers, as well as mechanical speed changers and recirculating systems.

However, these restrictive devices waste energy, dissipate power by friction, and diffuse heat. It is as inefficient as driving an automobile with the gas pedal to the floor and controlling speed by pressing the brake pedal. Moreover, it is costly and accelerates equipment wear.

With two-thirds of all electricity being used to power centrifugal or flow applications, this market offers great potential for energy savings and productivity improvements.

CONTROL SPEED. REDUCE ENERGY COSTS. ELIMINATE THE COSTS AND LOSSES OF THROTTLING DEVICES.

A typical flow/volume profile is depicted in the graph below (fan operating conditions are between 40% and 70% of CFM). The motor Hp rating is based on the maximum required CFM or flow, even though such power levels are needed infrequently.

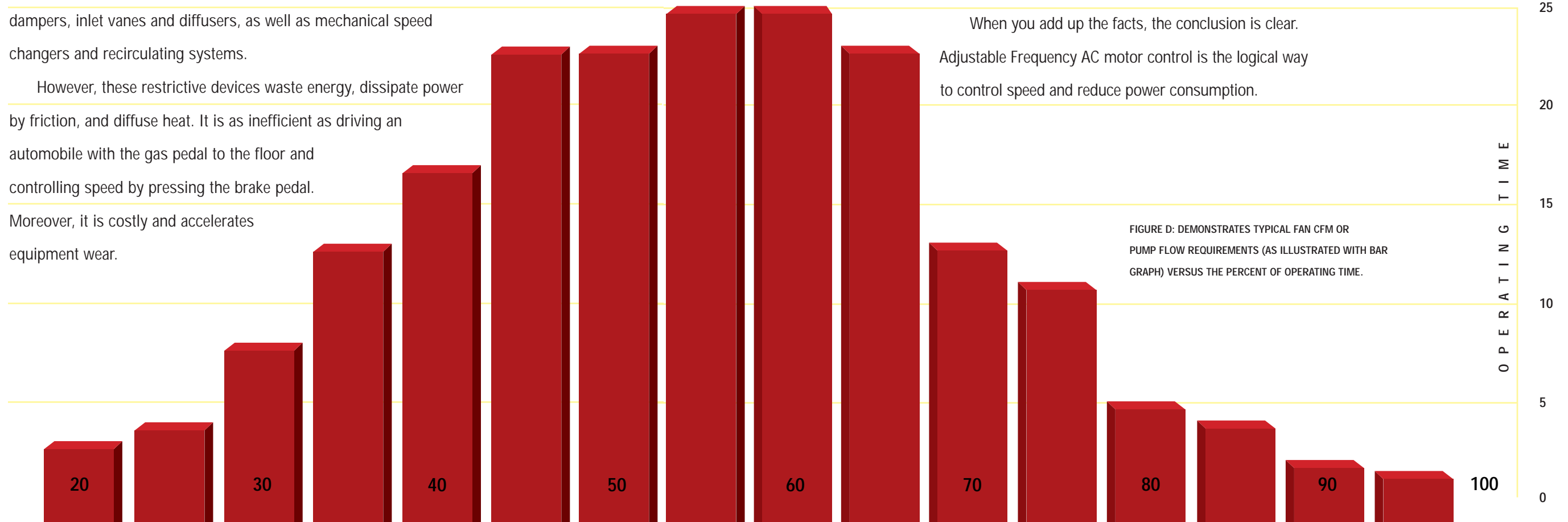
Fixed-speed pumps or fans draw nearly full horsepower and consume nearly maximum energy full time, even though it is needed only briefly. Power requirements for throttled systems drop slightly even though flow or volume is reduced significantly.

Variable speed devices such as belts, gears, magnetic clutches and hydraulic drives accomplish this function mechanically, but they are costly, bulky, waste power and require high maintenance.

Also, DC Adjustable Speed Drives have been used to obtain speed variations. However, DC motors require a far higher initial investment (two to three times the cost of an equivalent AC motor of the same Hp). In contrast to AC motors, DC motors are larger and heavier, require more maintenance, and are more difficult to apply in damp, dirty and combustible environments.

CUTLER-HAMMER DRIVES ARE SOLID STATE, EASY TO INSTALL AND PROVIDE:

- LOW COST RETROFITTING
- HIGH SYSTEM EFFICIENCY
- NOISE REDUCTION
- REDUCED MECHANICAL WEAR AND MAINTENANCE
- REDUCED KW DEMAND
- EASY INTERFACING WITH ANY ENERGY MANAGEMENT SYSTEM



When you add up the facts, the conclusion is clear. Adjustable Frequency AC motor control is the logical way to control speed and reduce power consumption.

FIGURE D: DEMONSTRATES TYPICAL FAN CFM OR PUMP FLOW REQUIREMENTS (AS ILLUSTRATED WITH BAR GRAPH) VERSUS THE PERCENT OF OPERATING TIME.

- MANY FLOW CONTROL SYSTEMS ARE DESIGNED TO KEEP CONSTANT PRESSURE IN THE MAIN SUPPLY LINE, REGARDLESS OF USAGE DOWNSTREAM. FIGURE Q SHOWS AN AFD CONTROLLING A FAN SYSTEM BASED ON A SIGNAL THAT REPRESENTS THE DIFFERENCE BETWEEN ACTUAL PRESSURE AND DESIRED PRESSURE.

- IN STEEL MILLS, AC DRIVES ARE APPLIED ON ANNEALING FANS TO IMPROVE CONTROL OF THE ANNEALING PROCESS, INCREASE RATES OF HEATING AND COOLING, AND ON REHEAT FURNACES FOR FLOW CONTROL OF FANS TO IMPROVE REHEATING CYCLES.

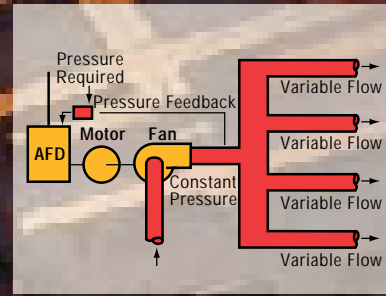


FIGURE Q.
Variable Air Volume (VAV) System

FIGURE E:
OUTLET DAMPER CONTROL
POINTS A, B AND C SHOW VOLUME AND PRESSURE AT THREE DIFFERENT DAMPER SETTINGS. ENERGY REQUIRED TO PRODUCE THESE AIR VOLUMES IS PROPORTIONAL TO THE PRESSURE MULTIPLIED BY FLOW (SHOWN ON LOWER GRAPH).

Significant energy savings can be realized by applying AC Drives to vary the flow from induced draft fans, forced draft fans, cooling tower fans, and in HVAC installations using variable air volume (VAV). Cutler-Hammer Drives are more efficient than outlet dampers, inlet vanes, or other types of motor speed control.

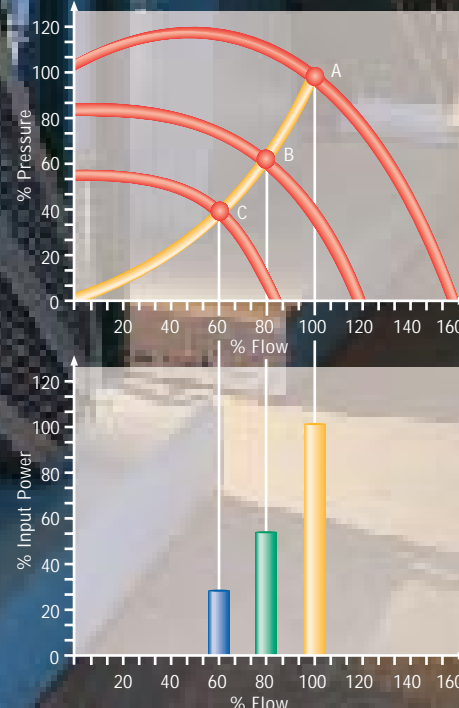
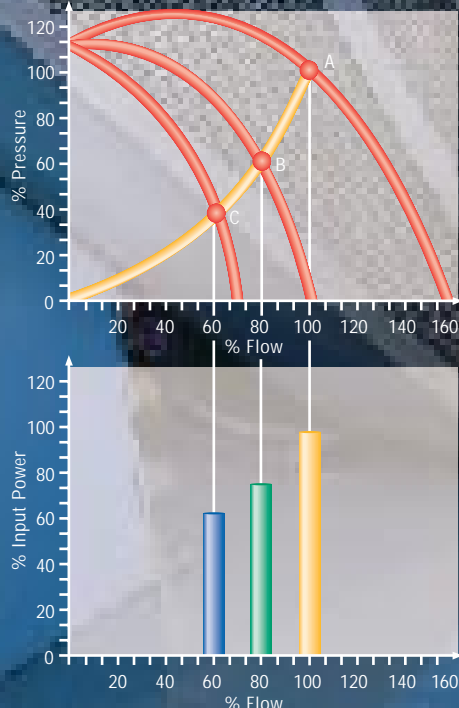
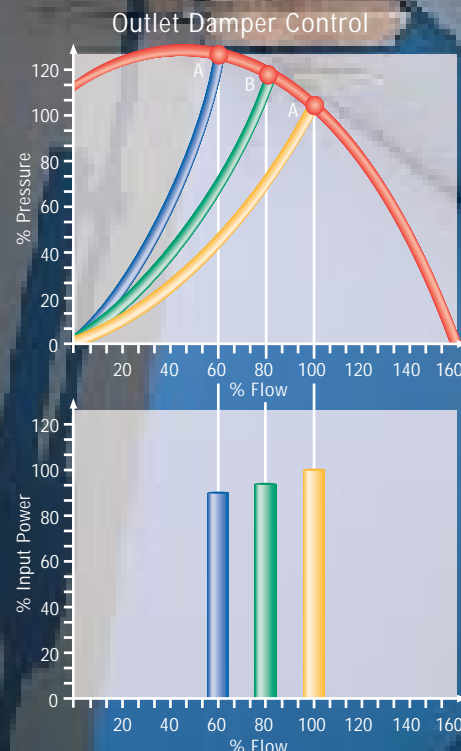
Adjustable Frequency Drives control the flow from fans or blowers by furnishing variable frequency power to the three-phase AC motor. As frequency varies, motor speed varies, with flow proportional to motor speed. As operating speeds are reduced, energy consumption drops drastically since power is needed only to overcome flow resistance.

Centrifugal Fan and Blower Application Advantages.

FIGURE E.

FIGURE F.

FIGURE G.



COMPARE THE INPUT POWER REQUIRED WITH AN AC DRIVE TO TRADITIONAL FLOW CONTROL METHODS TO SEE HOW TREMENDOUS ENERGY SAVINGS CAN BE ACHIEVED.

FIGURE F:
INLET VANE CONTROL
POINTS A, B AND C ILLUSTRATE PRESSURE AND VOLUME AT THREE DIFFERENT VANE ANGLES. REGARDLESS OF VANE POSITION, FAN SPEED REMAINS RELATIVELY CONSTANT WITH ONLY MODEST REDUCTION IN REQUIRED INPUT POWER AS AIR VOLUME IS REDUCED. SEE THE LOWER GRAPH.

A comparison of fan curves illustrates how adjustable frequency drives are the most energy efficient method of controlling air volume, saving much more energy than conventional flow devices. In figures E, F and G, the red curves indicate fan performance and the other curves indicate "system" curves, such as ductwork and other restrictions.

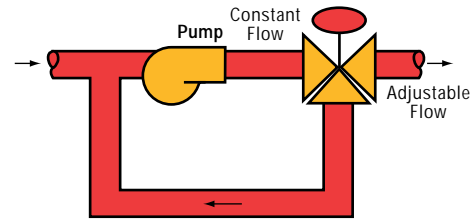
Wherever the two intersect is the point of operation. The bar graphs represent input horsepower energy required by each flow control method when operating at 60%, 80% and 100%.

The outlet damper is mounted in the air stream on the outlet side of the fan. By closing the damper, pressure produced by the fan increases, resulting in reduced flow volume.

FIGURE G: CUTLER-HAMMER AFD CONTROL
FIGURE G SHOWS DRAMATIC ENERGY SAVINGS WITH CUTLER-HAMMER DRIVES. POINT A SHOWS FAN CAPACITY AND SYSTEM PRESSURE FOR A FAN OPERATING AT FULL SPEED. POINTS B AND C SHOW THE SAME WHEN THE FAN IS OPERATING AT REDUCED SPEEDS.

THE SPEED (FLOW)-TO-INPUT POWER RELATIONSHIP IS SHOWN IN THE LOWER GRAPH.

FIGURE J: TYPICAL THROTTLING VALVE CONTROL



The Key to Centrifugal Pump Efficiency.

Flow or pressure in liquid pumping systems is often regulated by in-line valves. The valve can be a significant source of energy loss by causing a restriction in the flow path, thus increasing the head. An AC Drive provides more efficient flow control by varying the pump motor speed.

Depending on the system's static and friction heads, energy savings using Adjustable Frequency AC Drives to control pumps can be justified with a quick payback.

With AC Drives, energy savings is achieved when compared to throttling valve control, (Figures H and I). The red curve represents pump performance while the other colored curves represents the "system." The bar graphs represent energy required by the two systems on a centrifugal pumping installation at 60%, 80% and 100% flow. In this instance, the AC Drive application uses 70% less power than a throttling valve at 60% flow.

Compare the input graph for an AC Drive application (Figure I) to see energy savings. Point A in Figure I shows pump capacity and system pressure for a pump at full speed. Points B and C show the pump at reduced speeds, similar to having a pump and impeller combination designed for each operating flow condition.

Since power varies as the cube of speed, electrical energy consumption is drastically lowered as speed is reduced.

FIGURE H: THROTTLING VALVE CONTROL

FIGURE H SHOWS ONE PUMP CURVE SINCE THE PUMP OPERATES AT FIXED SPEED. FLOW IS CONTROLLED ON THE OUTLET SIDE OF THE PUMP. THE SYSTEM CURVE IS MODIFIED BY PARTIALLY CLOSING THE VALVE WHICH INCREASES THE FRICTION HEAD, THUS REDUCING FLOW. POINTS A, B AND C REPRESENT THREE DIFFERENT SETTINGS OF THE THROTTLE VALVE. THE BOTTOM GRAPH SHOWS THE INPUT POWER REQUIRED AT 60%, 80% AND 100% FLOW.

FIGURE I: AC DRIVE SYSTEM

FIGURE I ILLUSTRATES POWER LOSS CAUSED BY THE THROTTLED VALVE. THIS POWER CAN BE SAVED BY REDUCING PUMP SPEED WITH AN AC DRIVE. SOME PUMPING ARRANGEMENTS UTILIZE A THREE-WAY VALVE AND BYPASS LOOP SIMPLY TO DIVERT THE PUMP'S OUTPUT BACK TO THE INTAKE SIDE. EVEN THOUGH REDUCED FLOW IS ACHIEVED, NO ENERGY SAVINGS IS REALIZED SINCE THE PUMP STILL OPERATES AT FULL CAPACITY.

FIGURE K: TYPICAL PUMP EFFICIENCY VS. FLOW AND SPEED

FIXED-SPEED PUMP EFFICIENCY WILL CHANGE WITH FLOW AS THE THROTTLING VALVE CAUSES IT TO PUMP AGAINST DIFFERENT PRESSURES; AC DRIVE-CONTROLLED PUMP EFFICIENCY WILL NOT. DIFFERENT EFFICIENCY CURVES FOR EACH SPEED ALLOW – JUST AS DIFFERENT SIZE IMPELLERS WOULD – THE PUMP TO STAY NEAR ITS MOST EFFICIENT OPERATING POINT.

FIGURE P: MULTIPLE PUMP APPLICATION

IN WATER TREATMENT PLANTS, DEPENDING ON SPECIFIC INSTALLATION REQUIREMENTS, ALL PUMPS CAN BE RUN ON ONE AC DRIVE AND CONTROLLED TOGETHER, OR THE PUMP MOTORS CAN BE ARRANGED SO THAT ANY ONE IS ON THE AC DRIVE WHILE THE OTHERS ARE EITHER OFF OR ON ACROSS THE LINE.

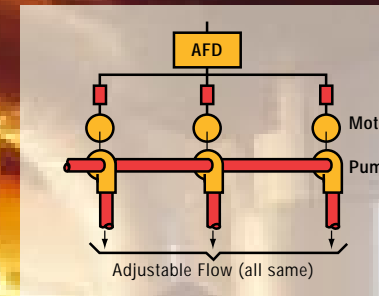


FIGURE P

FIGURE H. Throttling Valve Control

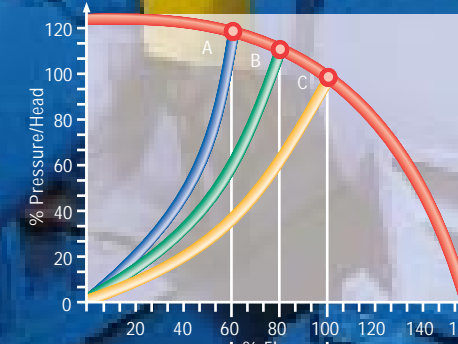


FIGURE I. AC Drive System

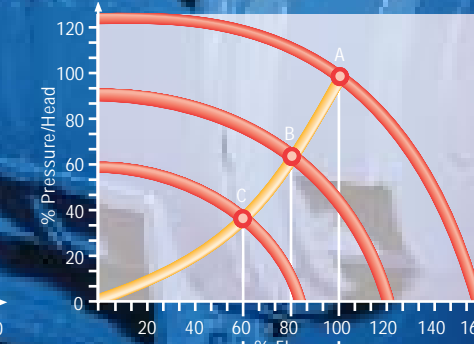
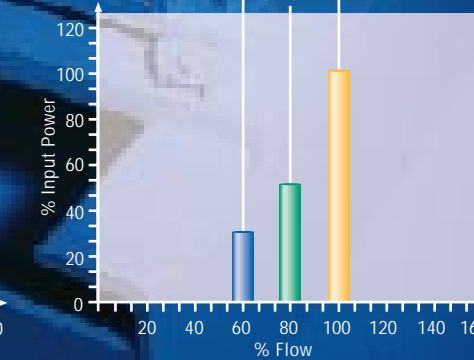
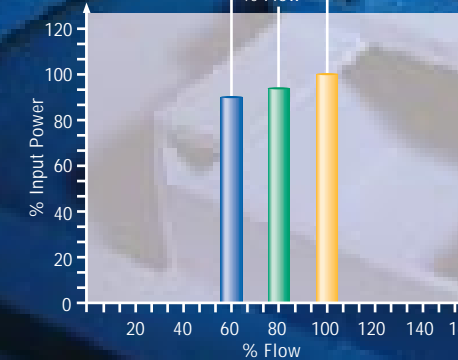
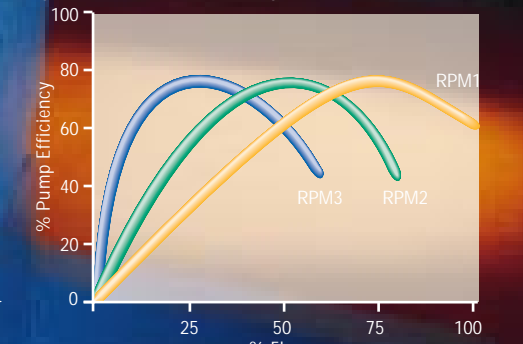


FIGURE K. Typical Pump Efficiency vs. Flow and Speed



THE STATIC HEADS OF THE COMPLETE SYSTEM ARE CONSTANT FOR ALL FLOW RATES. STATIC HEADS ILLUSTRATE FRICTION AND FLOW VELOCITY PEAKS ONLY.

- IN PAPER MILLS AC DRIVES ARE USED ON COATING PUMPS FOR CLOSER CONTROL OF THE PAPER COATING PROCESS, ON MUD PUMPS TO REDUCE MAINTENANCE REQUIREMENTS ON PUMP IMPELLERS, AND ON COUCH-PIT PUMPS FOR SIGNIFICANT ENERGY SAVINGS.
- IN FOOD PROCESSING FACILITIES, AC DRIVES PROVIDE VOLUME CONTROL FOR LIQUID FOOD PUMPING, AND PRESSURE CONTROL FOR WATER CONSERVATION.

Cost-Effective Flow Control Solutions.

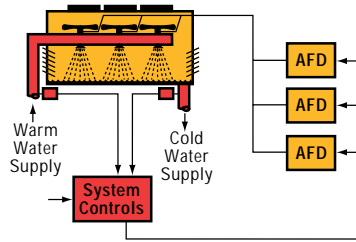


FIGURE R: COOLING TOWER APPLICATION

AC DRIVES ARE USED WITH FIN FANS AND COOLING TOWER FANS. THE SPEED OF THE FANS IS CONTROLLED BASED ON THE TEMPERATURES SENSED, PROVIDING THE MOST EFFICIENT OPERATION AND POSSIBLY ELIMINATING THE MIXING VALVES.

- AC DRIVES ON FANS PROVIDE VARIABLE AIR VOLUME CONTROL FOR ENERGY SAVINGS IN HOSPITALS, MEDICAL CLINICS AND SHOPPING PLAZAS, AS WELL AS IN COLLEGES AND SCHOOLS.

- IN AMUSEMENT PARKS AC DRIVES ARE USED ON RIVER RIDES FOR CLOSER CONTROL OF WATER FLOW AND ENERGY SAVINGS.

Whether retrofitting an existing facility or installing a new pump/flow system, applying an AC Drive is more cost-effective than installing a valve, even if the valve is never adjusted. And, any incremental flow adjustment with an AC Drive means additional energy savings.

In a typical flow system utilizing control valves (Figure N, with relative horsepower losses shown), there may be approximately 15 Hp in "initial turndown" valve losses (closing the valve to compensate for oversizing), 10 Hp in piping losses, 15 Hp in pump losses (due to pump inefficiencies), with 50 Hp allocated to the actual head requirement. Total losses would be 40 Hp for a 100 Hp AC motor requirement for the system.

However, with an AC Drive (Figure O, with relative Hp losses shown) there will be 0 Hp in valve losses, only 8 Hp inherent in piping losses (due to the elimination of some piping and elbows needed for the valve location), and 10 Hp in pump losses (a smaller pump can be used), with 50 Hp required to maintain the same head. Total losses would be 18 Hp enabling a 75 Hp AC motor to perform the identical task.

TO DETERMINE THE MOST COST-EFFECTIVE FLOW CONTROL SOLUTION, EVALUATE INITIAL COSTS, CUMULATIVE ENERGY SAVINGS, AND REDUCED MAINTENANCE EXPENDITURES, CUTLER-HAMMER HAS A PAYBACK ANALYSIS PROGRAM THAT WILL AID IN YOUR EVALUATION.



ESTIMATING SAVINGS

Determine power and dollar savings with Figures L and M.
EXAMPLE: Fan, 25 BHP using outlet dampers

STEP 1
DETERMINE AMOUNT OF TIME AT EACH FLOW POINT

- 70% OF TIME AT 60% FLOW
- 30% OF TIME AT 80% FLOW

STEP 2
READ DIFFERENCE IN POWER REQUIRED FOR EACH POINT BY CUTLER-HAMMER AFD VERSUS AN ALTERNATIVE APPROACH.

60% FLOW:

- 95% OUTLET DAMPERS
- -31% AFD SPEED CONTROL
- 64% SAVED

80% FLOW:

- 111% OUTLET DAMPERS
- -60% AFD SPEED CONTROL
- 51% SAVED

STEP 3
WEIGHT EACH SAVINGS VALUE BY THE PERCENT OF TIME AT THAT CONDITION AND COMBINE.

- $.70(64\%) + .30(51\%) = 60\%$

STEP 4
CONVERT FAN/PUMP FULL SPEED HP TO KW.

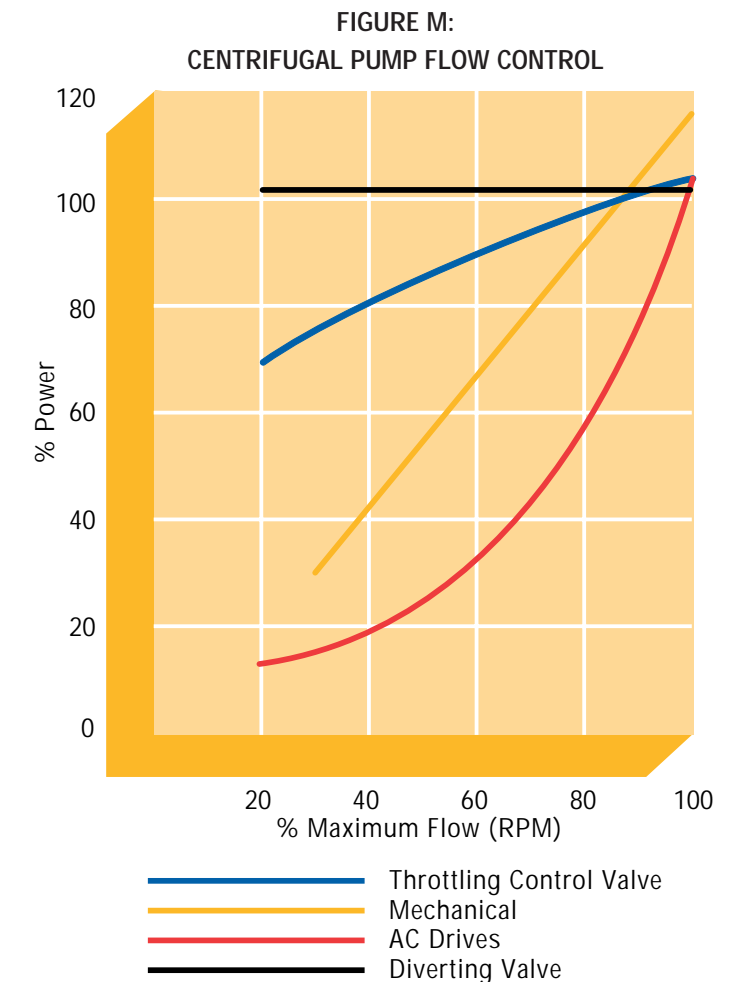
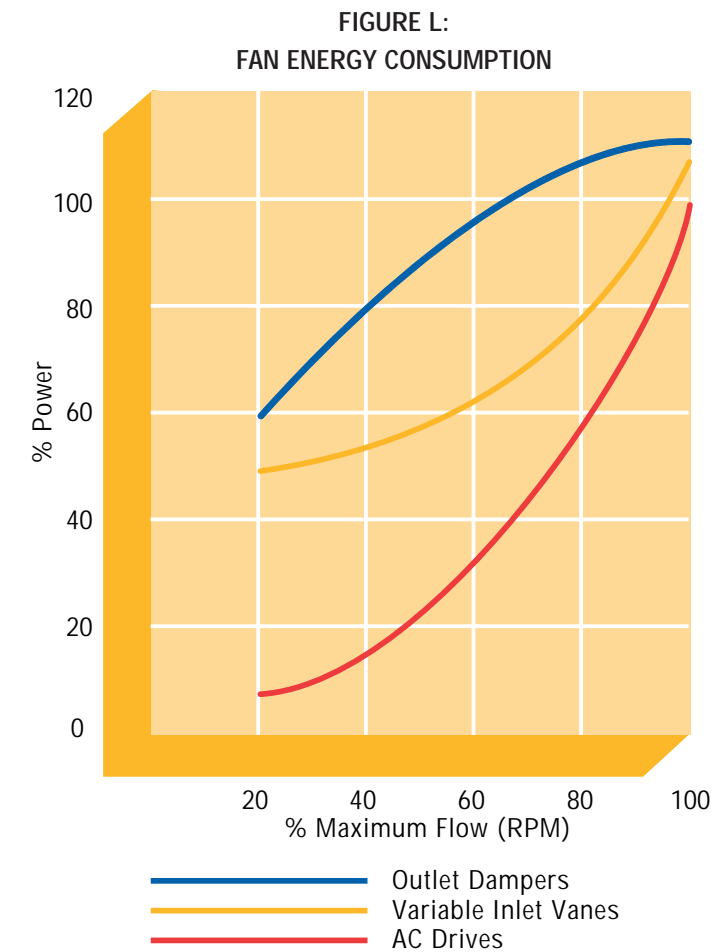
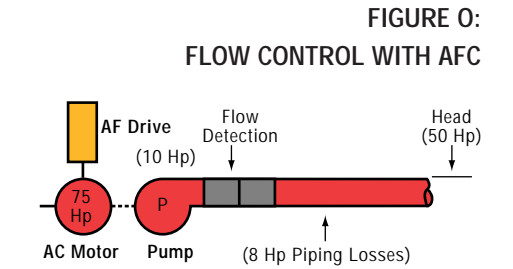
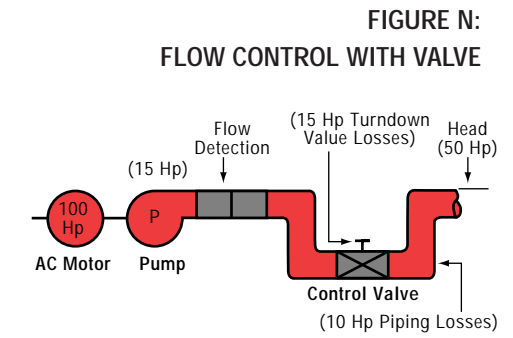
- $25\text{Hp} \times .746 = 18.65\text{KW}$

STEP 5
MULTIPLY FAN/PUMP KW FROM STEP 4 BY TOTAL WEIGHTED SAVINGS FROM STEP 3.

- $18.65\text{KW} \times 60\% \text{ SAVINGS} = 11.2\text{KW SAVED}$

STEP 6
MULTIPLY THE KW SAVINGS BY THE ANNUAL HOURS OF OPERATION AND THE COST OF ELECTRICITY.

- $11.2\text{KW} \times 5000 \text{ HOURS} \times 8¢/\text{KWHR} = \$4,480 \text{ ANNUAL SAVINGS.}$



• IN WATER TREATMENT FACILITIES, AC DRIVES ARE APPLIED ON WASTE WATER PUMPS TO SAVE ENERGY THROUGH IMPROVED FLOW CONTROL.

• AT PRINTING COMPANIES, AC DRIVES ARE USED ON FANS TO PROVIDE MORE EFFICIENT RECOVERY FROM EXHAUST AIR.

Application Benefits.

Cutler-Hammer Drives are uniquely suited for a wide variety of commercial, industrial, municipal and utility applications.

While applications within these market segments are diverse, Cutler-Hammer Drives are key to significant energy and operating savings. Energy savings can be many times more than that obtained by the use of constant speed energy-efficient AC motors.

Adjustable Frequency Drives make a motor a variable-speed drive (with a speed range up to 60-to-1, with soft starts and stops and smooth accelerations and decelerations). It can easily be made responsive to signals from flow sensors, programmable controllers and control computers.

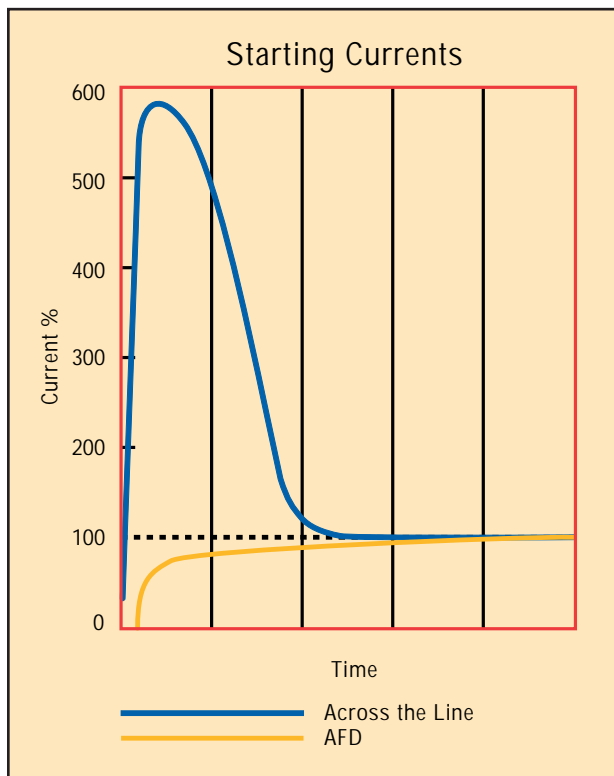
These features allow adjustable frequency controllers to play an important role in energy management systems. Instead of shedding fan and pump loads by turning them totally off, the AC Drive can slow them down and still significantly reduce electrical power consumption. This is done to allow starting of large motors, or as part of total demand control.

In an age of increasing demands on performance, efficiency and cost reduction, Cutler-Hammer Adjustable Frequency Drives fill a critical role. With a full complement of AC Drives, enclosure options, and other industrial control devices, trust Cutler-Hammer to provide the best solutions to flow control.

FIGURE 5:

STARTING CURRENTS

STARTING CURRENTS ARE GREATLY REDUCED WHEN STARTING AN ADJUSTABLE FREQUENCY DRIVE SINCE BOTH VOLTAGE AND FREQUENCY (SPEED) ARE CONTROLLED. INSTEAD OF NEEDING UP TO 600% CURRENT TO START, CENTRIFUGAL FANS AND PUMPS CAN BE STARTED WITHOUT DRAWING MUCH MORE THAN FULL-LOAD CURRENT.



Product Benefits.

Compare the adjustable frequency speed control approach to any other for flow control applications. Then compare adjustable frequency drives for features, efficiency, performance, reliability and support services. The benefits are impressive:

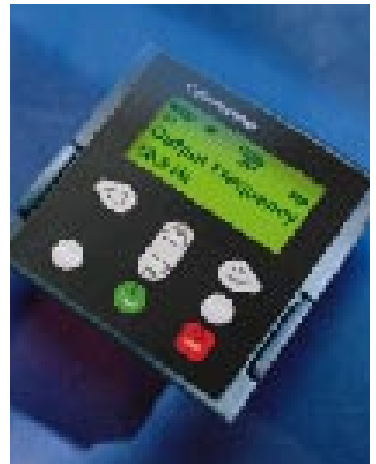
- Longer life for fans, pump impellers, and pump seals when operating at reduced speeds and against reduced pressures
- Longer motor life by operating at reduced loads and soft starting
- Minimal motor maintenance—bearings last longer at reduced speeds
- Longer lifecycles for belts, gear boxes, drive trains
- Reduced noise and vibration by fans and pumps
- Elimination of mechanical flow control devices and maintenance
- High efficiency/low operating cost
- Availability to use standard AC motors for replacements and spares
- Application of enclosed AC motors for hazardous or corrosive environments
- No power surge on starting
- Operating speeds above motor nameplate
- Improved power factor

You'll also find Cutler-Hammer is the answer for worldwide support, application assistance, operator and maintenance training, start-up and repair services, as well as replacement parts. For more information, contact your local Cutler-Hammer Distributor.


That's the Cutler-Hammer Drive advantage.



WITH SV9000 SVReady™ BUILT-IN APPLICATIONS, YOU'LL GET UP AND RUNNING QUICKLY. JUST SELECT THE ONE THAT BEST SUITS YOUR APPLICATION.



OUR SVMulti-line™ CONTROL PANEL COMES STANDARD WITH THE SV9000 DRIVE. AT A GLANCE, CHECK DRIVE STATUS ICONS AND VIEW ALPHA-NUMERIC CHARACTERS ON ITS BACKLIT LCD DISPLAY.



Cutler-Hammer, a part of Eaton Corporation, is a worldwide leader providing customer-driven solutions. From power distribution and electrical control products to industrial automation, Cutler-Hammer utilizes advanced product development, world-class manufacturing, and offers global engineering services and support.

For more information on Cutler-Hammer products and services, call 1-800-525-2000 or 1-732-417-5660, or visit our website at www.cutlerhammer.eaton.com

For Cutler-Hammer Adjustable Frequency Drives technical information and support, please call 1-800-322-4986.



B.8H.02.S.E

Cutler-Hammer

Milwaukee, Wisconsin U.S.A.

Publication No. B.8H.02.S.E
October 1998
Printed in U.S.A. / GSP 1093

Copyright Cutler-Hammer, 1998
All Rights Reserved

EATON