Compressed Air Overview

- Survey
- Compressed air system components
- Estimating load factor
- Why optimize a compressed air system?
- Common Recommendations
- Review of CD-ROM

Uses of Compressed Air

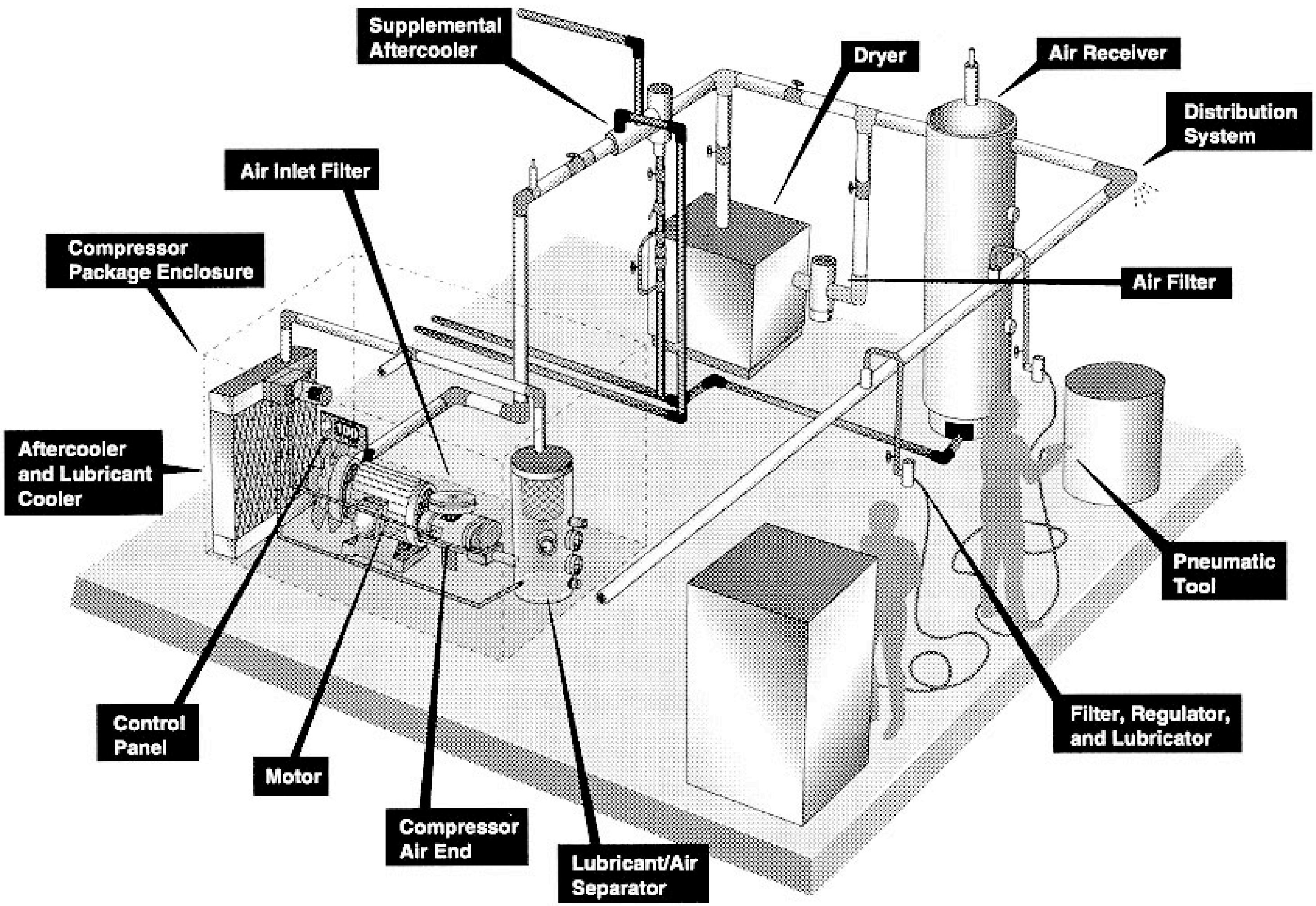
Industrial

- Blow Molding
- Conveying
- Actuators
- Pneumatic Tools
- Agitation
- Hoisting

Non-Industrial

- Pneumatic Tools
- Air Brake Systems
- Climate Control
- Emission Control
- Starting Gas Turbines
- Elevators

Compressed Air System Layout



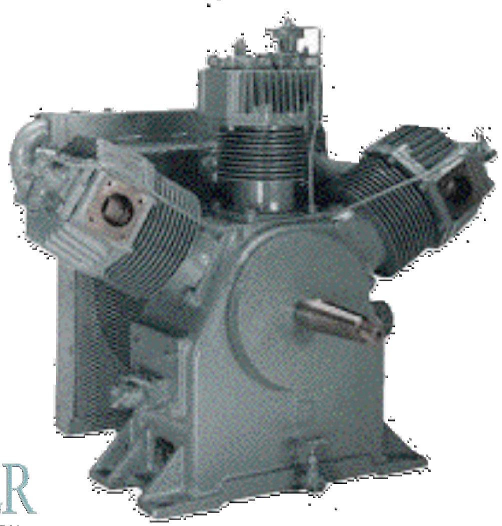
Compressed Air System Components

- Compressor
- Air filters
- System controls
- Compressor and Compressed Air Cooling
- Separators
- Dryers
- Air receiver
- Traps and drains
- Air distribution system

Compressor types

- Positive-displacement
  - Reciprocating
  - Rotary
- Dynamic
  - Axial
  - Centrifugal

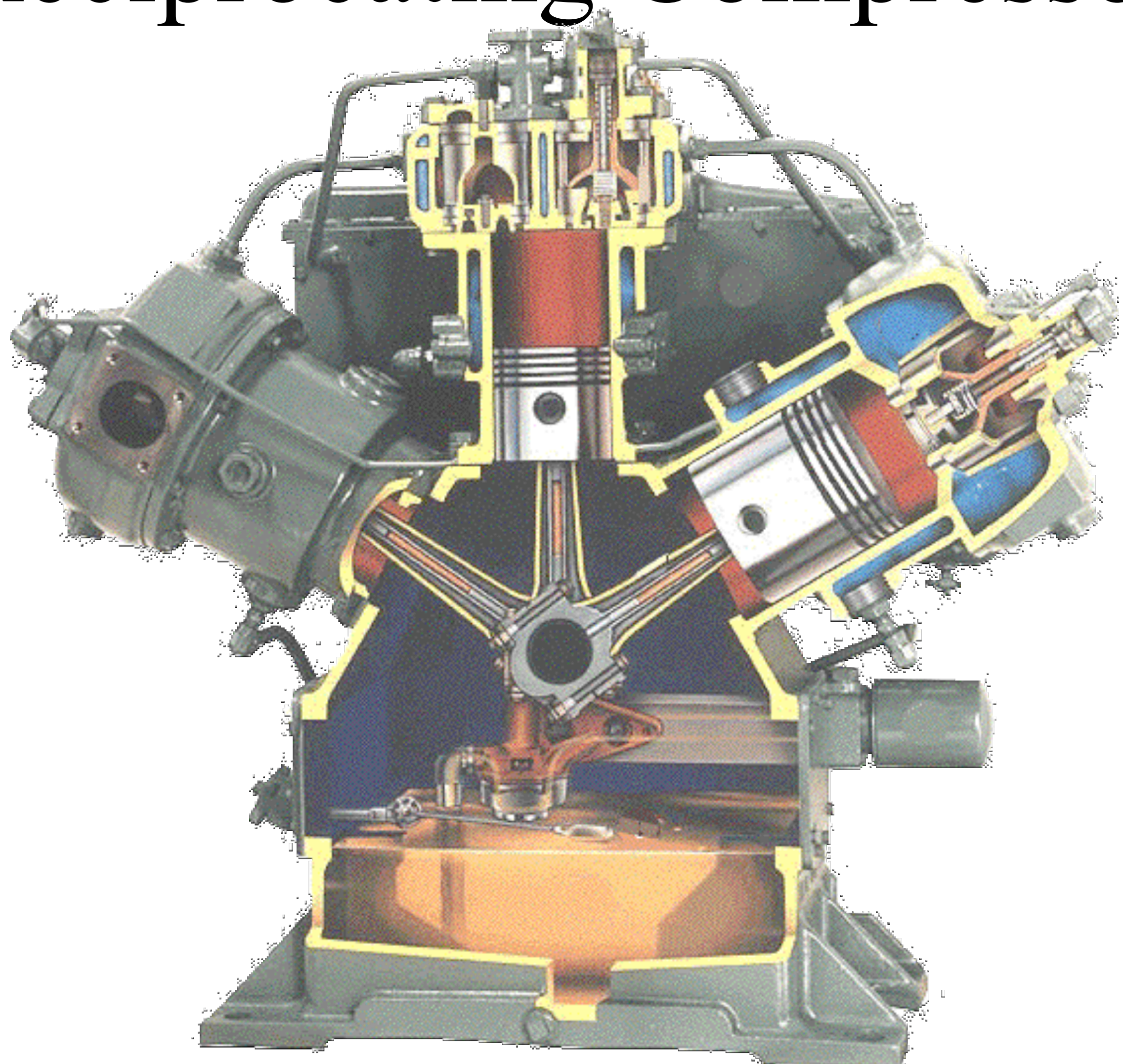
Positive-displacement Compressors



Reciprocating Compressor

- How do they work?
- Single and double-acting
- Multi-stage double-acting are most efficient
- Less than 1 hp to more than 600 hp sizes available

Reciprocating Compressor



Source: Gardner-Denver Co.

Rotary Compressors

- Most commonly used sizes are from about 30-200 hp
- Helical twin screw-type (rotary screw)
- Compact size, low weight, and are easy to maintain
- Rotary screw are available in sizes from 3-600 hp

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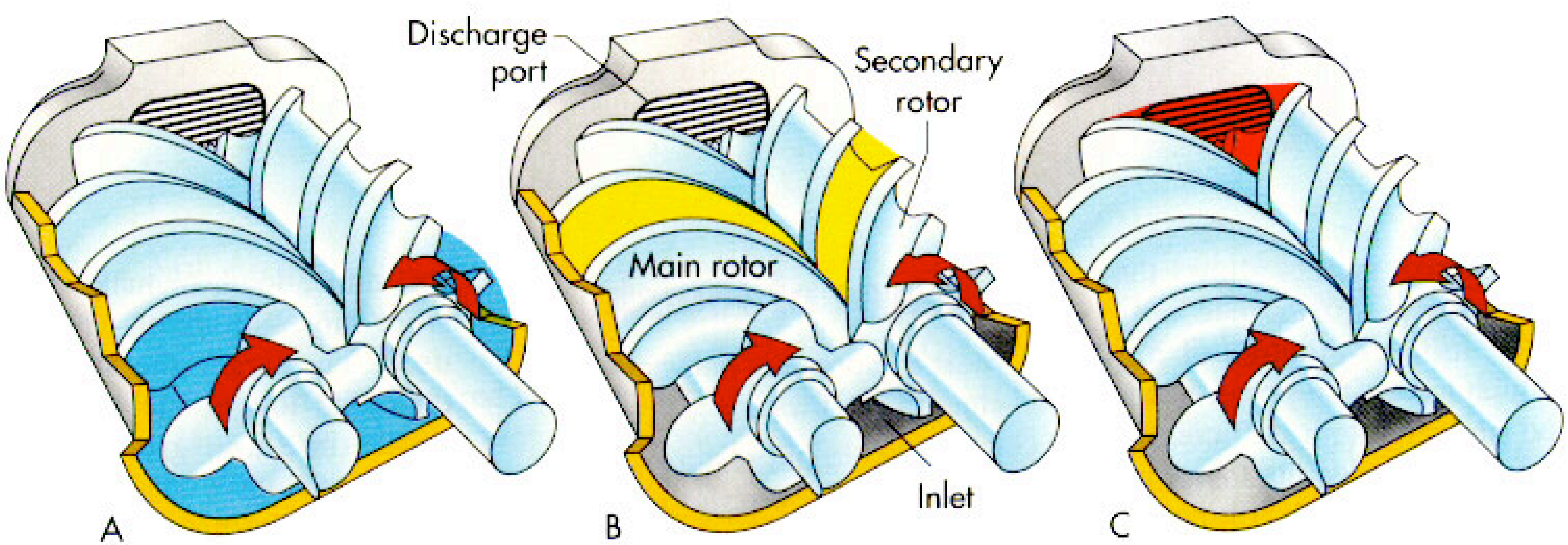
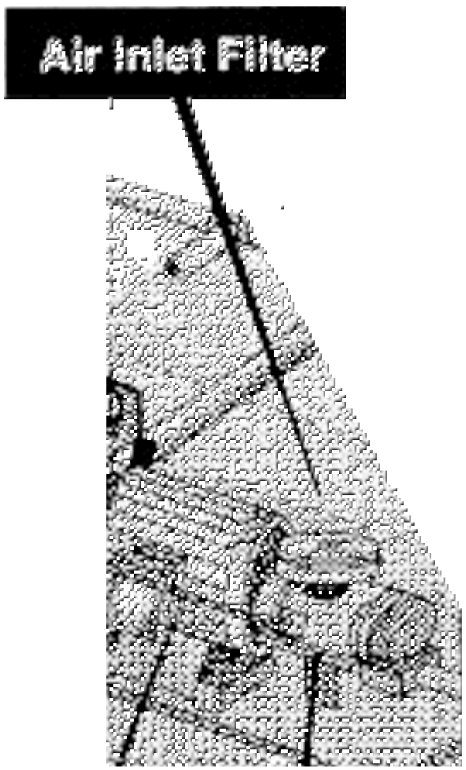
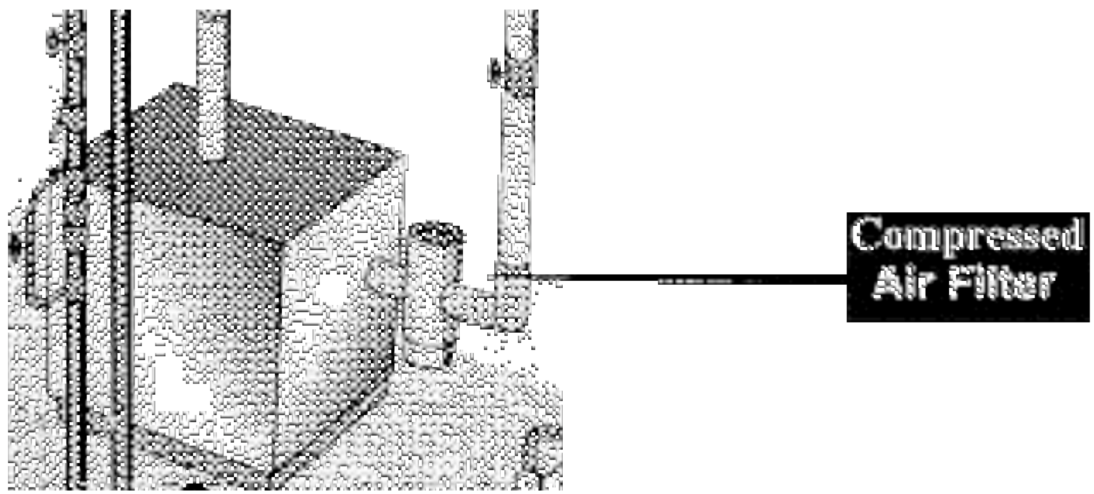
Rotary Screw Compressor



Air filters





Air filters

- Removes contaminants such as:
  - Solid particulates
  - Oil aerosols and vapors
  - Water aerosols and vapors
  - Other gases
- Most contaminants are in the form of aerosols.
- Aerosol – a suspension of small solid or liquid particles in a gas ranging in size from 0.1-10 □ in diameter.

Air filters

Typical airborne contaminants	
Contaminant	**Particle size, microns**
Dirt and pollen particles	0.01-20
Microorganisms	<0.01-2
Water	0.05-10
Oil from well-maintained compressor	0.01-10
Unburned hydrocarbons	Gas phase

Contaminant Sources

- Air drawn into a compressor
  - Airborne particles smaller than 10
  - Gases and vapors around inlet
  - Pollen and dirt
- Internal compressor mechanisms
  - Oil and hydrocarbon aerosols
- Compressed air distribution system
  - Pipe scale and rust particles

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Air Inlet Filter

- Designed to stop larger particles that could cause rapid wear of compressor parts.
- Draw in virtually all particles, vapors, and gases in the air within a 6-ft radius.
- Most airborne particles smaller than 10 microns enter the compressor.

Compressed Air Filter

- Used downstream of the compressor
- Particulate – solid particles
- Coalescing – lubricant and moisture
- Adsorbent – very fine contaminants and vaporous contaminants
- Filtration only to the level required
  - 2 psig of pressure change increases or decreases power draw by 1%

Particulate Air Filter

- Frequently made with a single layer of cellulose paper
- Diameter of cellulose fiber too large to be effective in removing liquid aerosols
- Liquids that are collected usually become re-entrained into the airstream
- Can be found on the downstream of a desiccant dryer to remove desiccant “fines”

Coalescing Air Filter

- Defined as the progressive accumulation of small liquid aerosols particles into larger ones
- Liquids are removed by gravity when droplets become large enough to fall into the sump area
- Theoretically could be used indefinitely but particulate accumulation creates large ΔP
- Can be found on the upstream of a desiccant dryer to prevent desiccant bed fouling

Adsorbent Air Filter

- Made with granular adsorptive media, such as activated carbon
- Adsorbent may be in a bed or impregnated in or on a carrier fabric
- Used in conjunction with a pre-filter/coalescer upstream to prevent liquid aerosol clogging
- Used to remove odors for applications such as blow molding food or pharmaceutical containers

Effects of Contaminants

- Particulate accumulation
  - Blocks clearances between moving parts
  - Erodes surfaces and seals
  - Leakage
  - Lowers □ in pneumatically operated equipment
  - Increases energy consumption

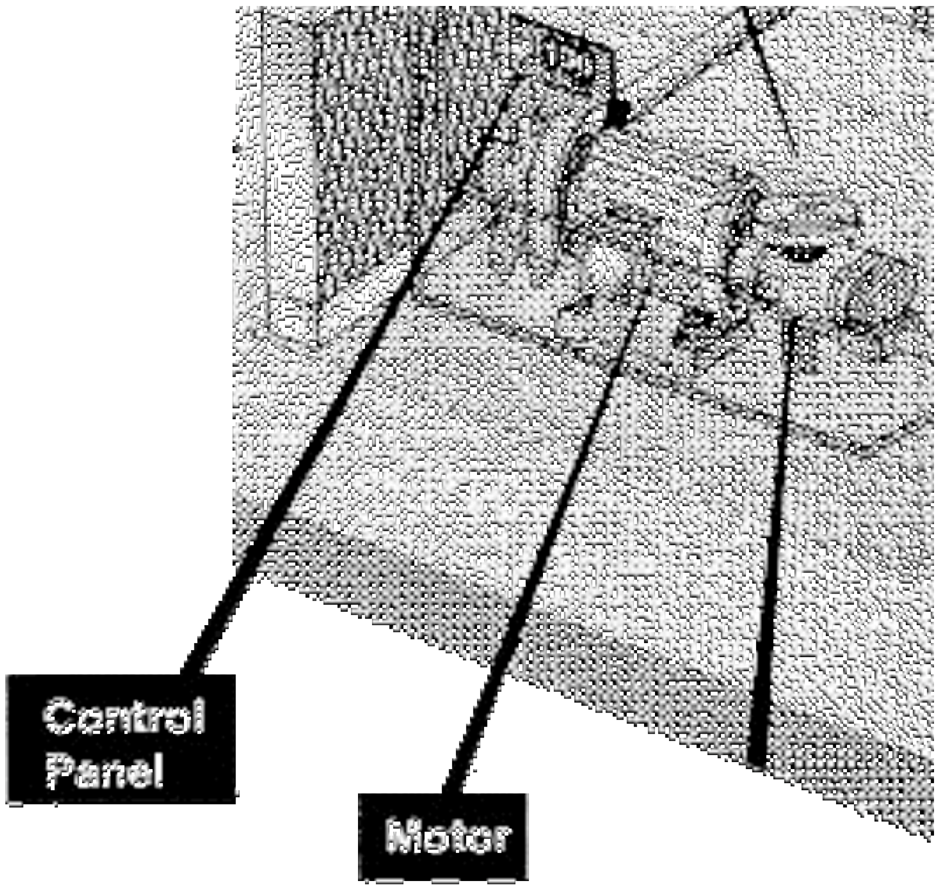
Effects of Contaminants

- Excessive oil
  - Particles adhere to oil-coated surfaces
  - Interferes with moving parts
  - Accelerates the obstruction of pipes leading to greater pressure drop
  - Higher energy consumption

Effects of Contaminants

- Excessive water
  - Can freeze in cold temperatures, shutting down entire system
  - Can destroy lubricating film on bearing surfaces
  - Corrode components surfaces creating rust particulates
  - If hydrocarbon and/or combustion byproducts are present, water can help condense contaminants to create oil aerosols; causing odor problems

System Controls



System Controls

- Start/Stop – motor turned on or off
  - 0 or 100% capacity
  - Typically on reciprocating compressors
  - Motor overheating can result from frequent cycling
- Multi-Step – allows operation in two or more partially loaded conditions
  - Applicable only with reciprocating compressors
  - Operating conditions are usually evenly spaced increments (i.e. 0, 25, 50, 75, and 100%)

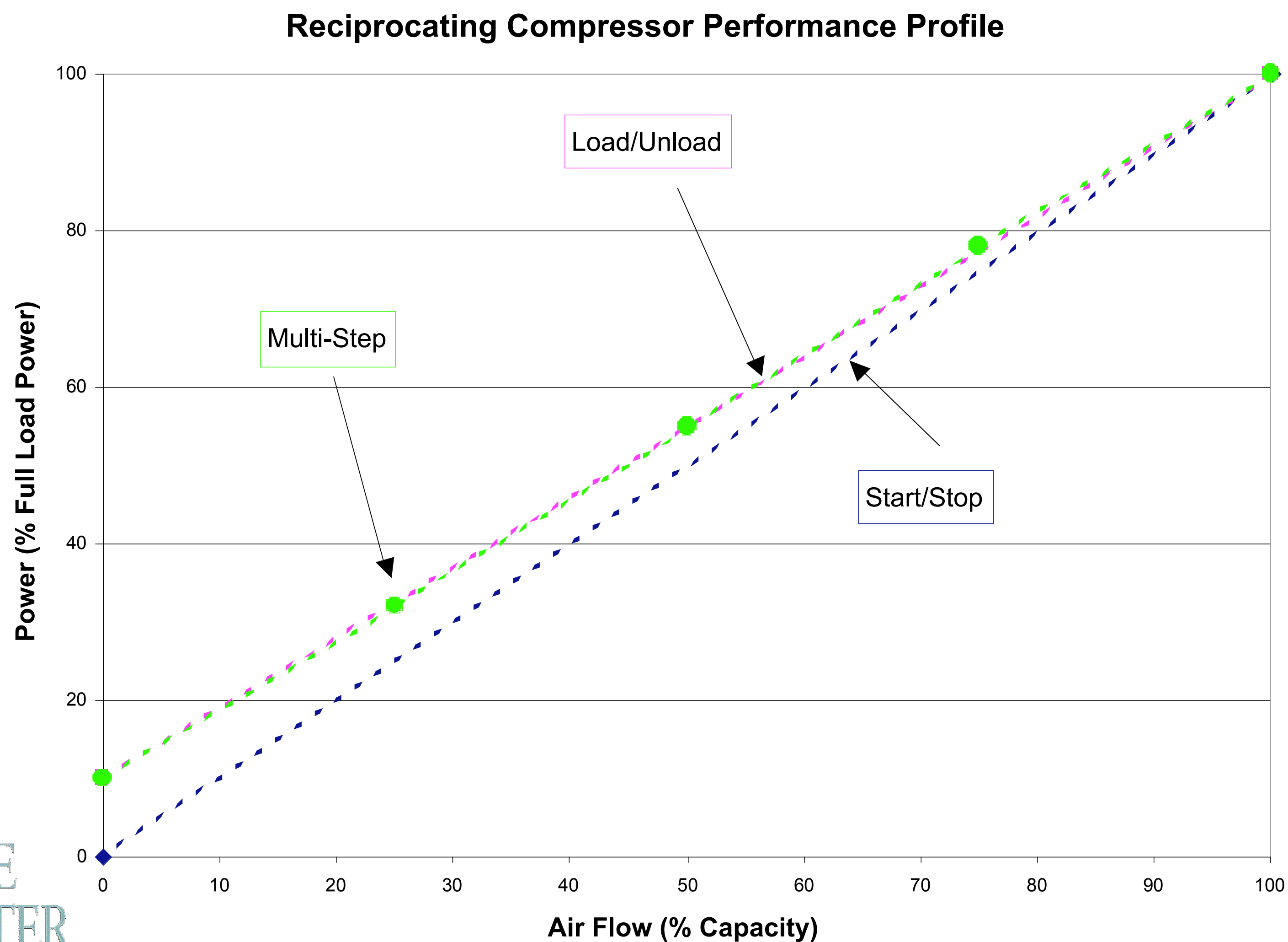
System Controls

- Load/Unload – motor runs continuously, but the compressor is controlled
  - Applies to rotary and reciprocating compressor
  - Opening inlet valves unloads reciprocating compressors, while closing inlet and bleeding off discharge unloads rotary compressors
  - Unloaded state in newer rotary screw units consume between 15-35% of full-load hp and up to 85% in older units

System Controls

- Modulating (Inlet throttling) – inlet opening is restricted to allow only the amount of air demanded
  - Used with rotary and centrifugal compressors
  - Effective down to a minimum capacity set by mfg, normally between 40 to 60% for rotary
  - Some mfgs allow the user to set the unload point to maximize savings, which some call “low-unload controls”

Reciprocating Compressor Controls



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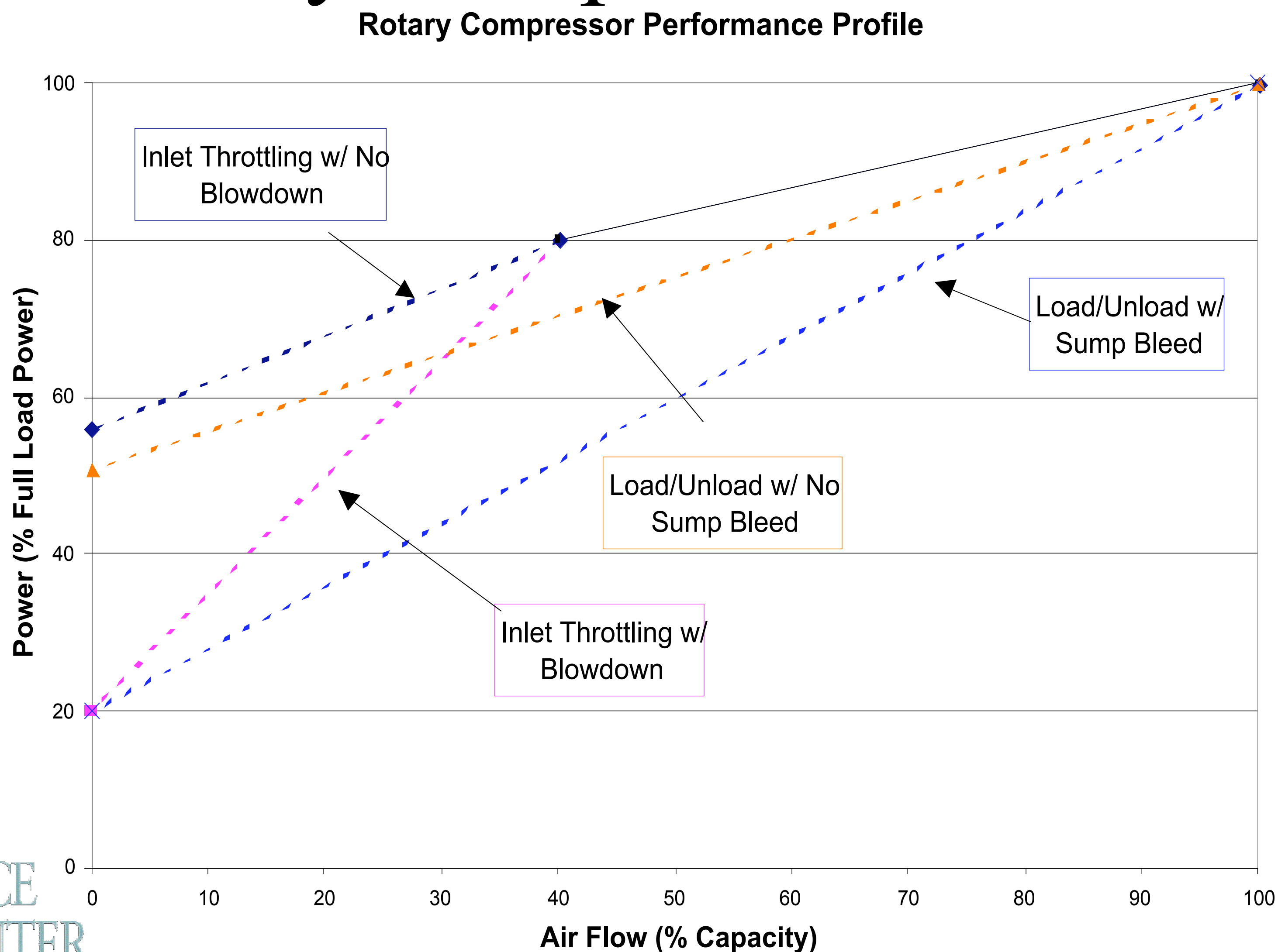
Rotary Compressor Controls



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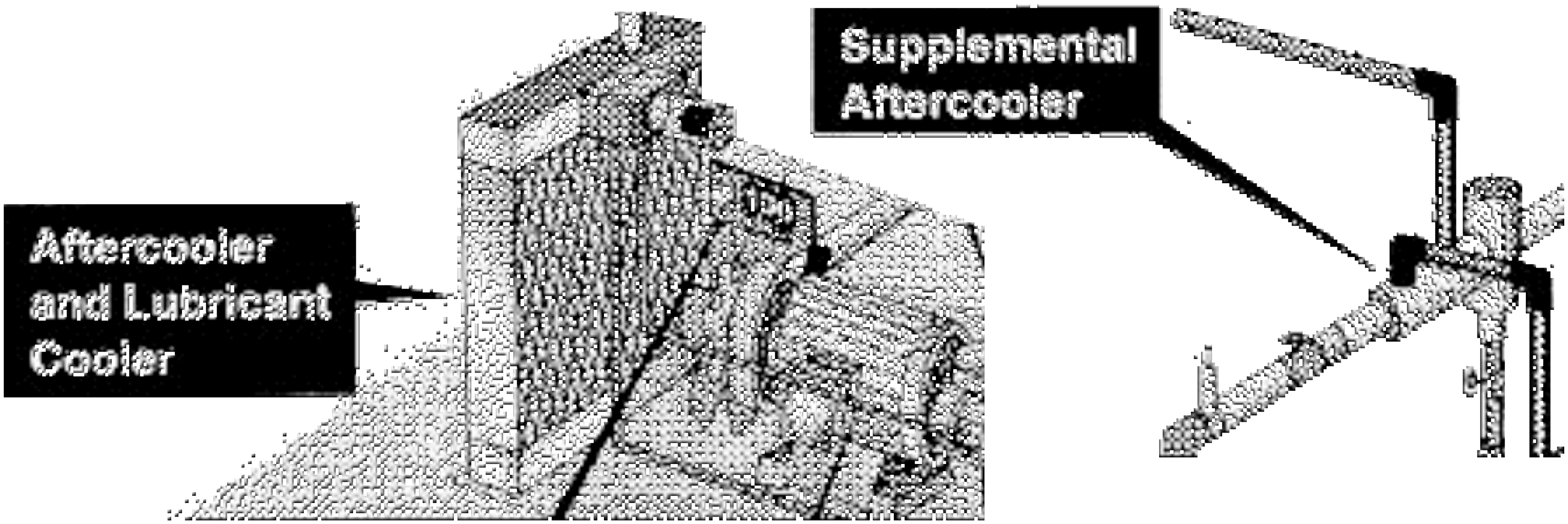
Compressor and Compressed Air Cooling



Compressor Cooling

- Compressing air generates heat
- Air, water, and/or lubricant can be used
- Reciprocating compressors of less than 100 hp are usually air-cooled
- Larger reciprocating units are typically water-cooled using cooling water jackets

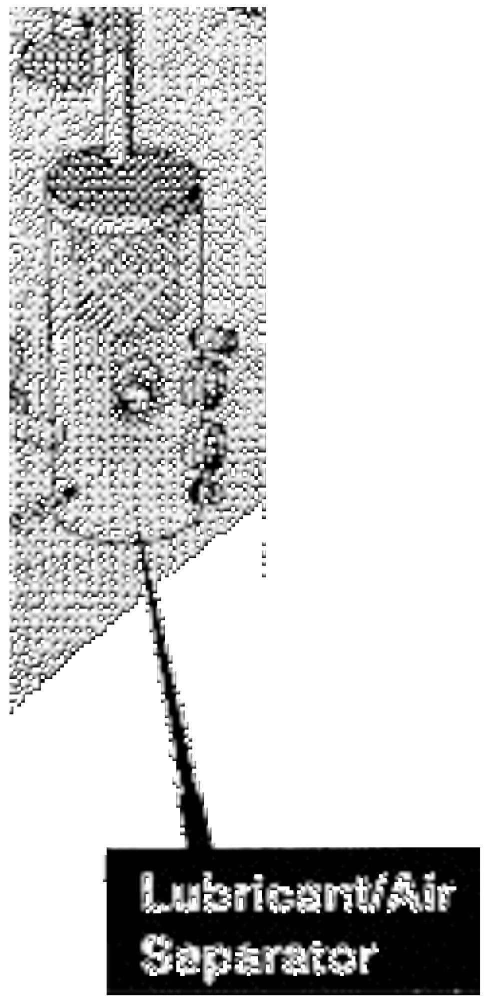
Compressor Cooling

- Rotary screw units can be either dry-running or lubricant or water injected
- Lubricant and water remove the heat of compression, seal internal clearances, and prevent rotor-to-rotor contact
- Less stages needed for a given discharge pressure when using oil injected version

Intercoolers and Aftercoolers

- Intercoolers are heat exchangers used in multi-stage compressors between each stage to remove the heat of compression
- Aftercoolers are installed at the final stage of compression to reduce the air temp
  - Condensate is separated, collected, and removed

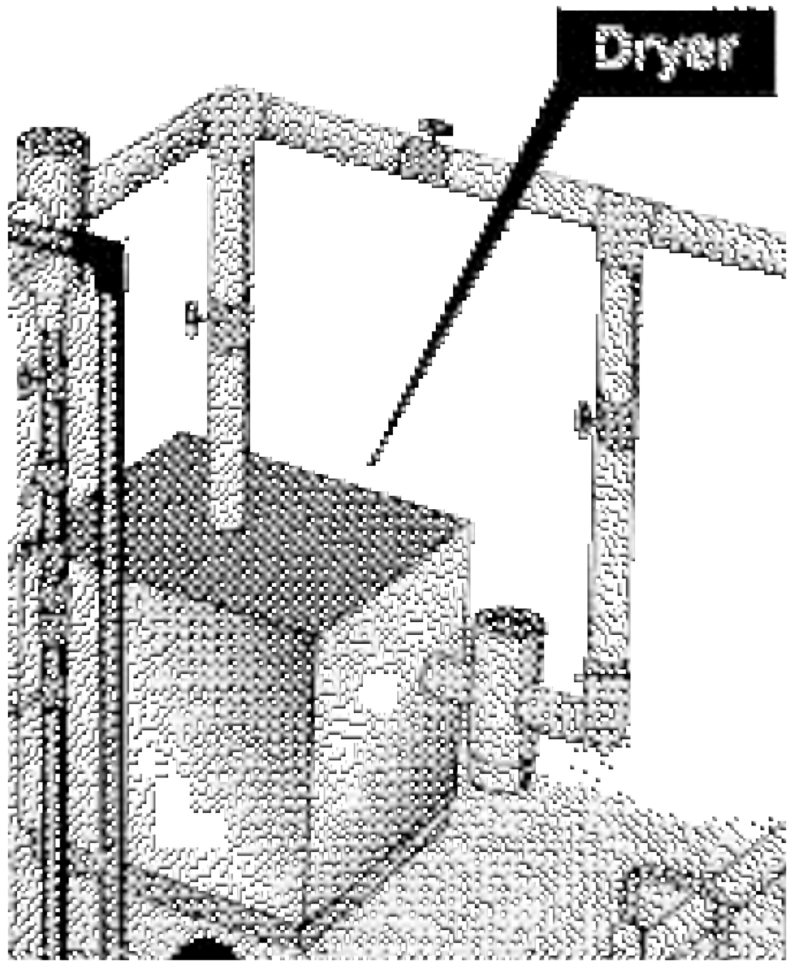
Separators



Separators

- Used to separate liquid entrained in the air
- Air/lubricant coalescing separator
  - Installed immediately after the compressor discharge to separate the injected lubricant before it is cooled to prevent liquid from being entrained in the air.

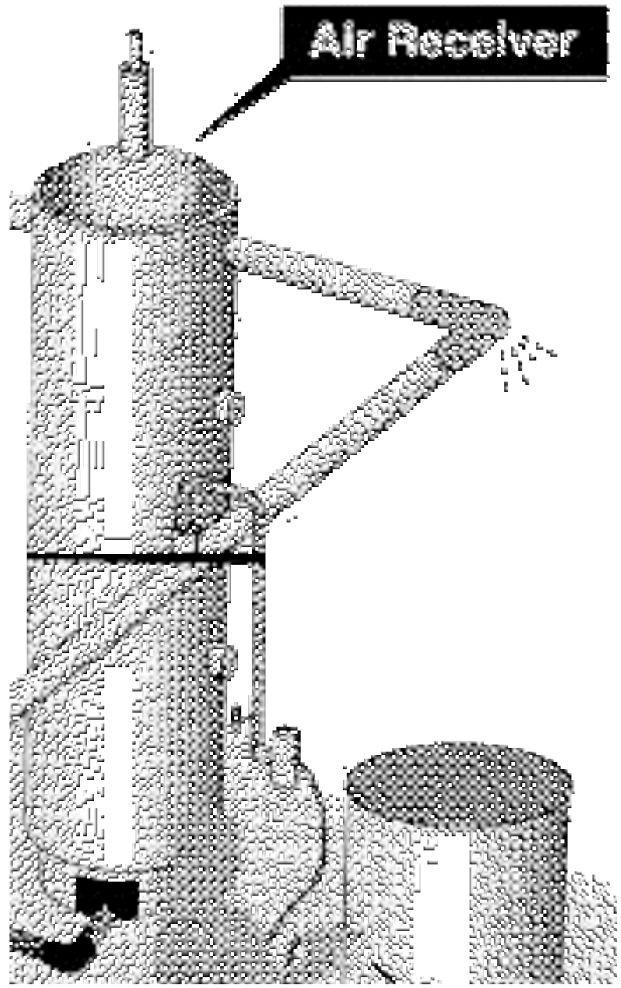
Dryers



Dryers

- Refrigerant-type – cools air to 35 to 40^{o}F then removes moisture before reheating
- Deliquescent-type – hygroscopic desiccant absorbs water vapor
- Twin tower regenerative-type – uses two towers filled with desiccant, one is used while other is being regenerated

Air receivers



Air receivers

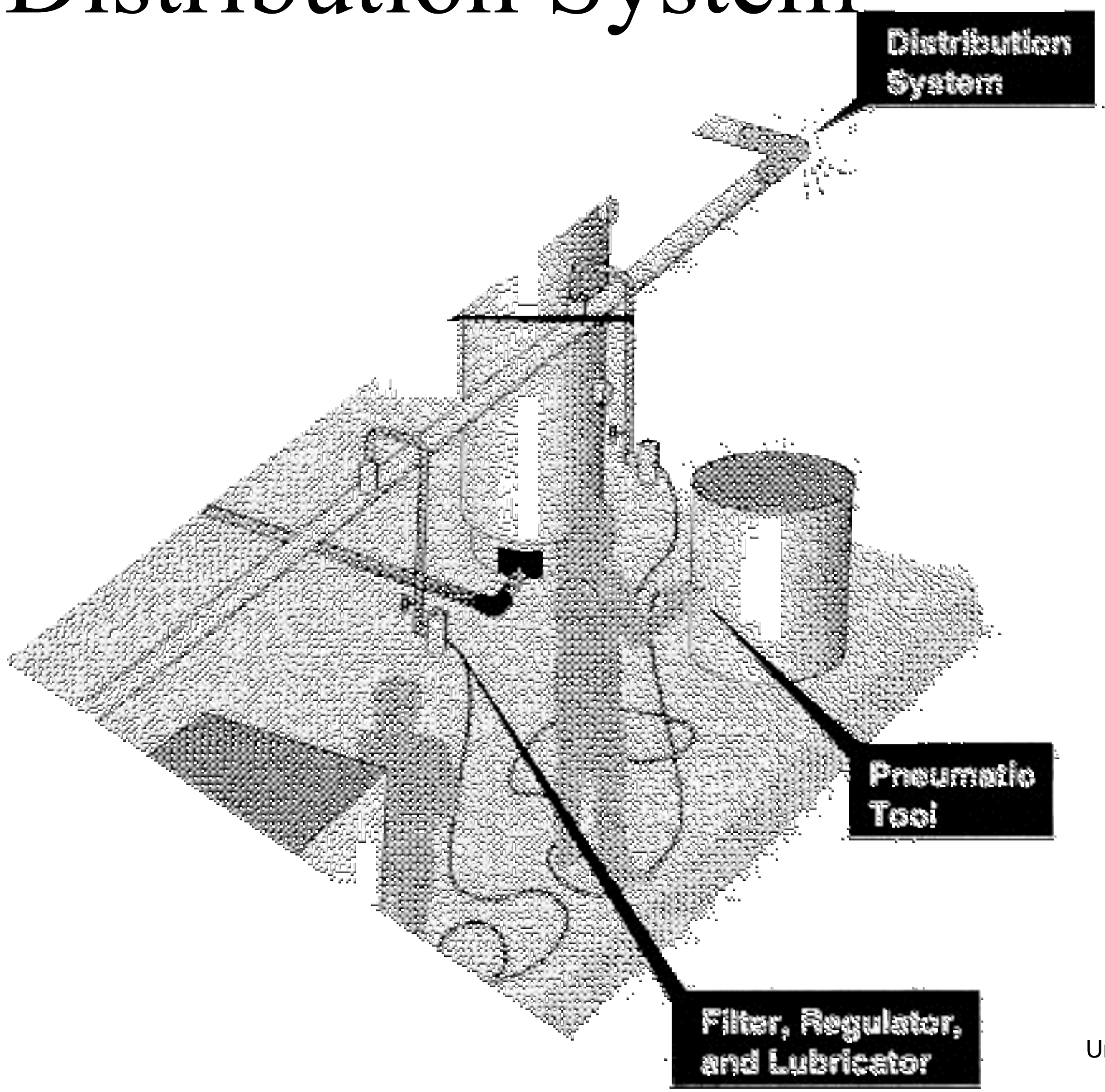
- Provide air storage capacity to meet peak demand
- Should be sized for about 2-4 gal/cfm of compressor capacity
- Effective for systems that have varying air flow capacity
- If installed after a reciprocating unit, can provide a reduction in pressure pulsations, radiant cooling, and condensate drainage

Traps and Drains

Traps and Drains

- Used to remove condensate from compressed air lines
- Mechanical traps – opens when condensate rises to a preset level
- Electrical solenoid drain valves – open on a preset time cycle whether condensate is present or not
- Some electrical devices sense liquid levels before opening

Air Distribution System



Air Distribution System

- Links the compressed air supply side with the demand side with minimal pressure loss
- Consists of main lines, branch lines, valves, and air hoses
- Pressure drop from compressor to the furthest end use point should be less than 10% of the discharge pressure

Lubricators

- Provide lubricant to moving parts in pneumatic tools
- Are sometimes combined with filters to form a filter/lubricator assembly
- Also can be combined with filters and pressure regulators to form a filter/regulator/lubricator assembly

Pressure Regulators

- Used to supply air to pneumatic equipment at pressures lower than the supply pressure
- Some regulators can deliver a specific volume of air (i.e. instrument air)
- Separate LP system is economical, if large quantities of low pressure air are required
- Air regulated from 100 to 60 psi results in approximately 40% energy waste

Compressor Load Factor

- "Loaded" refers to the state when the compressor is actually compressing air
- "Unloaded" refers to the state when a compressor is continuously running but no useful work is produced
- For reciprocating units with on/off controls, LF is fairly constant
- For rotary screw units, LF is a weighted avg

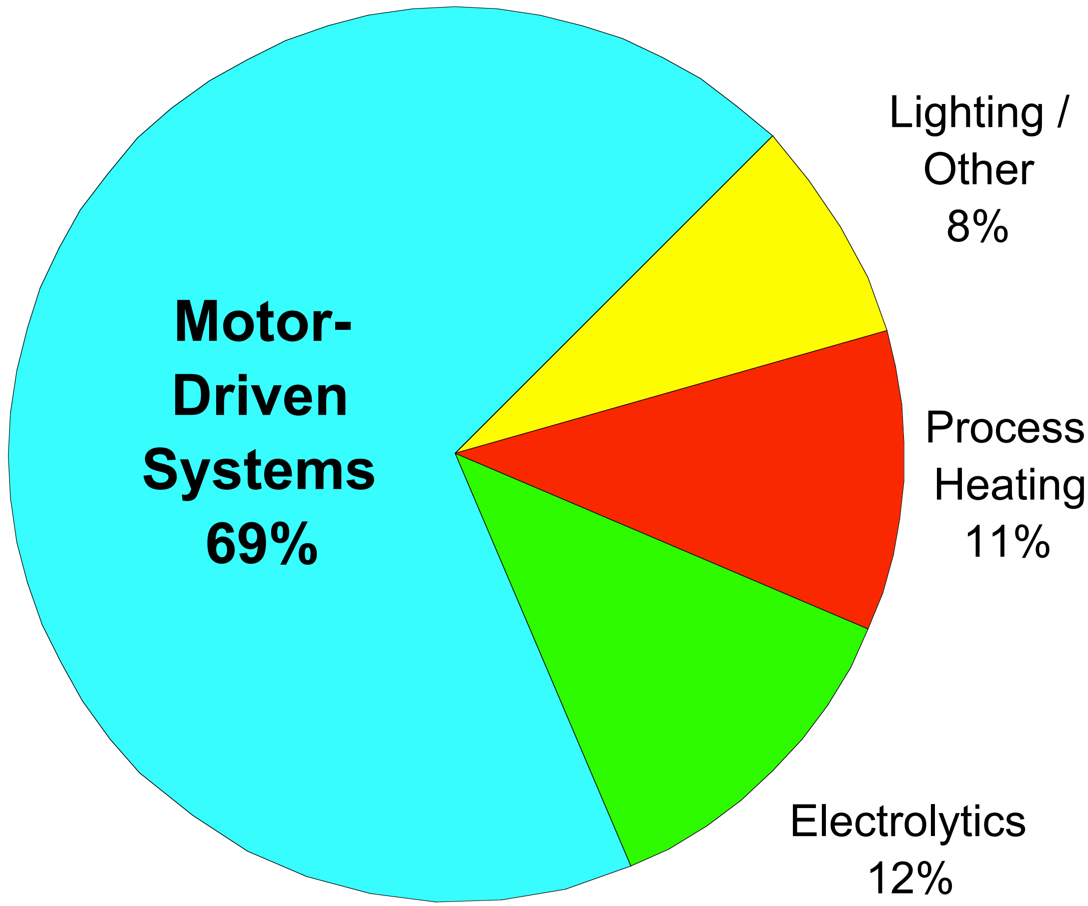
Compressor Load Factor

$$LF = \left[(FL) \times (FTL)\right] + \left[(FU) \times (FTU)\right]$$

FL = fraction of rated power when loaded
FTL = fraction of operating time compressor is loaded
FU = fraction of rated power when unloaded
FTU = fraction of operating time compressor is unloaded

❖ Note: For reciprocating compressors, LF = FL

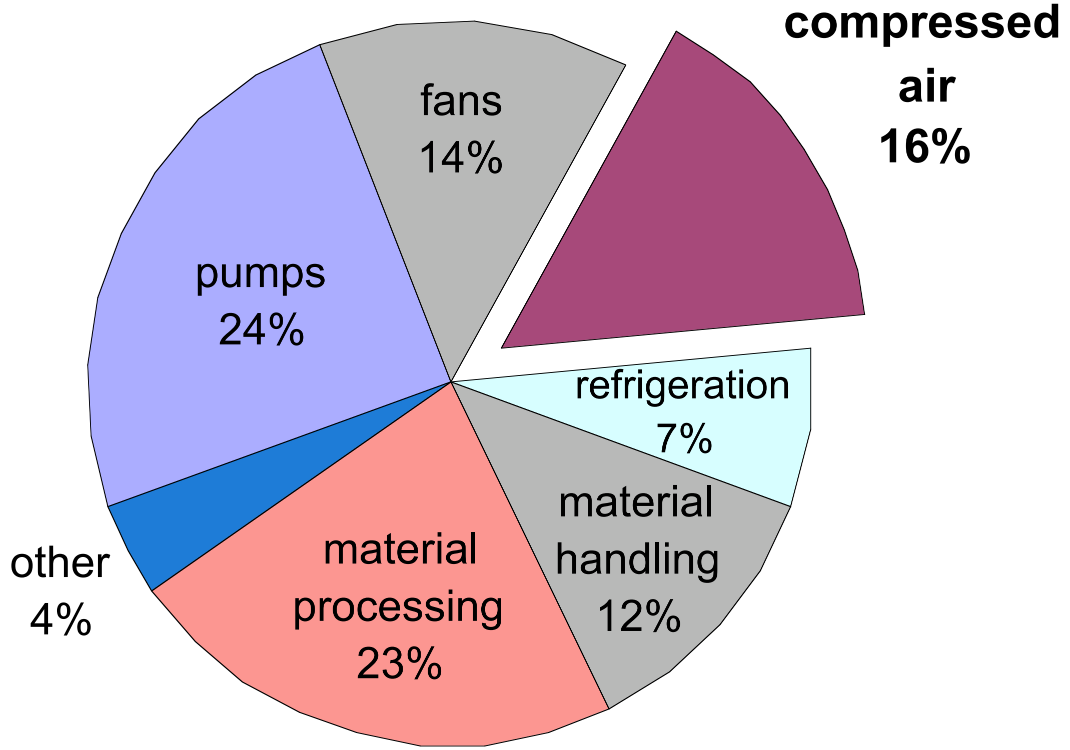
Industrial Electricity Use



Source: DOE presentation, March 1999:
Introduction to Motor Systems Management

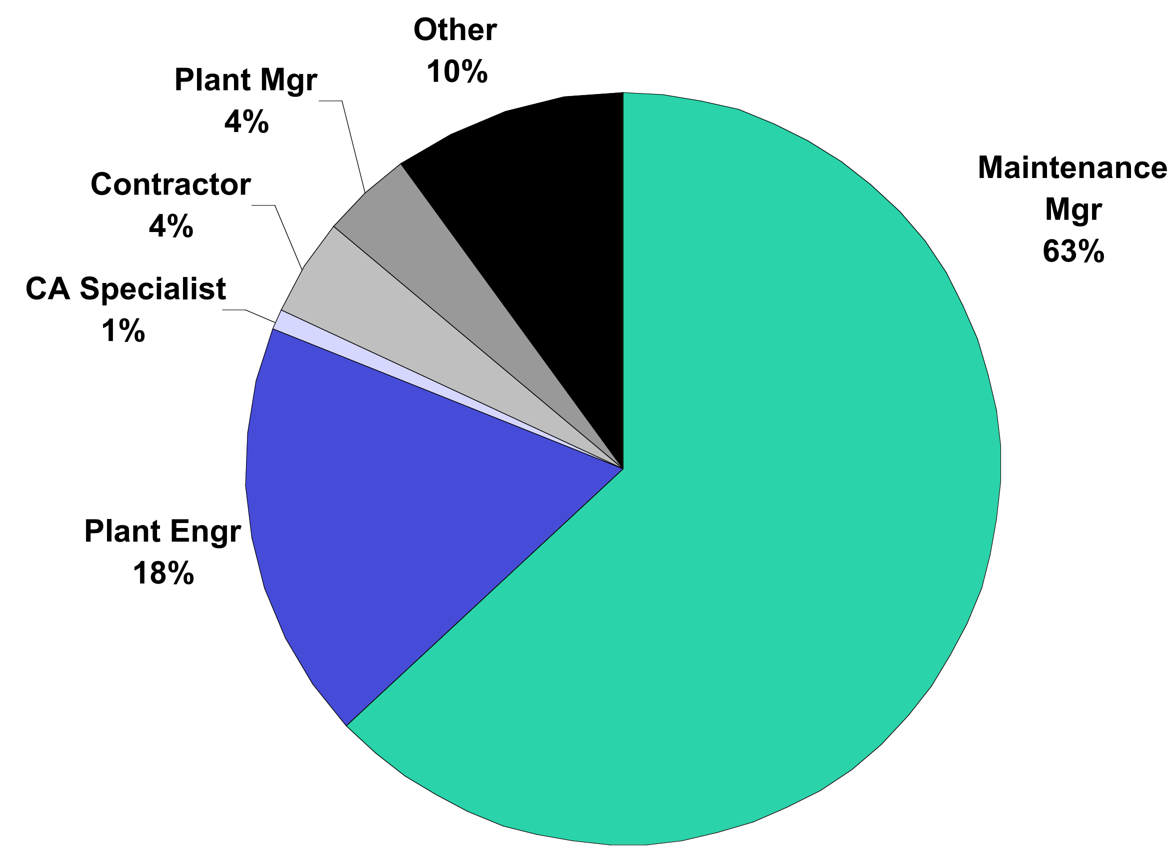
Industrial motor energy use by application

Total 2.3 Quadrillion Btu/yr



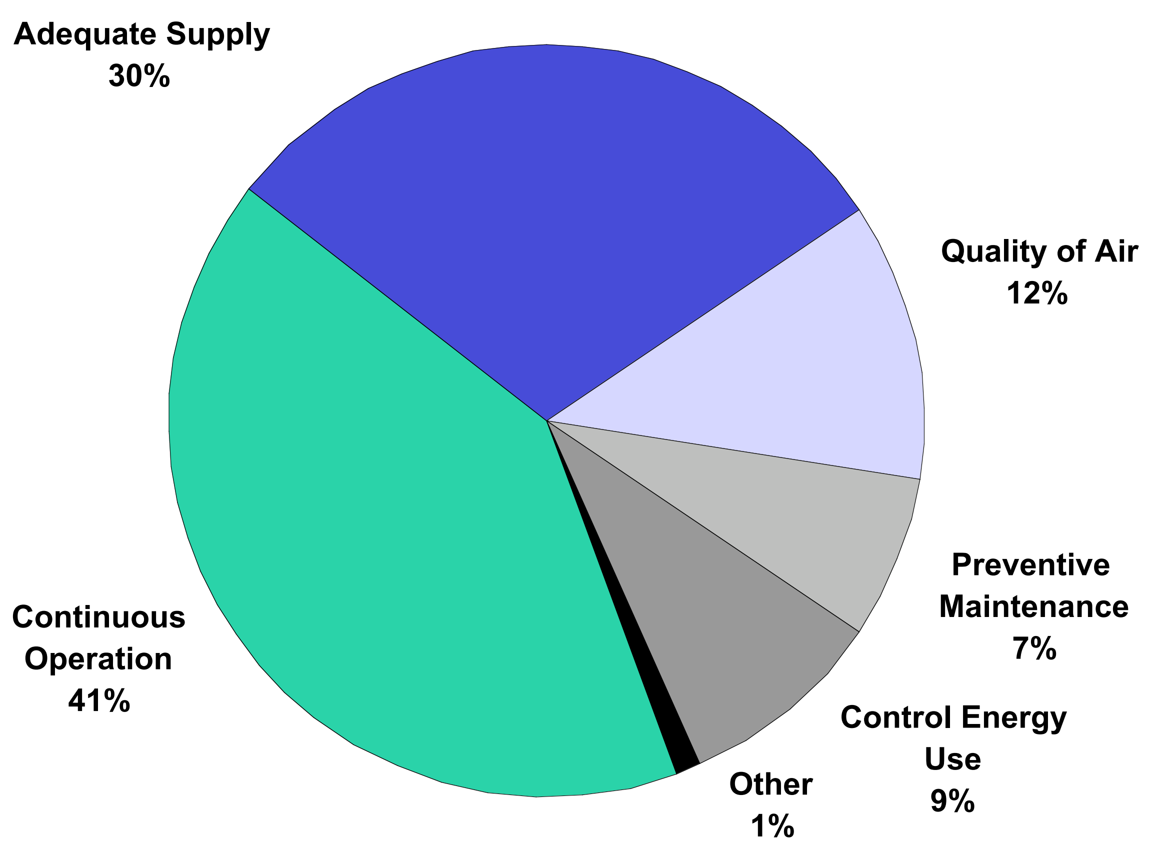
Source: United States Industrial Electric Motor Systems Market Opportunities Assessment, Office of Industrial Technologies, Office of Energy Efficiency and Renewable energy, US DOE, December 1998, Table 1-16, page 43

Position Responsible for CA System



Source: Assessment of the Market for Compressed Air Efficiency Services, Office of Industrial Technologies, Office of Energy Efficiency and Renewable energy, US DOE, 2001

Primary Objective of CA Management



Source: Assessment of the Market for Compressed Air Efficiency Services, Office of Industrial Technologies, Office of Energy Efficiency and Renewable energy, US DOE, 2001

Objectives of CA Management

	Primary Objective	Objective
Maintain Continuous Operation	41 %	57 %
Ensure Adequate Supply	30 %	50 %
Maintain Quality of Air	12 %	37 %
Control/Reduce Energy Use*	9 %	22 %
Preventive Maintenance	7 %	19 %
Other	1 %	3 %

* Only 10% indicated they kept track of the CA system energy cost.

CA System Measurements

Operating Parameter Measured	Percent
Pressure Levels	65
Demand on Compressor Motors (kW)	39
Compressor Motor Energy Use (kWh)	21
Leak Loads	19
Load Profiles	16
None of the Above	25

Are Service Contracts the Answer?

Services Provided*	Percent
Preventive Maintenance on Compressors	67
Preventive Maintenance on Auxiliaries	44
Emergency Repair	33
Leak Repair	20
Assessment of Control Strategies and Equipment	14
Leak Detection	13
Load Profiling	5
Energy Use Monitoring	3

*30% of respondents had service contracts: 83% vendors, 17% consultants/contractors.

CA Efficiency Assessment Activities

Compressed Air Efficiency Study Services*	Percent
Estimate of CA System Energy Use	79
Recommendations for Improvements	74
Assessment of Auxiliary Equipment (e.g., dryers, separators)	68
Load Profile Based on System Measurements	63
Estimation of Losses Due to Leaks	63
Assessment of Control System and Alternate Strategies	63
Identification of Inappropriate Uses of Compressed Air	61
Assessment of Distribution System for Pressure Drops and Eff.	61
Assessment of Air Storage Capacity	61
Estimates of Costs and Energy Savings for Recommendations	47

*20% of respondents had efficiency study performed.

Measures Implemented After CA Efficiency Assessment

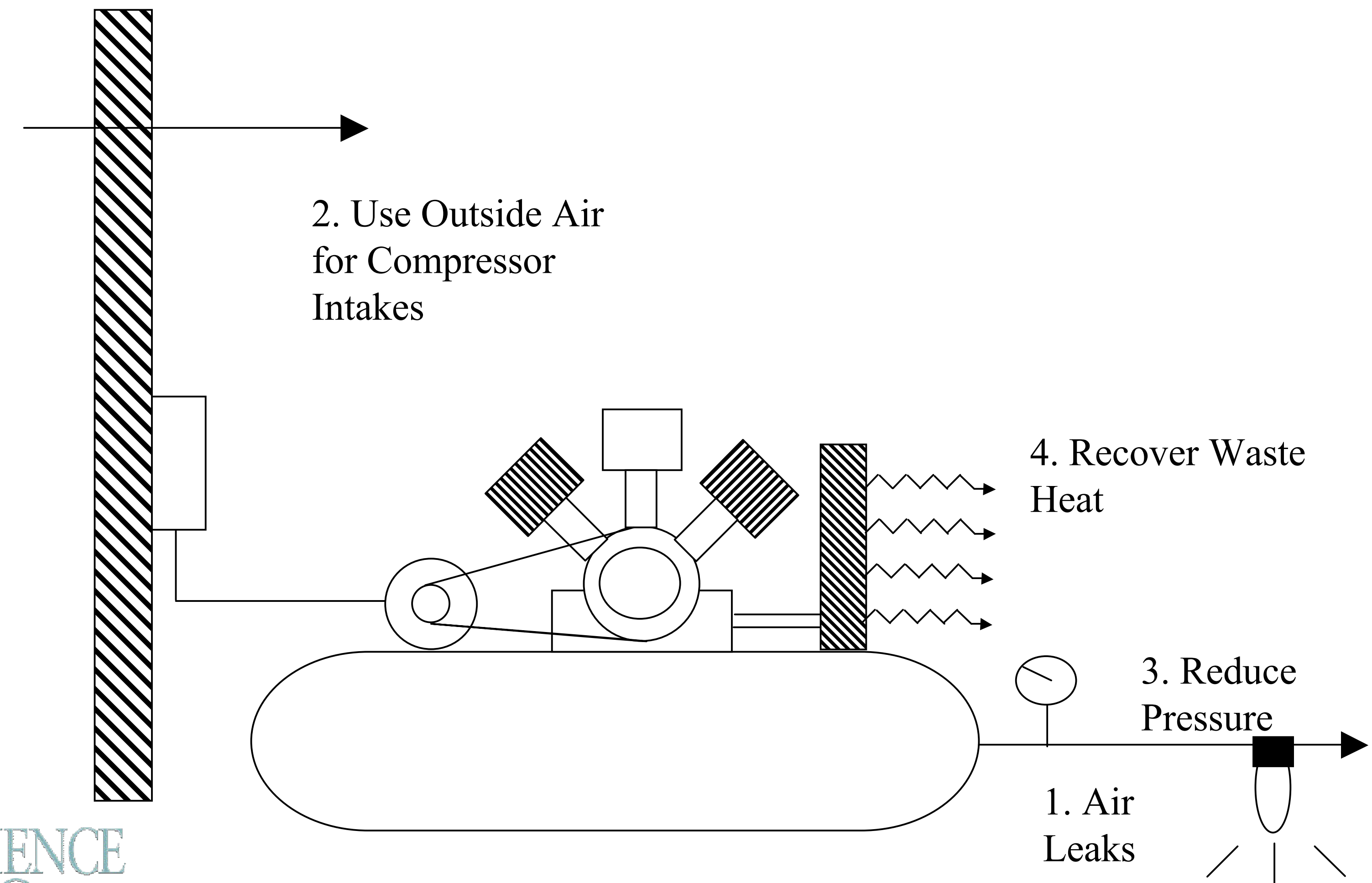
Measures	Percent Implemented
Improvements to System Auxiliaries	40
Changes to Piping, Distribution System	40
Leak Reduction	32
Added Air Storage Capacity	28
Changes to Compressor Controls	24
Reduced Unnecessary Compressed Air Uses	16
Installed Heat-Recovery Equipment	16

*66% implemented at least one measure.

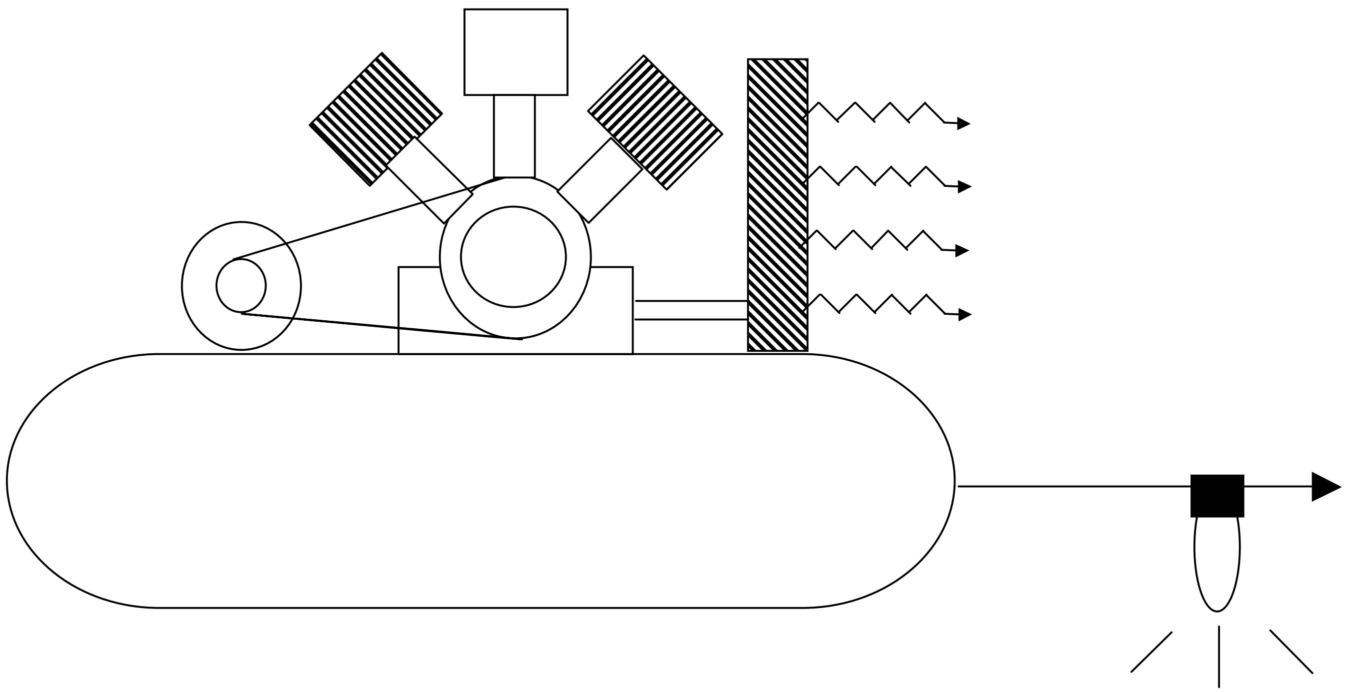
IAC Compressor Recommendations Summary

Measure	# Recs.	Avg. Savings ($/yr)	Simple Payback (yr)	% Implemented
Fix Air Leaks	3399	3,553	0.2	83
Reduce Air Intake Temperature	3246	1,383	0.5	51
Reduce Pressure	1570	2,510	0.3	48
Recover Waste Heat	650	2,921	0.8	36
Eliminate Unnecessary CA Use	500	6,153	0.6	52
Optimize Compressor Size	195	7,805	1.0	51
Upgrade Compressor Controls	121	7,469	0.7	55
Improve Distribution System	66	5,262	0.8	67
Other	40	5,953	1.1	45

Compressor Recommendations



Reduce Compressor Air Leaks

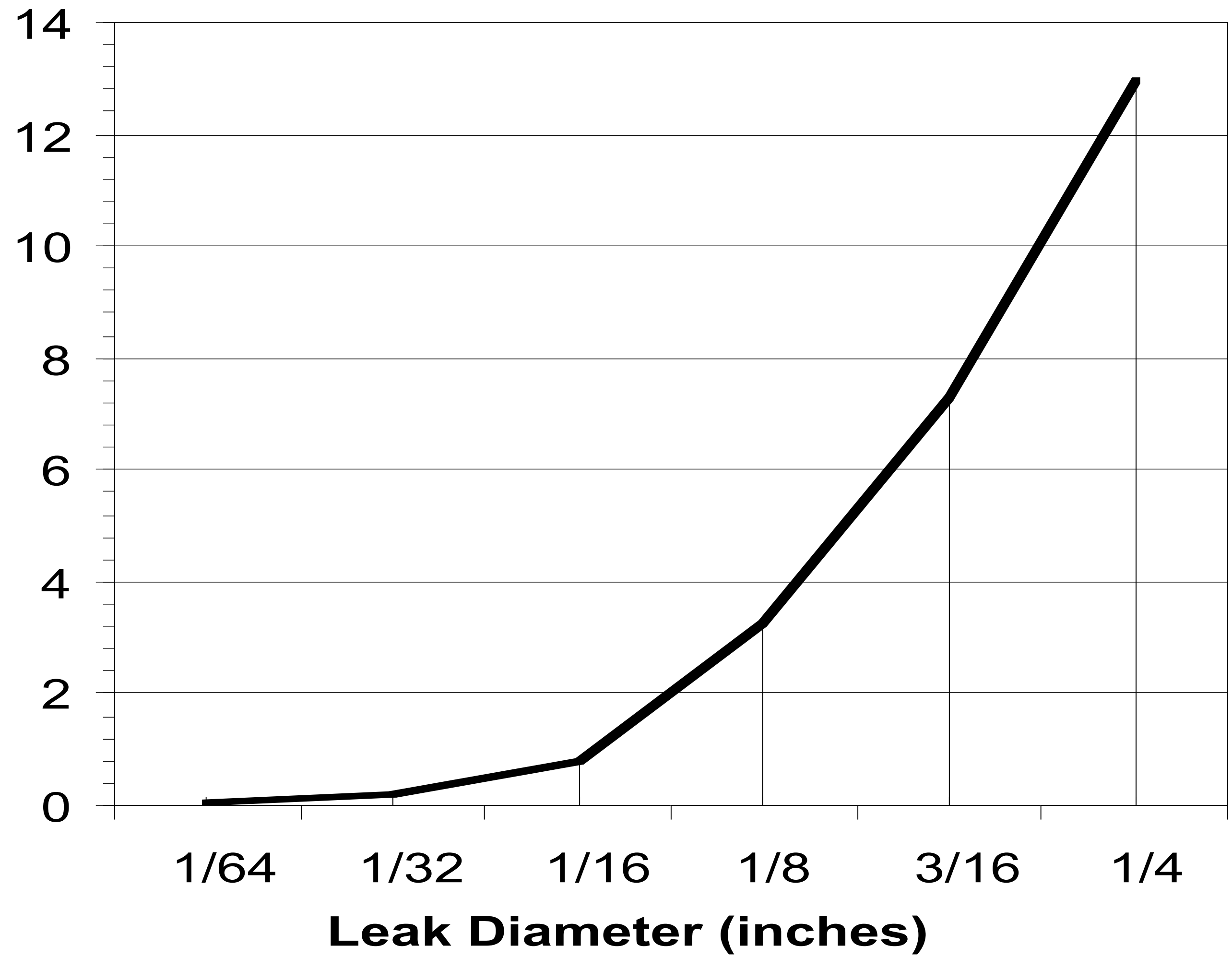


Air Leaks - Background

- 20% of total energy consumed is lost to air leaks
- Amount of lost air depends on:
  - line pressure
  - air temperature at leak
  - air temperature at compressor inlet
  - area of the leak
- Percentage lost to leakage should be less than 10% in a well-maintained system

Air Leaks –Power Loss (kW)

Hole Diameter (inches)	Demand Loss (kW)
1/64	0.05
1/32	0.2
1/16	0.8
1/8	3.2
3/16	7.1
1/4	12.6



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Estimating Amount of Leakage

- For compressors that cycle on and off, turn all air demanding equipment off

$$\text{Leakage}\,\% = \left[\frac{(T \times 100)}{(T + t)}\right]$$

T = on-load time (minutes)
t = off-load time (minutes)

Estimating Amount of Leakage

- Another method uses a pressure gauge located down stream of an air receiver, for compressors using other control strategies

$$\text{Leakage (cfm)} = \left[\frac{V \times (P_1 - P_2)}{(T \times 14.7)}\right] \times 1.25$$

P_1 = normal operating pressure (psig)
P_2 = 50% of operating pressure (psig)
V = total system volume (ft^3)
T = (minutes)

Air Leaks – Anticipated Savings

$$V_f = \frac{NL \times (T_i + 460) \times \frac{P_1}{P_i} \times C_i \times C_2 \times C_d \times \frac{\partial D^2}{4}}{C_3 \times \sqrt{T_1 + 460}}$$

$$L = \frac{P_i \times C_3 \times V_f \times \frac{k}{k-1} \times N \times C_4 \times \left[\left(\frac{P_o}{P_i} \right)^{\frac{k-1}{k \times N}} - 1 \right]}{\text{ç}_a \times \text{ç}_m}$$

Air Leaks – Anticipated Savings

V_f – volumetric flow rate of free air, cfm

NL – number of air leaks, no units

T_i – temperature of the air at the compressor inlet, °F

P_1 – line pressure at leak in question, psia

P_i – inlet (atmospheric) pressure, 14.7 psia

C_i – isentropic sonic volumetric flow constant

– 28.37 ft/sec-°$R^{0.5}$

C_2 – conversion constant, 60 sec/min

C_3 – conversion constant, 144 in^2/ft^2

Air Leaks – Anticipated Savings

C_d – coefficient of discharge for square edged orifice, 0.8 no units

D – leak diameter, inches

T_1 – average line temperature, °F

L – power loss due to air leak, hp

k – specific heat ratio of air, 1.4, no units

N – number of stages, no units

C_4 – conversion constant, 3.03 x 10^{-5} hp-min/ft-lb

P_o – compressor operating pressure, psia

$\_m$ – compressor motor efficiency

Air Leaks – Anticipated Savings

$\_a$ – air compressor isentropic (adiabatic) efficiency

- $\_a = 0.88$ for single stage reciprocating compressors
- $\_a = 0.75$ for multi-stage reciprocating compressors
- $\_a = 0.82$ for rotary screw compressors
- $\_a = 0.72$ for sliding vane compressors
- $\_a = 0.80$ for single stage centrifugal compressors
- $\_a = 0.70$ for multi-stage centrifugal compressors
- $\_a = 0.70$ for turbo blowers
- $\_a = 0.62$ for Roots blowers

Air Leaks – Anticipated Savings

- The demand reduction, *DR*, energy conservation, *EC*, and total cost savings, *TCS*, attributed to repairing air leaks are calculated using the following equations:

$$DR = L \square C_1 \square CF$$

$$EC = L \square H \square C_1$$

$$TCS = (DR \text{ x effective demand rate x } C_5) + (EC \text{ x effective energy rate})$$

Air Leaks – Anticipated Savings

L – power loss due to air leak, hp

DR – demand reduction, kW/mo

CF – coincidence factor

EC – annual energy conservation

H – annual time during which leak occurs, h/yr

C_5 – number of months per year equipment contributes to the peak demand, generally this constant is 12 months/yr

Air Leaks – Sample Problem

Location	Leak Diameter (inches)	Number of leaks
Air Hammer	1/8	1
Machine Nozzle	1/32	2
Grinder	1/8	2

Calculate the potential annual cost savings if the leaks are repaired. If each leak costs $50 to fix, estimate the simple payback period.

Given:

Operating hours = 8,760 hr/yr
Air temperature at compressor inlet = 75 °F
Air temperature at point of leak = 75 °F
Compressor operating pressure = 110 psig
Compressed air line pressure = 105 psig
Effective demand rate = $10.00 / kW
Effective energy rate = $0.05 / kWh

Air Leaks – Problem Solution

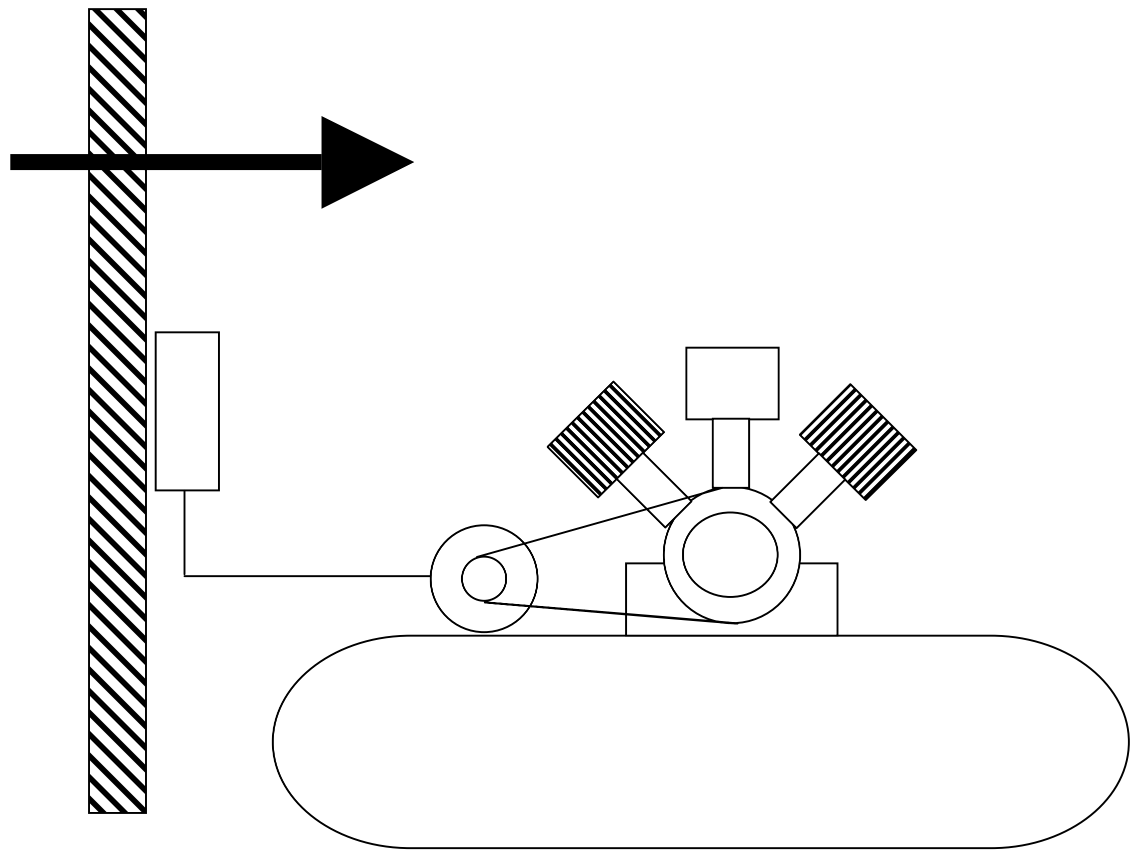
DR = [(3.2 kW/mo)(3)+(0.2 kW/mo)(2)] = 10 kW/mo

EC = ((3.2 kW)(3)+(0.2 kW)(2))(8,760 hr/yr) = 87,600 kWh/yr

TCS = (10 kW/mo)($10/kW)(12 mo/yr) +
(87,600 kWh/yr x $0.05/kWh) = $5,580/yr

5 leaks x $50/leak = $250; simple payback is less than one month

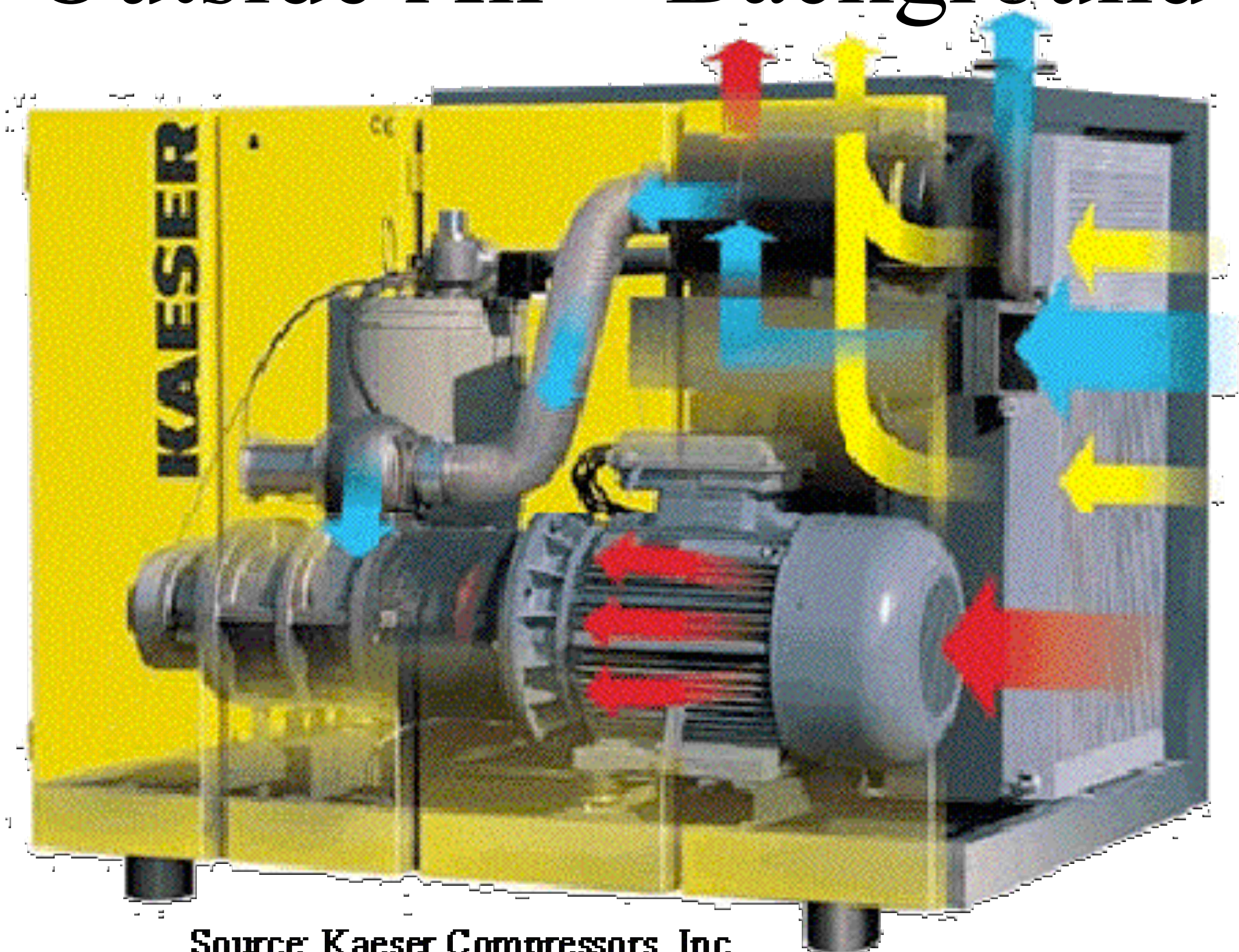
Use Outside Air For Compressor Intakes



Outside Air – Background

- Heat given off by the compressor warms intake air
- Use cooler outside air as the supply
- Outside air is cooler and denser than indoor air
- Less work is required
- Energy requirements can be reduced

Outside Air – Background



Source: Kaeser Compressors, Inc.

Outside Air-Anticipated Savings

The fractional reduction in compressor work:

$$WR = \frac{WI - WO}{WI} \quad \text{or} \quad WR = \frac{TI - TO}{TI + 460}$$

The annual energy conservation:

$$EC = P \times H \times WR$$

The power drawn by the compressor:

$$P = \frac{LF \times HP \times C_1}{\varsigma_m}$$

Outside Air-Anticipated Savings

WR – fractional reduction in compressor work, no units

WI – work of compressor with inside air, hp

WO – work of compressor with outside air, hp

TI – average temperature of inside air, °F

TO – annual average outside air temperature, °F

P – power drawn by compressor, kW

H – hours per year of compressor operation, h/yr

LF – load factor

HP – horsepower rating of the air compressor, hp

C_1 – conversion constant, 0.746 kW/hp

$\_{m}$ – compressor motor efficiency

Outside Air – Sample Problem

A 200 hp screw compressor is located along the north wall of the plant in an isolated room next to an insulated wall. The average ambient air temperature in the room is 90°F. The plant is located in a rural area where the average outside temperature is 50°F. The compressor is constantly loaded to supply the plant compressed air requirements. The compressor operates 24 hours/day, 7 days/week.

At an installed cost of $500, would it benefit the plant to duct outside air to the intake of the plant air compressor? If so, estimate the energy cost savings.

Given:
Loaded efficiency = 90%
Load factor = 0.8
Effective demand rate = $10.00 / kW
Effective energy rate = $0.05 / kWh

Outside Air-Problem Solution

$$WR = \frac{90 - 50}{90 + 460} = 0.073$$

P = (0.80)(200 hp)(0.746 kW/hp) / (0.90) = 133 kW

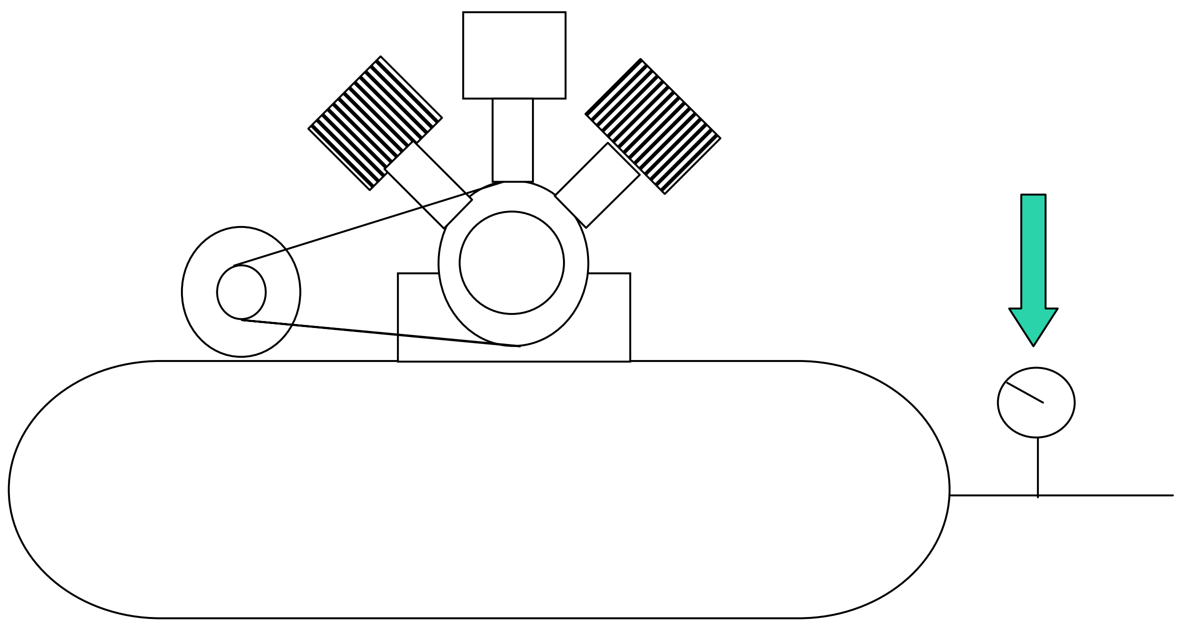
EC = (133 kW)(8,760 hr/yr)(0.073) = 85,051 kWh/yr

DR = (133 kW/mo)(0.073) = 9.7 kW/mo

TCS = (85,051 kWh/yr)($0.05/kWh)+(9.7 kW/mo)(12mo/yr)($10/kW) = $5,417/yr

Simple Payback = ($500)/($5,417/yr) = 0.1 years

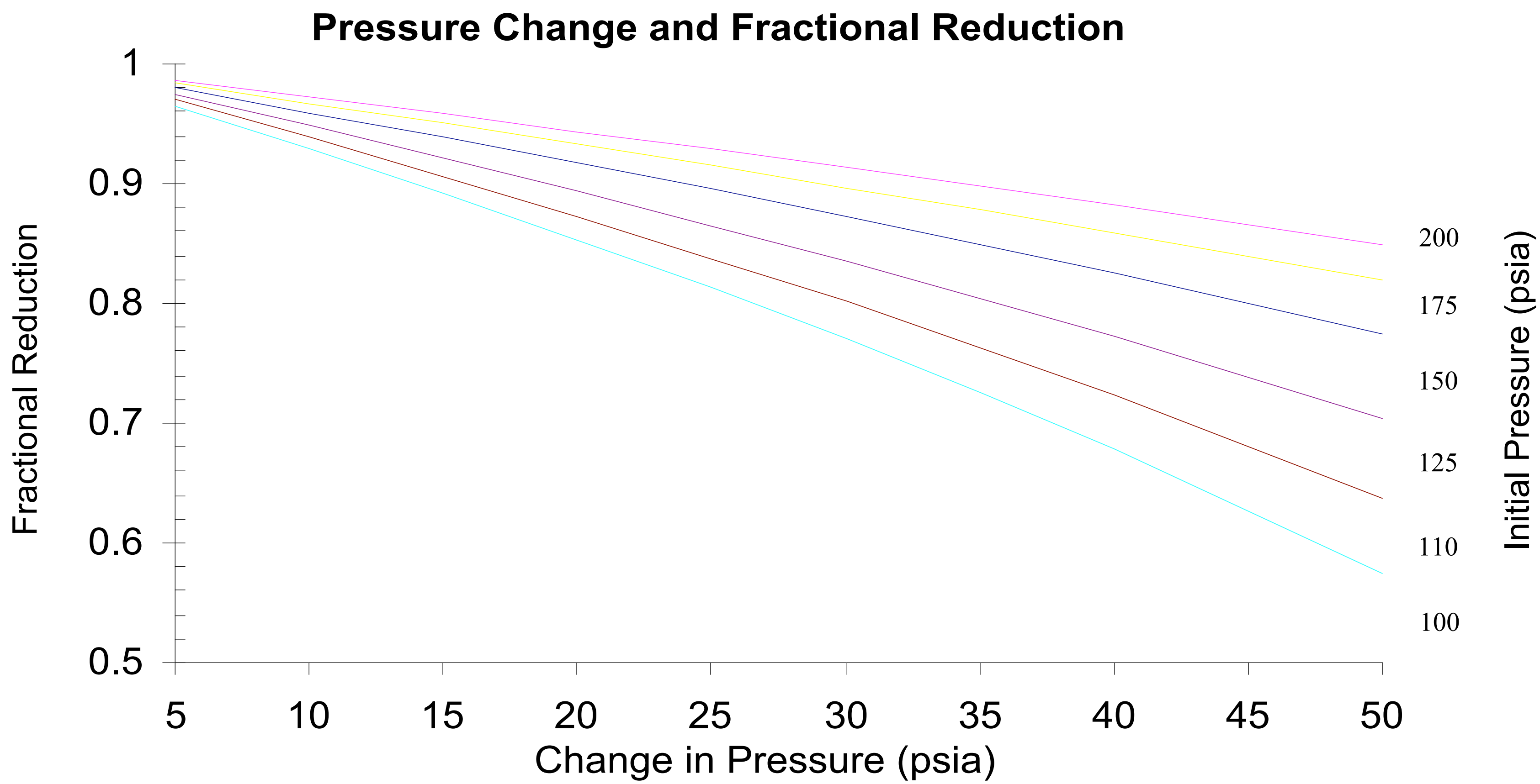
Reduce Compressor Air Pressure



Air Pressure – Background

- Air compressed to higher pressure than required
- Demand and energy savings can be realized
- Pressure control setting can easily be lowered
- Plant personnel should lower in 5 psig increments

Air Pressure – Background



Air Pressure – Anticipated Savings

$$EC = \frac{(1 - FR) \times HP \times LF \times UF \times C_1 \times H}{\text{ç}_m}$$

$$ECS = EC \times (\text{effective energy rate})$$

$$DR = \frac{(1 - FR) \times HP \times LF \times C_1 \times CF}{\text{ç}_m}$$

$$DS = DR \times C_5 \times (\text{effective demand rate})$$

$$TCS = ECS + DS$$

Air Pressure – Anticipated Savings

FR – fractional reduction, ratio of proposed to current power consumption

UF – usage factor

H – hours per year of compressor operation, h/yr

LF – load factor

HP – horsepower rating of the air compressor, hp

C_1 – conversion constant, 0.746 kW/hp

$\_m$ – compressor motor efficiency

ECS – energy cost savings, $/yr

CF – coincidence factor

DS – demand savings, $/yr

Air Pressure – Anticipated Savings

$$\text{Fractional Reduction} = \frac{\left(\frac{P_{dp}}{P_i}\right)^{\frac{(k-1)}{(k \cdot N)}} - 1}{\left(\frac{P_{dc}}{P_i}\right)^{\frac{(k-1)}{(k \cdot N)}} - 1}$$

Air Pressure – Anticipated Savings

P_{dp} – discharge pressure at proposed operating pressure, psia

P_{dc} – discharge pressure at current operating pressure, psia

P_i – inlet (atmospheric) pressure

k – specific heat ratio of air, 1.4, no units

N – number of stages, no units

Air Pressure - Sample Problem

The air compressor is currently set to operate at 150 psia; the pressure at the furthest point from the air compressor is 140 psia. An equipment survey indicated that all of the equipment using compressed air requires no more than 100 psia to operate effectively. The air compressor is loaded 25% of the time and operates 12 hours/day, 7 days/week.

What new compressor air pressure would you recommend? What are the horsepower reduction factor, energy conservation, energy cost savings, demand reduction, and demand cost savings?

Given: Compressor horsepower = 100 hp
Load factor = 0.8
Air compressor efficiency = 90%
Effective demand rate = $10.00 / kW
Effective energy rate = $0.05 / kWh

Air Pressure – Problem Solution

- Assume New Recommended Compressed Air Pressure of 110 psia

EC = (1 – 0.84)(100hp)(0.8)(0.25)(0.746 kW/hp)(4,368 h/yr)/(0.90)

EC = 11,586 kWh/yr

ECS = (11,586 kWh/yr)($0.05/kWh) = $579/yr

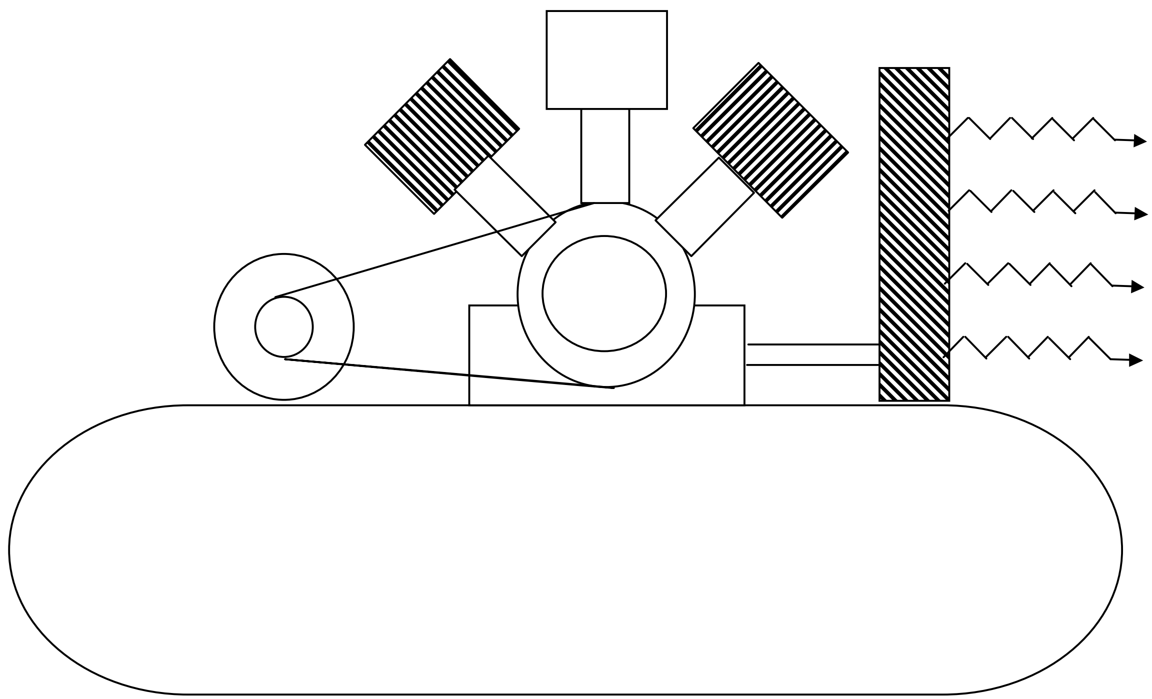
DR = (1 – 0.84)(100 hp)(0.8)(0.746 kW/hp)(1)/(0.90)

DR = 10.6 kW/mo

DS = (10.6 kW/mo)(12 mo/yr)($10.00/kW) = $1,272/yr

TCS = $579 + $1,272 = $1,851/yr

Recover Compressor Waste Heat



Waste Heat – Background

- 80-93% of electrical energy used is converted into heat
- Heat recovery unit recovers 50-90% of thermal energy
- Typical uses for recovered heat include:
  - supplemental space heating
  - industrial process heating
  - water heating
  - makeup air heating
  - boiler makeup water preheating

Waste Heat – Background

- Heat recovery with air-cooled rotary screw for space heating is very common and easy
- Heat can be extracted from lubricant coolers in water-cooled reciprocating or rotary screw units for hot water
- Heat recovery for space heating with water-cooled reciprocating units is not as common

Waste Heat – Anticipated Savings

$$EC = \frac{\square \times Q \times C_p \times C_6 \times (T_e - T_r) \times HH}{ç}$$

$$ECS = EC \square (\text{effective energy rate})$$

Waste Heat – Anticipated Savings

_ – density of air at exhaust temperature, lb/ft^3

Q – volumetric flow rate through exhaust fan, cfm

C_P – specific heat of exhausted air, Btu/lb°F

T_e – average exhaust temperature, °F

T_r – set-point temperature of room to be heated, °F

HH – annual hours during which heating is required, h/yr

_ – efficiency of space heating system, no units

C_6 – conversion factor, 60 min/h

Waste Heat-Sample Problem

Plant management is concerned about the rising natural gas prices and feels that steps need to be taken to reduce their natural gas consumption for the winter. Currently, the whole facility is heated using natural gas units operating at 80% efficiency with a setpoint temperature of 70ºF. You are hired to evaluate potential energy savings and notice a 100 hp air-cooled rotary screw air compressor located in an enclosed room next to the wood staining area.

Given the information below, what is the estimated energy conservation and energy cost savings from ducting compressor waste heat to the wood staining area for space heating?

Given:
- Air compressor exhaust air temperature = 135ºF
- Density of air @ 135ºF = 0.0668 lb/ft^3
- Volumetric flow rate through exhaust fan = 3,200 cfm
- Specific heat of exhausted air = 0.24 Btu/lbºF
- Annual hours during which heating is required = 1,500 h/yr
- Natural gas rate = $5.00/MCF (1 MCF = 1×10^6 Btu)

Waste Heat-Problem Solution

$$EC = \frac{(0.0668\ lb/ft^3)(3{,}200\ cfm)(0.24\ Btu/lb^\circ F)(60\ min/h)(135^\circ F - 70^\circ F)(1{,}500\ h/yr)}{0.80}$$

$$EC = 375{,}148{,}800\ Btu/yr$$

$$ECS = (375{,}148{,}800\ Btu/yr)(\$5.00/MCF)(1\ MCF/1x10^6\ Btu)$$

$$ECS = \$1{,}876/yr$$

Compressed Air Resources

- Compressed Air Challenge Program
  - www.knowpressure.org
- "Rotary screw air compressor basics", Plant Engineering, February 2000, Vol. 54, No.2
- "Cost-effective compressor selection and specification", Chemical Engineering, September 2000, Vol.107, No. 10

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- Compressed Air Systems: A Guidebook on Energy and Cost Savings, Talbott, E.M., Englewood Cliffs, NJ, 1992

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