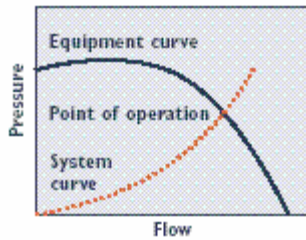
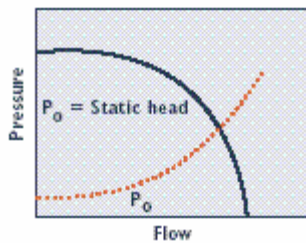


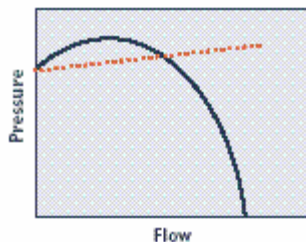
## MOTOR SYSTEM FUNDAMENTALS



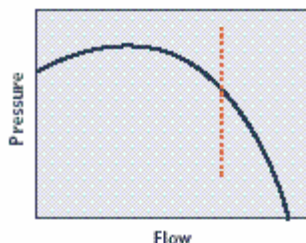
FIXED RESISTANCE SYSTEM  
 $P \sim Q^2$   
 FORCED-DRAFT FAN



FIXED RESISTANCE  
 WITH STATIC PRESSURE  
 $P \sim (Q^2) + P_0$   
 PUMP TO STORAGE TANK



VARIABLE RESISTANCE  
 WITH CONSTANT PRESSURE  
 $P = \text{CONSTANT}$   
 INDUCED-DRAFT FAN



VARIABLE RESISTANCE  
 WITH CONSTANT FLOW  
 $Q = \text{CONSTANT}$   
 PNEUMATIC CONVEYOR

**The sum of the whole is greater than the value of the individual pieces.**

Each component in the system has its own efficiency. To achieve maximum overall system efficiency, each component should be selected to operate at its most efficient point of operation for the majority of the time the system is running. System efficiency should relate the amount of energy used to the useful work produced or number of units manufactured. If no useful work or product is produced, the system efficiency drops to zero. The total system efficiency at a given operating point is the product of each component's efficiency (E) in the system.

$$E_{\text{system}} = \frac{\text{system output}}{\text{total power input}} = \frac{\text{units produced}}{[\text{power required} / (E_{\text{components}} \times F_{\text{system}} \text{ effect factor } )]}$$

The system effect factor (F) is a multiplier that reflects the sum of friction and other losses of the distribution system.

### FACTORS AFFECTING MOTOR POWER CONSUMPTION

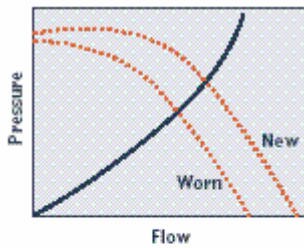
Motors provide torque to rotate fans and pumps at a specific speed. General rules of thumb imply that flow is proportional to the rotational speed of the motor and power can vary as high as the cube of the speed. The system resistance curve (SRC) is used to determine how changes in flow affect pressure and is obtained by measuring and plotting the pressure or head at various system volume flow rates. The SRC can be superimposed onto turbo-machine performance curves of pressure, flow, power consumption and efficiency. These curves can be obtained from the pump and fan manufacturers.

System curves will differ depending on the system design, and each SRC is unique. Determine the type of system you have at the start of the evaluation. The point of operation occurs at the intersection of the turbo machine performance curve and the system resistance curve. This intersection point determines the volume flow rate through the system

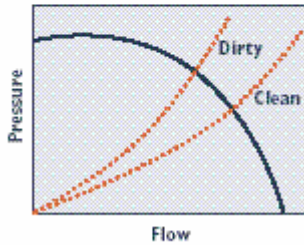
The point of operation can change due to:

- change in turbomachine performance – worn impeller or casing, change in rpm
- change in system resistance – line extension, corrosion, holes or material buildup in ducts

- change in both system resistance and the turbomachine



CHANGES IN TURBOMACHINE PERFORMANCE



CHANGES IN SYSTEM RESISTANCE

### DURATION CURVE OR CHART

Most systems will operate at different points of operation over the year due to changes in production volume, weather and type of product produced. The characteristics of the performance curve can be altered to meet system demand by using various control methods such as varying the rotational speed (adjustable speed drives), throttling the flow (increasing system resistance) or by changing the turbo machine characteristics (varying the pitch of the impeller blade). The load duty cycle is a curve or chart that represents the percent operating time versus percent maximum flow for each operating point. Applications with more than three operating points may be good candidates for adjustable speed drive technologies. Those with a few distinct operating points could benefit from the use of multi-speed motors. Constant flow applications operating at one point may require no flow control. Efficiencies and power consumption must be calculated separately at each point of operation and then totalled when doing the annual cost analysis.

### AFFINITY LAWS FOR TURBOMACHINERY

In assessing various systems, affinity laws can be used to calculate how changes of one variable will affect other variables such as speed, flow, pressure and power consumption. Check with the manufacturer to determine how changes will affect the performance curves.

In general where N = turbomachine rpm, Q = flow,

P = pressure, hp = horsepower

$$Q_2/Q_1 = N_2/N_1 \quad P_2/P_1 = (N_2/N_1)^2 \quad hp_2/hp_1 = (N_2/N_1)^3$$

- For most turbomachinery, power consumption is proportional to the cube of the rotational speed; flow is directly proportional to the rotational speed. Dropping the speed by 20% reduces power consumption by approximately 50%.
- Trimming the impeller is a cost-effective method of reducing flow and power consumption:  $Q_1/Q_2 = (N_1/N_2) \times (D_1/D_2)^3$ , where Q=flow, N=fan speed, D= impeller diameter  $D_2 < 3\%$  for conditions when  $D_2 < 3\%$  of  $D_1$ .
- Friction increases as the square of the fluid velocity.

Reference:

[http://oee.nrcan.gc.ca/infosource/pdfs/M92-165\\_1999E.pdf](http://oee.nrcan.gc.ca/infosource/pdfs/M92-165_1999E.pdf)