MINISTRY OF
INDUSTRY AND TRADE

EU - VIET NAM SUSTAINABLE ENERGY
TRANSITION PROGRAMME (SETP)

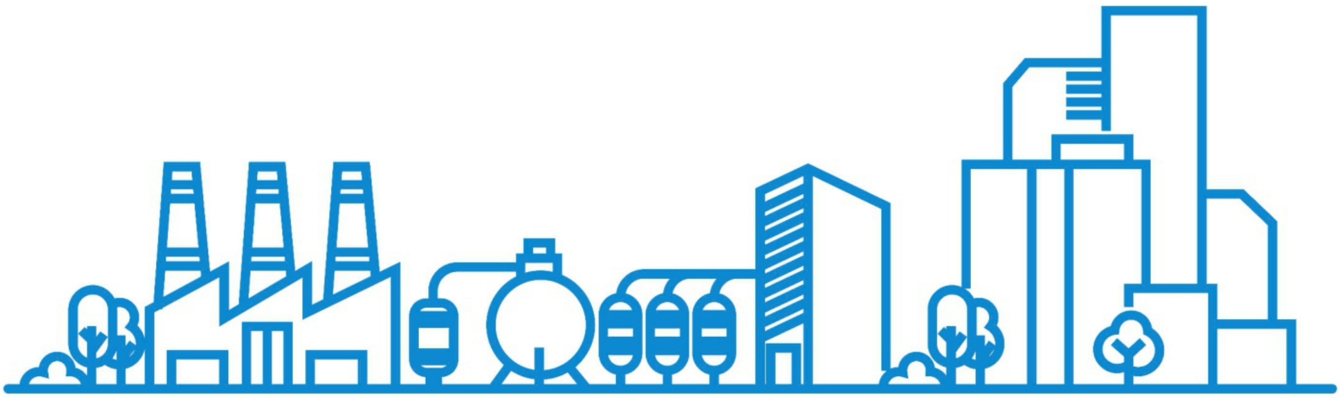
Global Gateway
Funded by
the European Union

UNIDO
UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Project "Accelerating energy efficiency (EE) in large industries through energy management system, system optimisation and the promotion and adoption of EE in SMEs" (IEEP)

VENDOR TRAINING PROGRAMME
COMPRESSED AIR SYSTEM OPTIMISATION

Ho Chi Minh, 10/06/2025



AGENDA

VENDOR TRAINING COURSE ON COMPRESSED AIR SYSTEMS – SYSTEM OPTIMISATION & NEW DEVELOPMENTS IN AIR COMPRESSORS

10 June 2025

Victory Hotel – 14 Vo Van Tan Street, Ward 6, District 3, Ho Chi Minh city

Time	Contents	Speakers
8.00-8.30	Registration and welcome	
8.30-8.35	Participants Introduction	UNIDO Project
8.35-8.45	Opening speech	MOIT/UNIDO Project
8.45-9.00	Compressed air systems optimization introduction	International Expert
9.00-9.30	Energy efficient compressed air system design	International Expert
9.30-9.45	Air compressor types	International Expert
9.45-10.00	Control of air compressors	International Expert
10.00-10.15	**Tea break**	
10.15-10.45	Calculating the compressed air demand	International Expert & Trainees
10.45-11.15	Calculating running costs of compressed air system	International Expert & Trainees
11.15-11.30	Components behind the air compressor	International Expert
11.30-12.00	Energy saving air using devices/solutions	International Expert
12.00-13.15	**Lunch at the Hotel**	

Compressed Air Systems

System Optimisation & New Developments in Air Compressors

Ian Moore CEng FIMechE – Technical Director

Experience…

Qualifications

BEng	1999
CEng MIMechE	2011
CEng FIMechE	2021

Experience

Carbon Trust	2005 – 2011
GSK	2012 – 2015 –
Intel	2003 –
UNIDO	2015 –

Optimizing compressed air systems includes:

- Evaluating energy requirements in factory.
- Matching system supply to these requirements
- Eliminating or reconfiguring inefficient uses and practices
- Changing out or supplementing existing equipment to better match work requirements and increase operating efficiency

Compressed Air Systems

- Most compressed air systems are initially designed with:
  - The assumption that "more" is better, where supply is concerned
  - Little or no thought given to system efficiency
  - No plan for increases or decreases in system demand
  - A "lowest first cost" goal

Compressed Air Systems

- **Energy awareness must start at the corporate management level for large corporations**
- **Energy awareness must start with the owners of SME's**
- **Operating culture must change and that change must be from the top down**
- **Changing company culture involves all employees**

MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Compressed air systems can be divided into supply and demand

- Supply involves
  - compressors
  - treatment systems
  - distribution networks
- Demand includes
  - Processes – (vendors must understand them)
  - point of use regulation
  - all using devices
  - leakage

Why use compressed air?

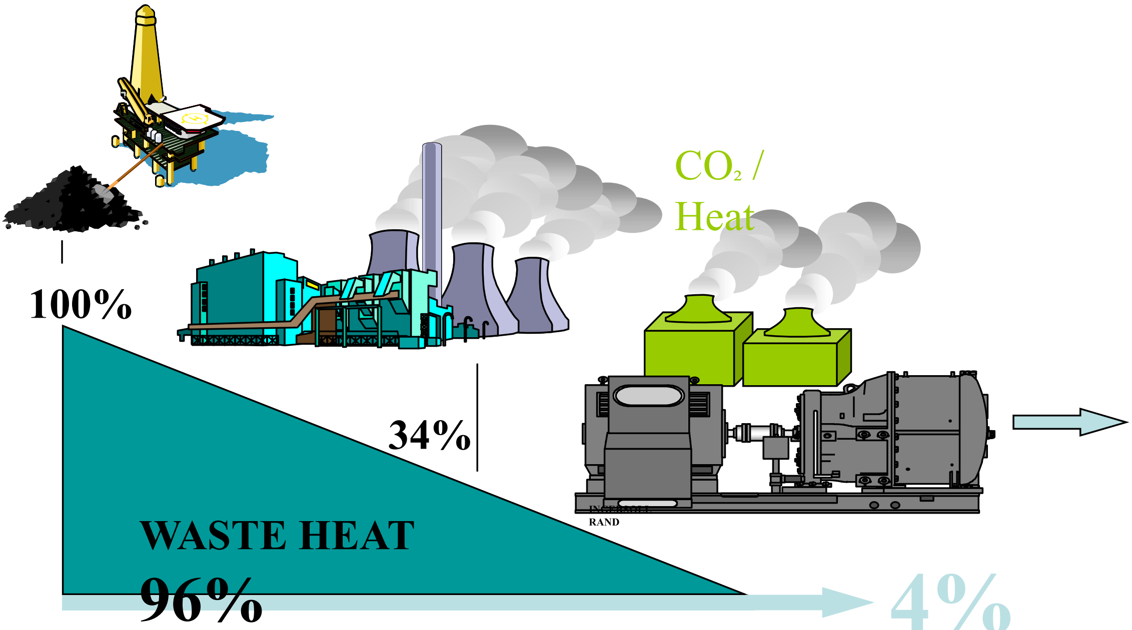
Because people think that it is :

- Cheap
- Safe
- Convenient
- New equipment can easily be connected anywhere on the existing system

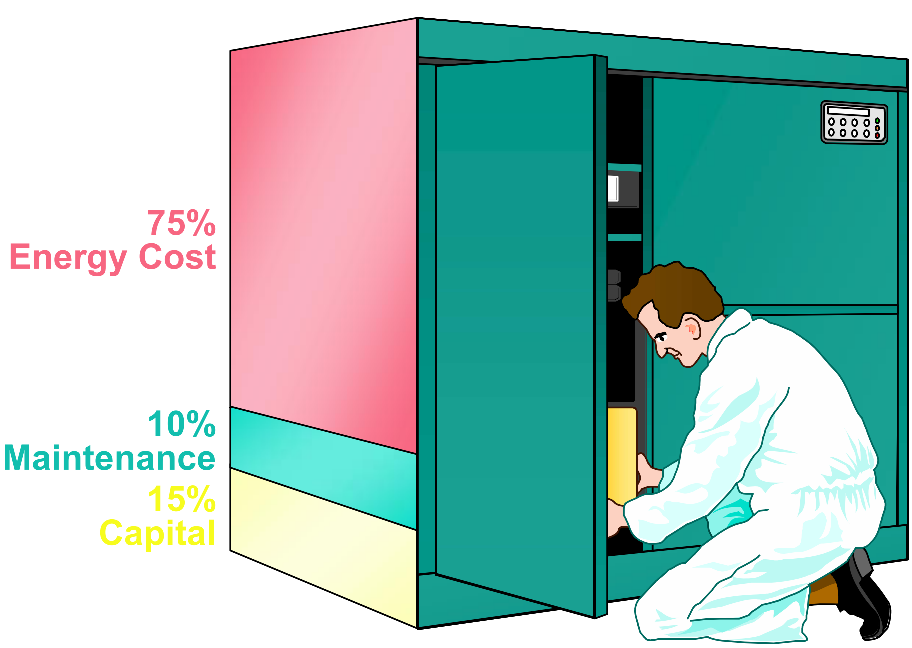
Compressed Air - The Facts

- 10% of industrial electricity is typically used to produce compressed air
- In Vietnam this equates to around VND2,610,000,000,000
- On average 30% can be saved some at little or no cost this equates to 250,500 Tonnes CO_2
- Compressed Air is necessary in most industries but its NOT free - it’s an expensive resource - don’t let your customers waste it

THE ENERGY TRAIN



Compressor life cycle costs



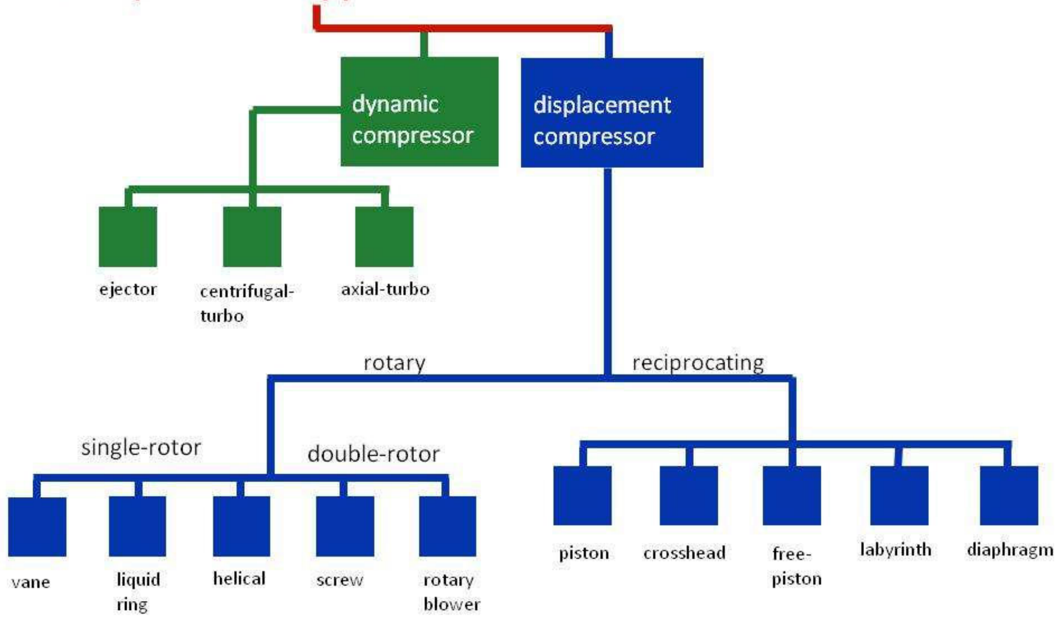
What constitutes a best practice system?

- Compressors well matched to the demand and well controlled
- Compressors are efficient and well maintained
- Treatment is to the minimum required standard
- Dryers are running efficiently
- Condensate is collected and treated correctly
- Piping correctly sized in all areas
- Operating pressure is the minimum required
- Pressure drop is <0.5 bar in compressor house
- Pressure drop is <0.2 bar in system
- Leakage is <10% of mean demand
- Air is on only when required

Poor design

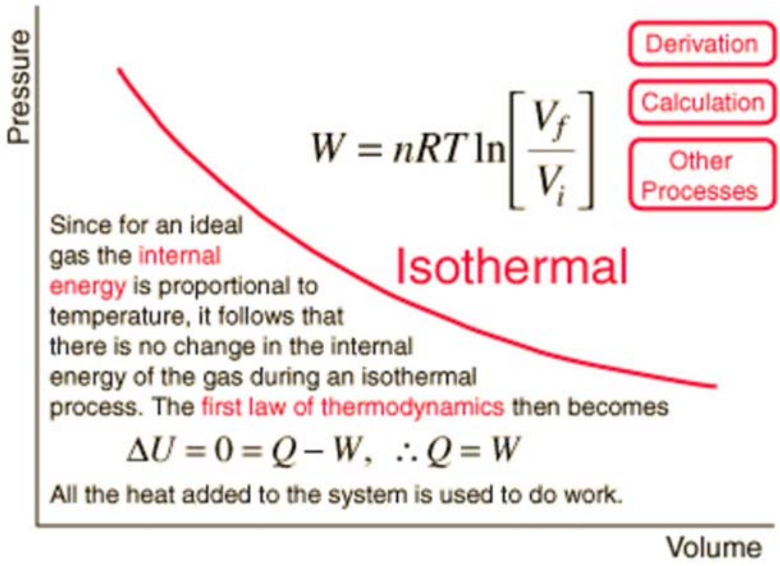
- Filter on compressor exit
- Restrictive valves
- 1 bar pressure drop on load
- Pressure equalises when off load so compressor reloads immediately

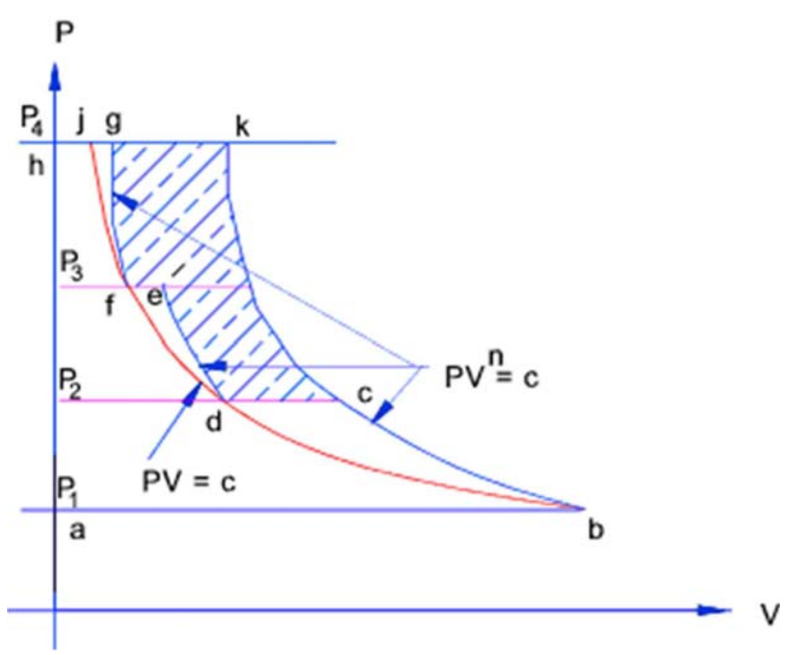
Compressor types



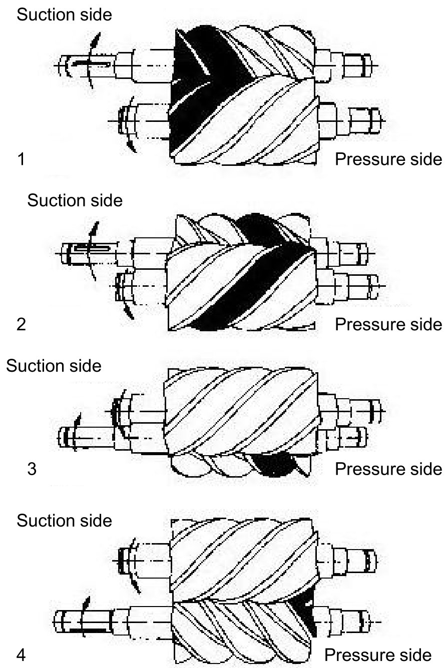
How do compressor manufacturers design
energy efficient machines
with the best possible specific power consumption (SPC)?

- By approaching isothermal compression
- Techniques
  - Multistaging
  - Cooling
  - Oil free machines
  - Oil injected machines
  - Water injected machines


Pressure
Derivation
Calculation
Other Processes
$W = nRT \ln\left[\frac{V_f}{V_i}\right]$
Isothermal
Since for an ideal gas the internal energy is proportional to temperature, it follows that there is no change in the internal energy of the gas during an isothermal process. The first law of thermodynamics then becomes
$\Delta U = 0 = Q - W, \quad \therefore Q = W$
All the heat added to the system is used to do work.
Volume


P
P_4
j
g
k
h
P_3
f
e
$PV^n = c$
P_2
c
d
PV = c
P_1
a
b
V

The oil injected screw compressor

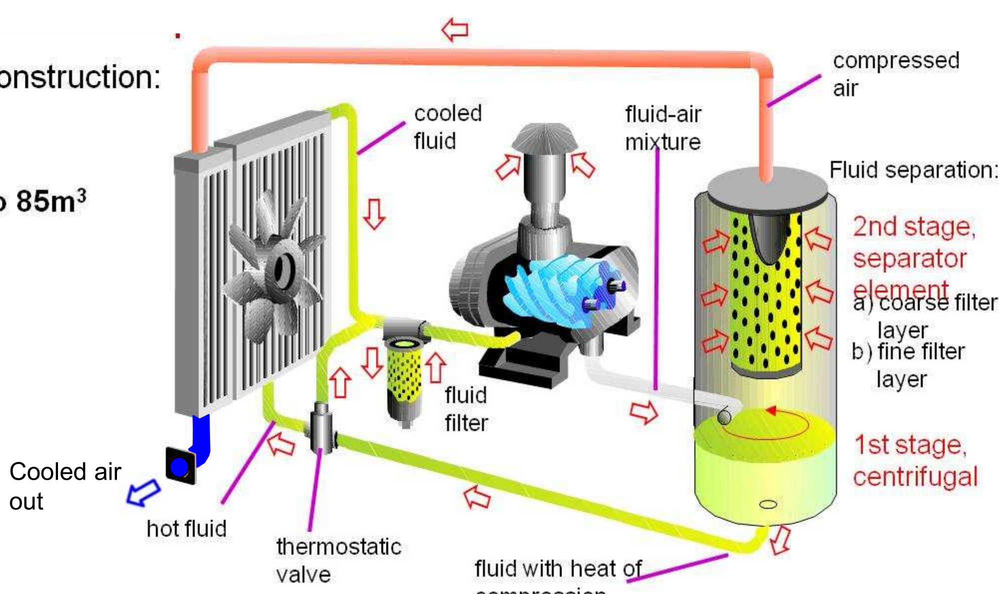


Oil injected – single and two stage

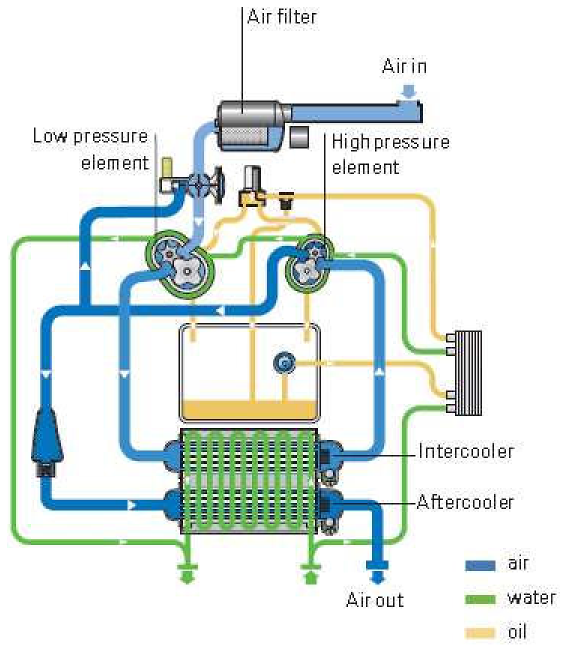
Oil injected screw compressor

Construction:

Up to 85m³

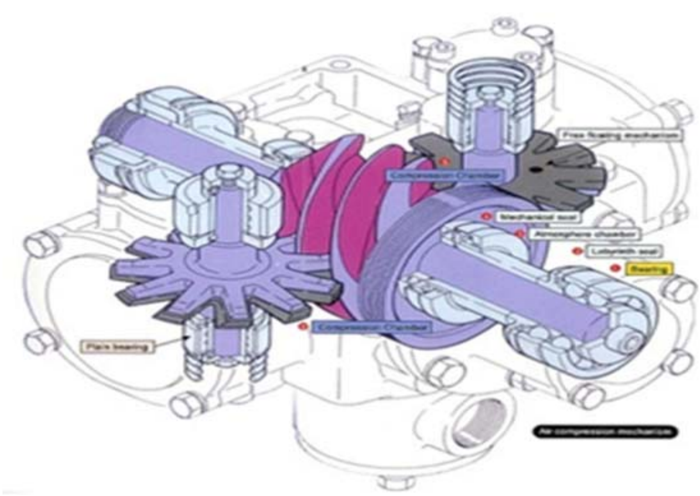


Oil free screw compressor



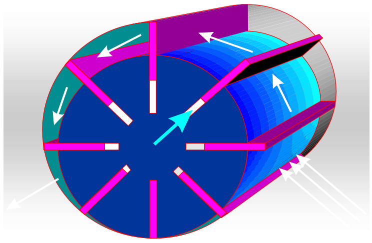
MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

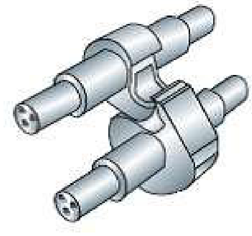
Water injected screw with RO filter other types
use condensate from built in refrigerated air dryers



Other Displacement Compressor types

- **Rotary vane**
- **Toothed Rotor**





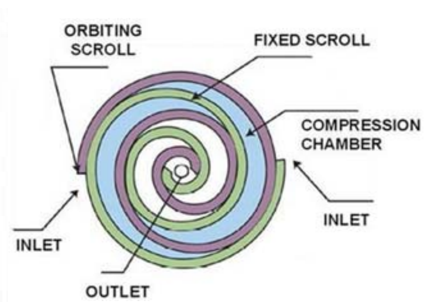
MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Single stage centrifugal compressor with magnetic bearings
for low pressure applications

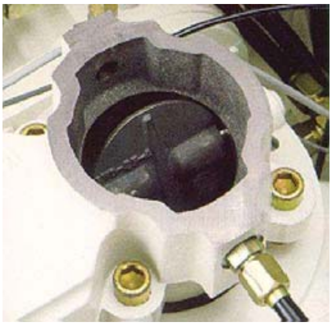
Small centrifugal compressor for 7 – 10 barg

- VSD centrifugal compressor
- 2 stage
- Single high speed magnetic bearing drive motor
- Impellers mounted directly on drive motor shaft: no gearbox, no oil
- Both impellers on one drive shaft
- Water-cooled only

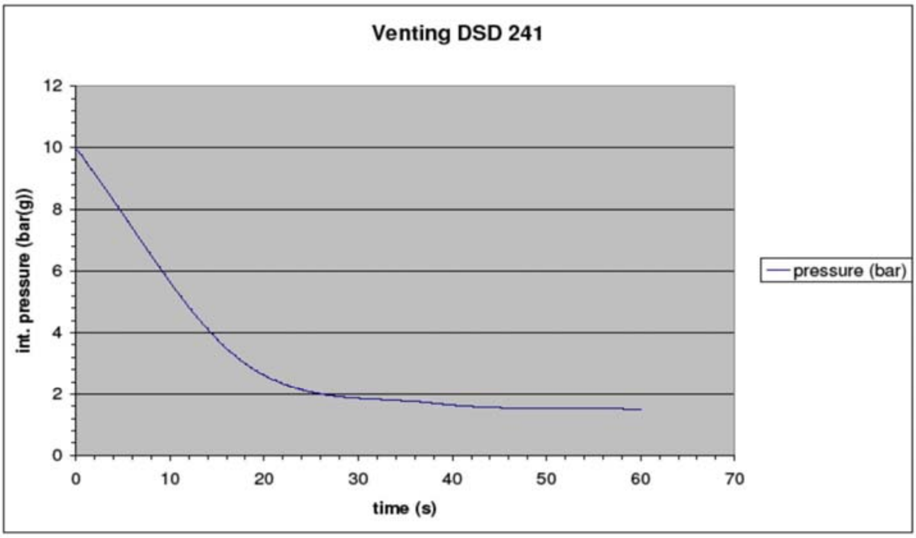
Oil free rotary scroll compressors



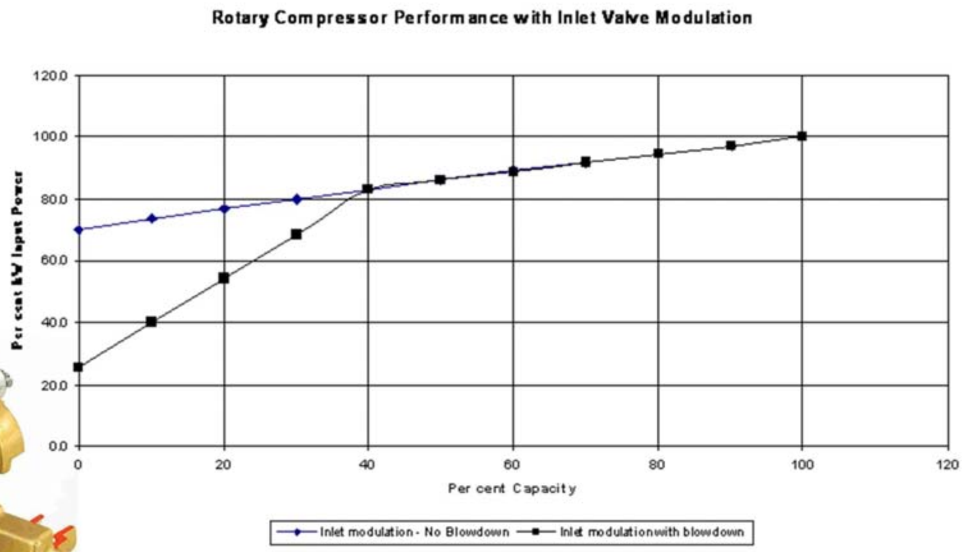
Compressor control – on/off load

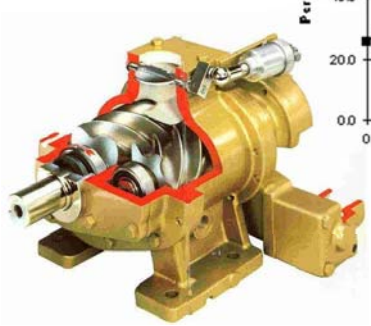


Unloading Power Time



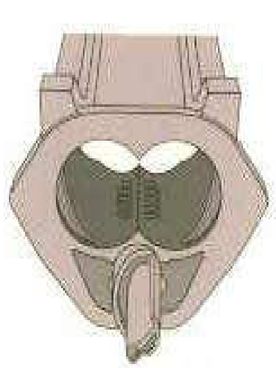
Compressor control – inlet modulation

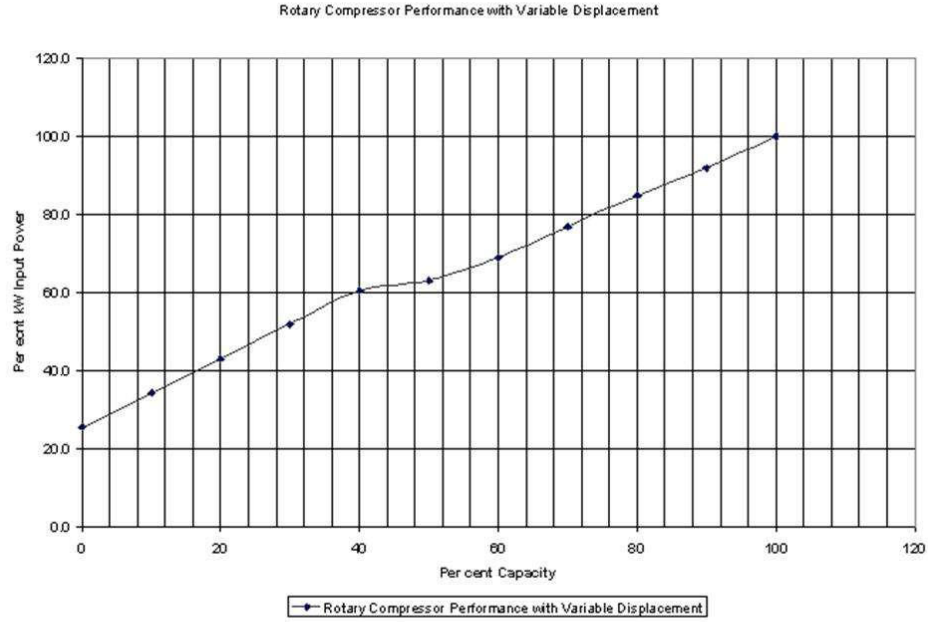




MINISTRY OF INDUSTRY AND TRADE Global Gateway UNIDO

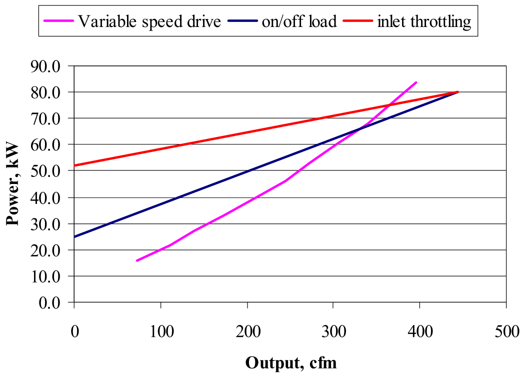
Compressor control – variable displacement





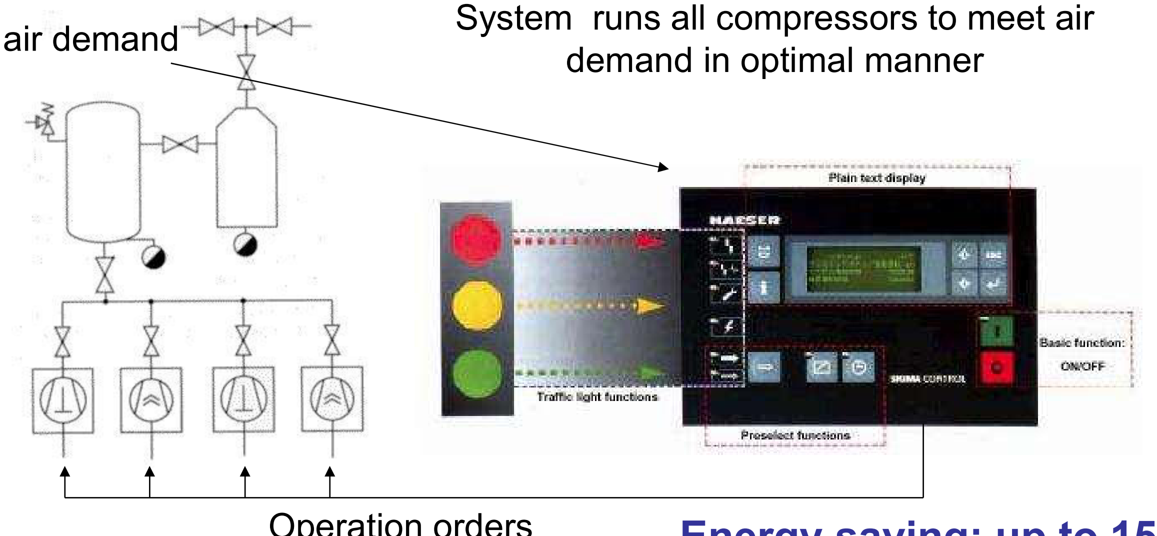
Control of compressors

- Only minimum required compressors should be on line
- How do the compressors control? – on/off, modulate, blow off
- Understand how they will interact with each other
- Consider a group control system
    - Minimise pressure band
- Auto shut down should be working to minimise long periods of no load running
- Can a variable speed drive machine be used?



Group control system

System runs all compressors to meet air demand in optimal manner

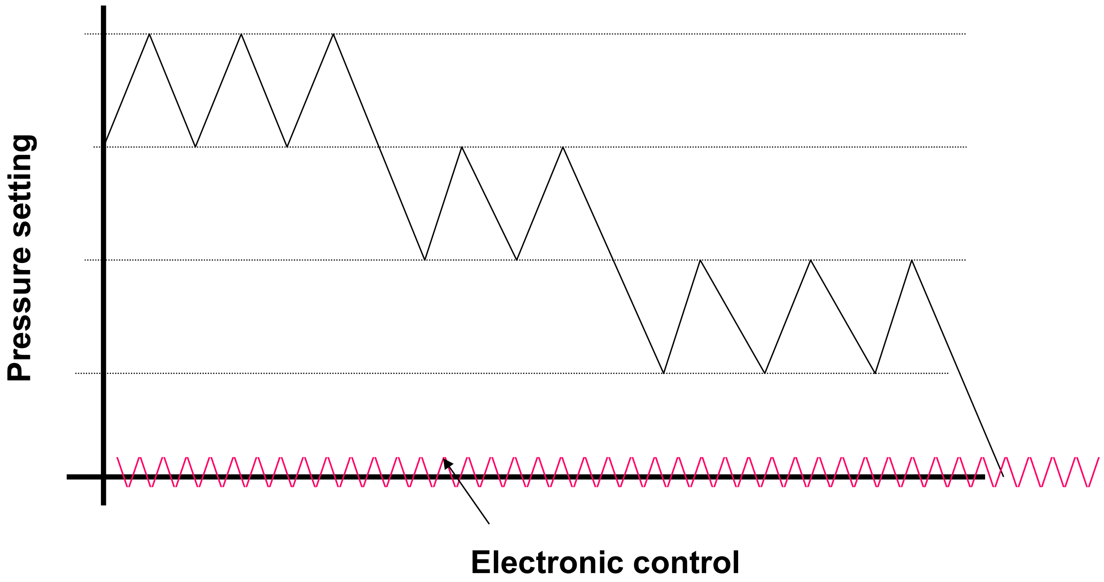


Energy saving: up to 15%

Group Control

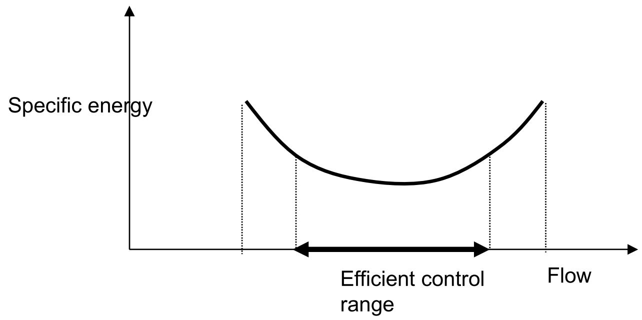
- To provide simple control of groups of compressors
  - Sequential switching and duty rotation
  - Turning off machines when not needed
- To provide targeting and monitoring information
  - SPC of compressor installations
  - Base leakage figures
- To control zone isolation valves
- To reduce generation pressure during non-production hours
- To provide maintenance information

Normal sequential control versus electronic control
Pressure versus demand



Variable speed drive limitations

Screw with variable speed Drive



- Different sizes have different control ranges
- Oil injected has larger turndown than oil free
- Not all manufacturers are the same

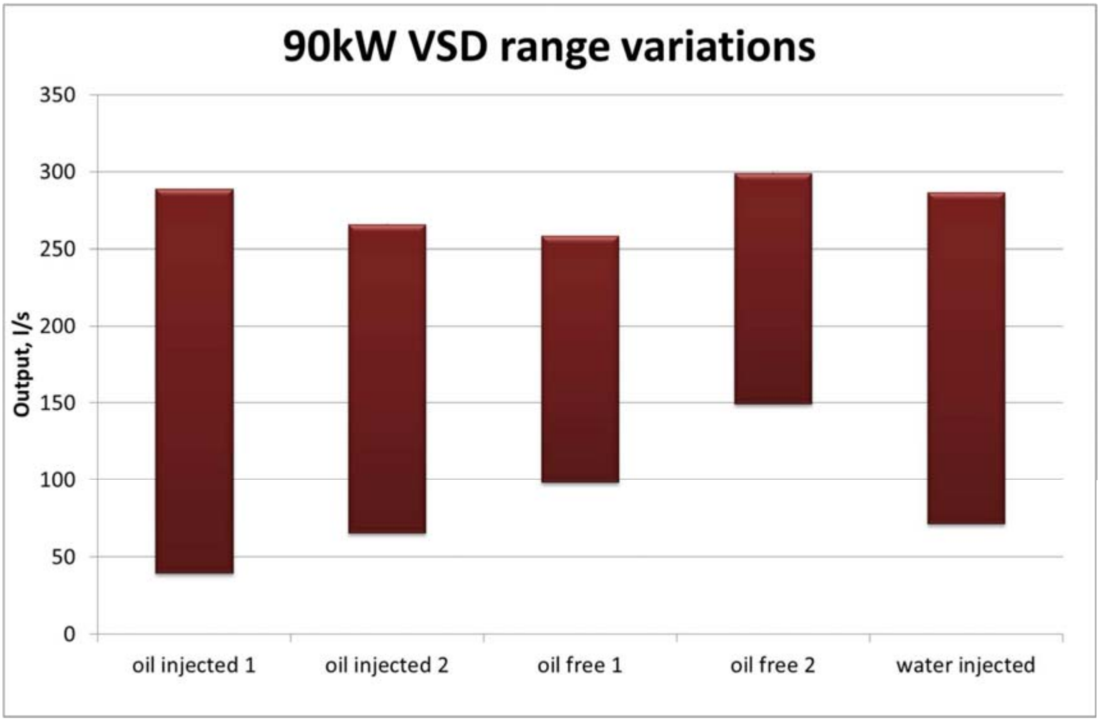
VSD compressors

✓ Size compressor to cover demand range

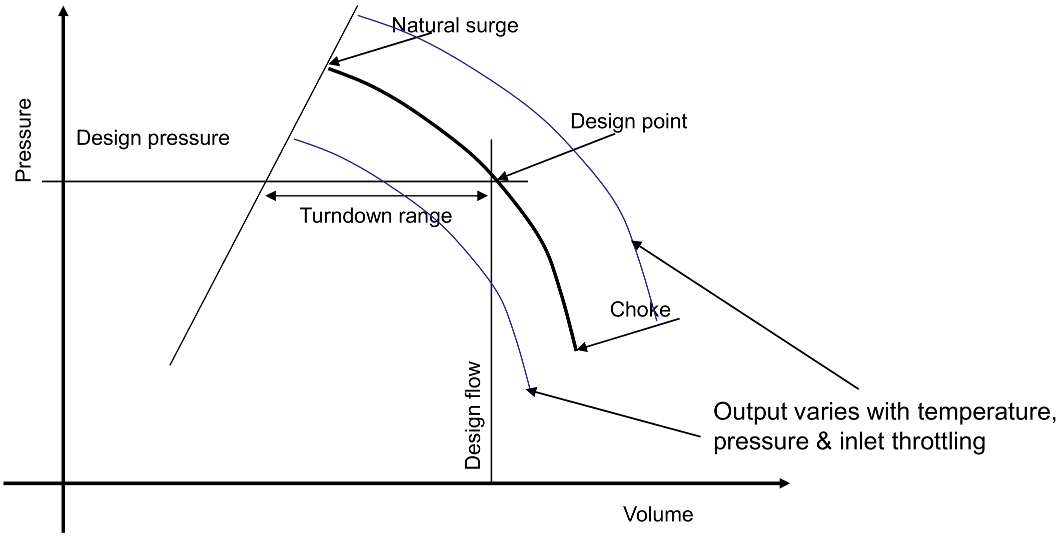
✓ Avoid control gaps

✓ Maximise running at mid range speeds

✓ Remember not all VSDs offer the same performance range



Centrifugal Compressor control range



Inlet conditions

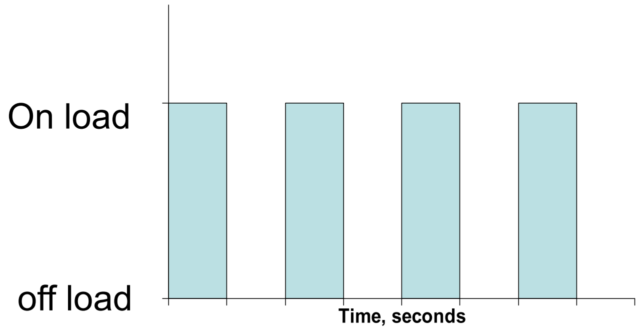
- Flow meter readings normally given at set conditions eg scfm, Nm^3/hr:
  - Standard – 1013 mbarA, 15C, 0%RH
  - Normal – 1013 mbarA, 0C, 0%RH
- Compressor outputs usually free air delivered at 1000 mbarA, 20C, 0%RH for screw compressors, different for centrifugal
- Corrections required between the two sets of data (can be over 15% difference)

The effect of inlet conditions

Inlet conditions	FAD	Nm^3/hr	Scfm	Comments
1000 mbarA, 20C, 60%RH	1000 m^3/hr 589 cfm	915 Nm^3/hr 91.5%	568 scfm 96.4%	Cold Asia
980 mbarA, 35C, 70%RH	**1000** m^3/hr 589 cfm	**845** Nm^3/hr **84.5%**	525 scfm 89.1%	Warm Asia
780 mbarA, 35C, 80%RH	1000 m^3/hr 589 cfm	670 Nm^3/hr 67%	416 scfm 70.6%	Mexico City

A 1,000 m^3/hr compressor will only deliver 845 Nm^3/hr at certain conditions
You need to know the inlet conditions to know if the compressor is performing correctly

No meters? - Calculating the demand



Average load = Time on load / Total cycle time

Repeat during non production time to estimate leakage
Isolate areas to split up base demand

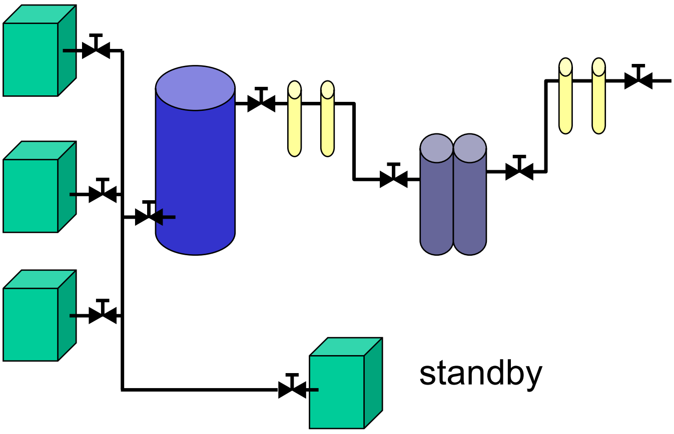
May not allow you to size a new compressor but will help you understand the system

Calculating the demand

450 cfm, 75 kW base load

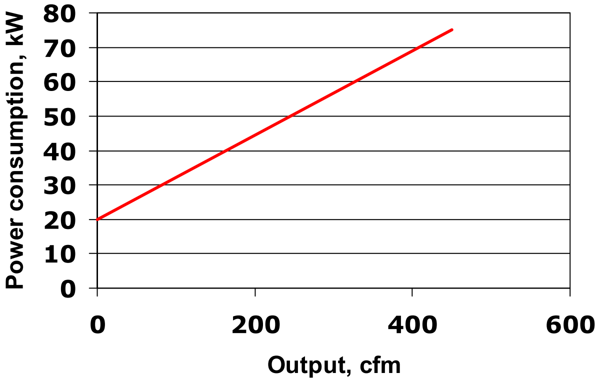
450 cfm, 75 kW base load

450 cfm, 75 kW on/off load



Calculating running costs

Typical screw compressor control characteristic



Full load = 75 kW, 450 cfm

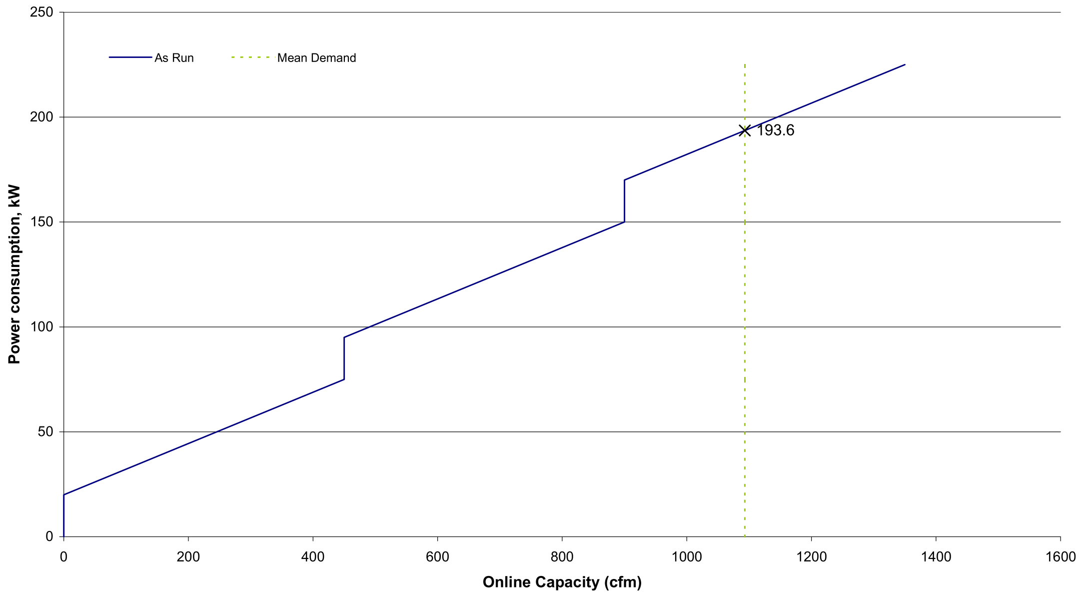
No load = 20 kW =26.66% of full load but 0 cfm

Timing calculation

Average time on load = 30 seconds
Average time off load = 40 seconds
Average loading = 30/70 = 43%

Demand = 450+450+(450*43%)
= 1094 cfm

Calculating generating costs



Demand Vs power consumption

3 off 75kW compressors

2 base load = 900 cfm, 150 kW
1 on/off load = 193 cfm, 43.6 kW

Output	450 cfm
Full load Power	75 kW
No load power	20 kW

Power = full load power + no load power
= 75*0.43 + 20*0.57
= 32.1 +11.4
= **43.6 kW**

Total power consumption 193.6 kW

Total annual running cost

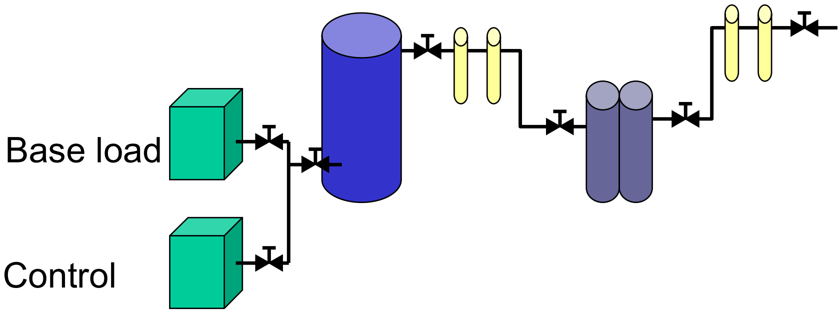
Production hours = 80 hours/week, 52 weeks/year

@ D3000/Kwh
Production cost = 193.6*80*52*3000 = VND2,416,128,000

Exercise - you calculate the annual air costs of this system

Compressors:
400 m3/hr
50 kW on load
20% no load power

600 m3/hr demand



16 hours a day
5 days a week
50 weeks a year
Electricity cost – VND3000/kWh

What is the annual operating cost?

Total annual running cost

Hours = 16 x 5 x 50 = 4000 hours/year

Base load = 400 m3/hr so, 50 kW x 4000hrs = 200,000kWh
= 200,000kWh x 3000 = **VND600,000,000**

Control = (600-400)/400 = 50% load, 50% no load
Full load = 50 x 4000hrs x 50% =100,000kWh
No load = 10 x 4000hrs x 50% =20,000kWh

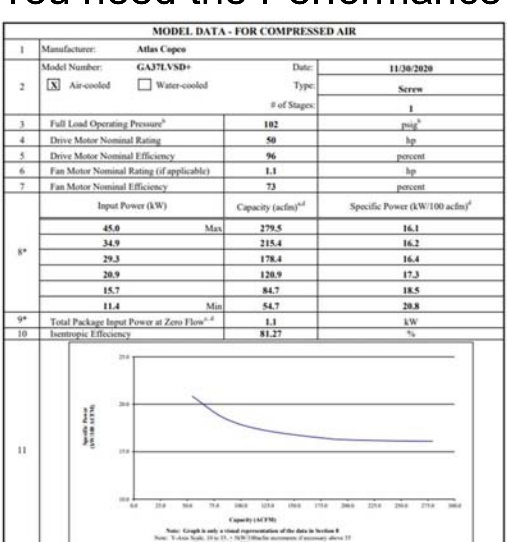
Total control = (100,000 x 3000) + (20,000 x 3000)
300,000,000 + 60,000,000 = **VND360,000,000**

Total compressor house = 600,000,000 + 360,000,000 = **VND960,000,000**

Session 2 slide 14

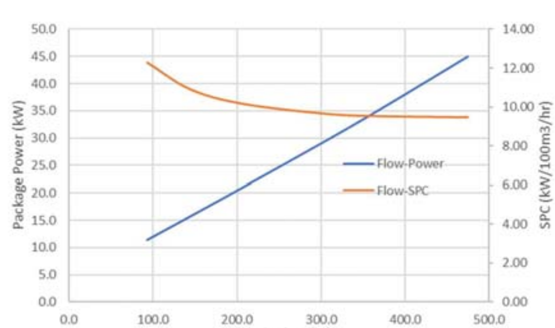
What about VSD Machines?

You need the Performance Data – See CAGI datasheets



MODEL DATA - FOR COMPRESSED AIR

1	Manufacturer: Atlas Copco		
2	Model Number: GA37LVSD+ / [X] Air-cooled [ ] Water-cooled	Date:	11/30/2020
		Type:	Screw
		# of Stages:	1
3	Full Load Operating Pressure	102	psig
4	Drive Motor Nominal Rating	50	hp
5	Drive Motor Nominal Efficiency	96	percent
6	Fan Motor Nominal Rating (if applicable)	1.1	hp
7	Fan Motor Nominal Efficiency	73	percent
8*	Input Power (kW)	Capacity (acfm)	Specific Power (kW/100 acfm)
	45.0 Max	279.5	16.1
	34.9	215.4	16.2
	29.3	178.4	16.4
	20.9	120.9	17.3
	15.7	84.7	18.5
	11.4 Min	54.7	20.8
9*	Total Package Input Power at Zero Flow	1.1	kW
10	Isentropic Effeciency	81.27	%
11			



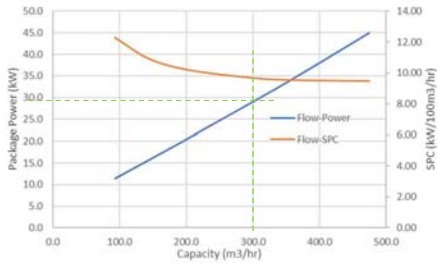
Can select power manually from data or use linear interpolation in excel
(can provide template for modification)

Session 2 slide 15

What about VSD Machines?

Demand is 600m3/hr using 2 equally sized machines

Each machine delivers 600/2 = 300m3/h



Power required at 300m3/hr = ~29kW

Total Power = 2 x 29kW = 58kW

58kW x 4,000hrs = 232,000kWh

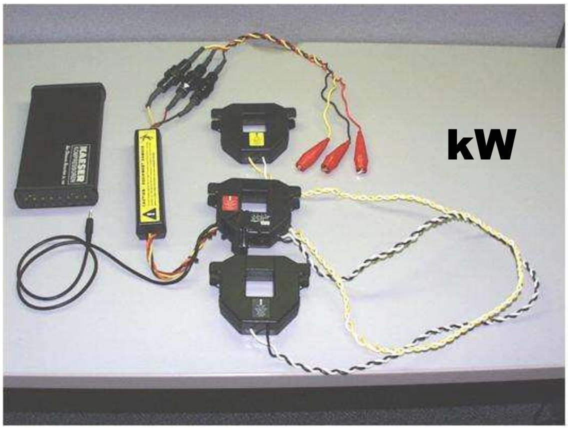
232,000kWh x 3,000VND = **696,000,000VND**

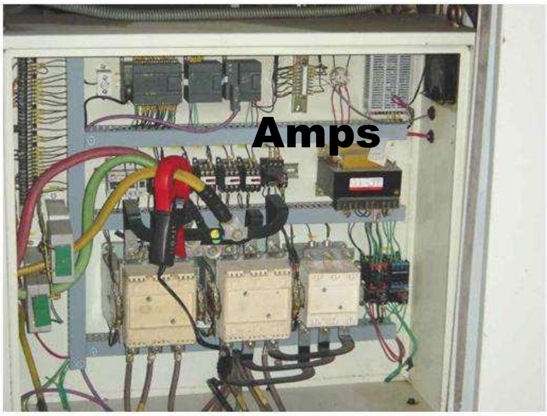
Session 2 slide 16

MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNIDO

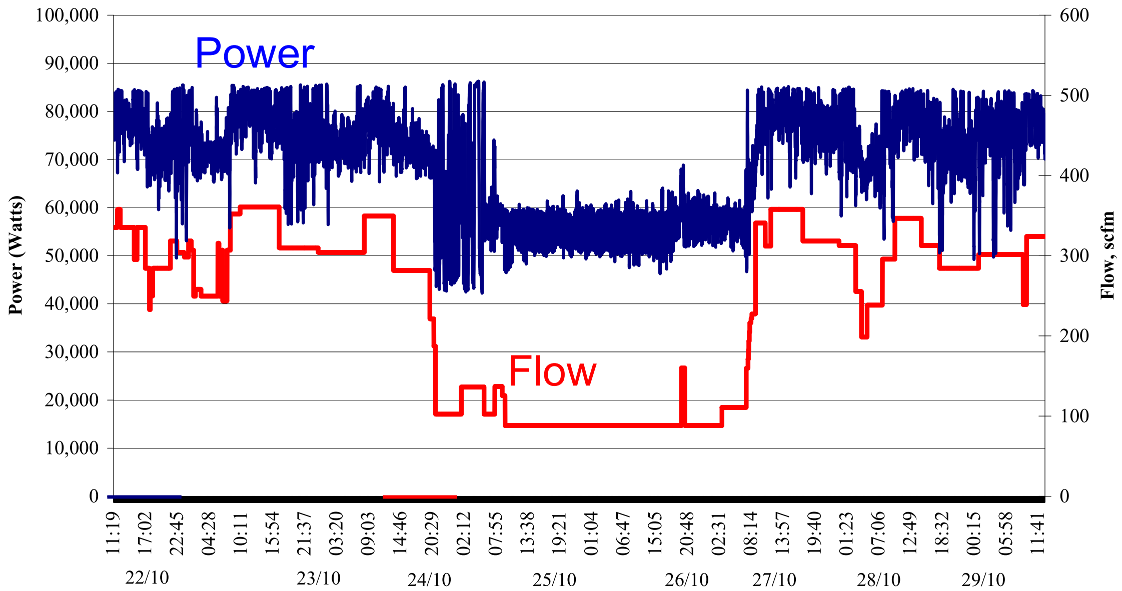
Power metering

- kW is the preferred measurement for power
- Amps can provide valuable information but power factor can be very low when off load (0.3-0.5)





Power metering



Compressed air treatment

Compressed air quality classes ISO8573.1:2010

Technology: Filtration Drying Filtration

Summary of ISO8573.1-2010						
Class	Particulate - Maximum number of particles per m³				Dewpoint	Oil carry over
	Particle size					
	≤0.1	0.1<d≤0.5µm	0.5<d≤1.0µm	1.0<d≤5.0µm	°C	Mg/m³
0	As specified by the equipment user or supplier and more stringent than class 1					
1	Not specified	20,000	400	10	≤-70	≤0.01
2	Not specified	400,000	6,000	100	≤-40	≤0.1
3	Not specified	Not specified	90,000	1,000	≤-20	≤1
4	Not specified	Not specified	Not specified	10,000	≤+3	≤5
5	Not specified	Not specified	Not specified	100,000	≤+7	
6	≤5 Mg/m³				≤+10	
7	5<Cp≤10 Mg/m³				Cw≤0.5g/m³	
8					0.5<Cw≤5	
9					5<Cw≤0.5	
X	Cp>10				Cw>10	>5

Sizing treatment systems

- Dryer capacities normally based on 7 barg 35C max
- Low pressure or high temperature reduces capacity
- Filters are tested at 21DegC and lose efficiency above this
- Make sure you quote at your clients conditions

MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

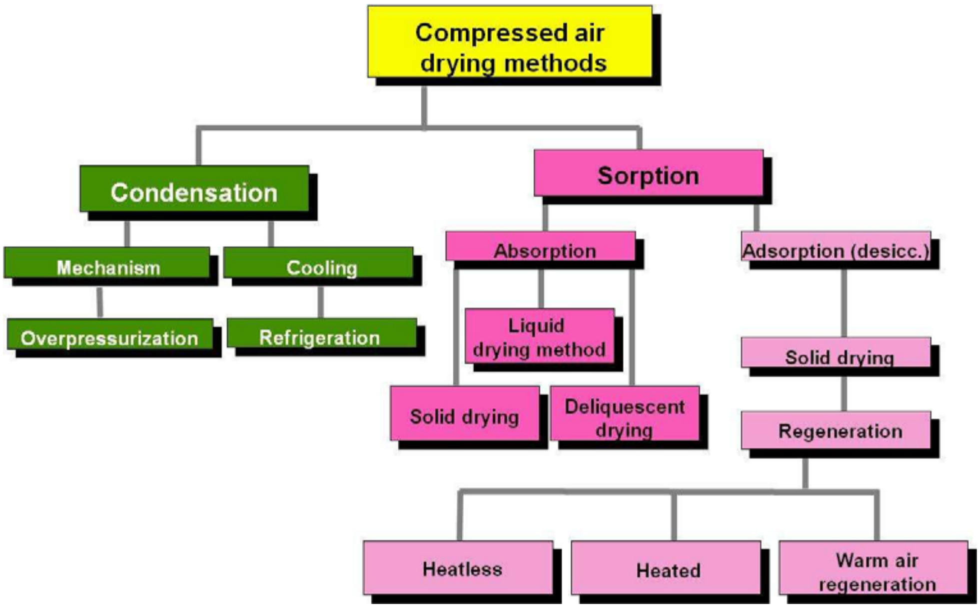
Sizing dryers

Typical correction factors

Air inlet temp, C	25	30	32	35	40	45	50
Factor	1.6	1.22	1.12	1	0.82	0.67	0.57
Inlet pressure, barg	3.5	5	7	8	10.5	14	
Factor	0.7	0.85	1	1.05	1.12	1.2	
Ambient temp, C	25	30	35	40	43		
Factor	1	0.95	0.88	0.78	0.7		

- Factors vary between manufacturers
- Choose factor for worst case condition
- Multiply factors where several vary from design

Compressed Air Drying



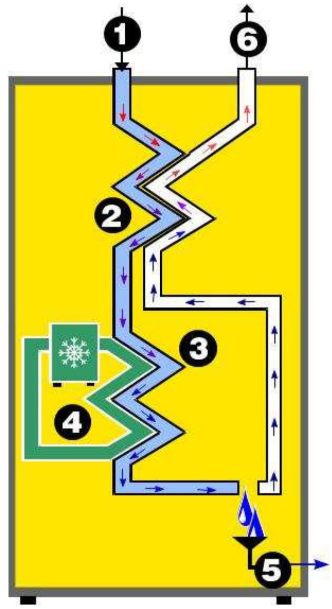
Additional Cost of Treatment

Pressure dewpoint, C	Dryer type	Filtration	Additional cost
+3	Refrigerant	General purpose	3%
-20	Waste heat regenerated	None	<1%
-40	Air regenerated	Pre & After	10-15%
-40	Heat regenerated	Pre & After	5-12%
-70	Air regenerated	Pre & After	15-21%

Incorrect sizing can significantly increase costs

Refrigeration drying

1. Air inlet
2. Air to air heat exchanger
3. Refrigerant to air heat exchanger
4. Refrigerant compressor
5. Condensate separation, automatic condensate drain
6. Compressed air outlet

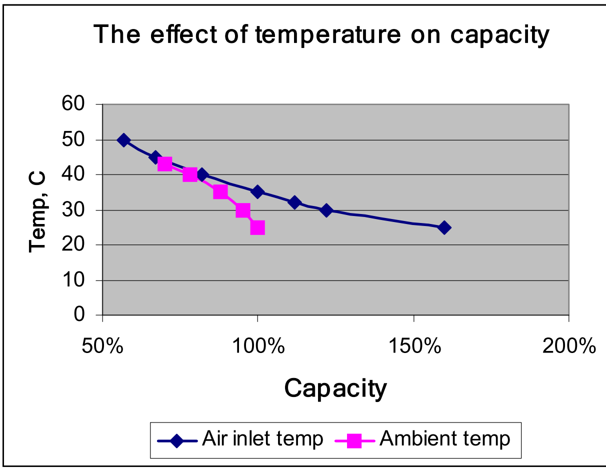


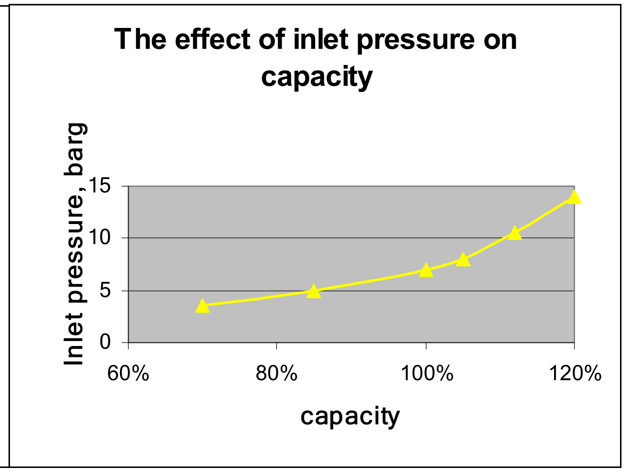
MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Refrigerant Dryers

- Rated at 35° C, 7 bar, 100% RH inlet air
- Refrigerated dryers:
  1) 3° C pressure dew point
  2) Non-cycling feature stable pressure dew point
  3) Cycling feature improved part-load power cost with fluctuating dew point
  4) Can be supplied with VSD
  5) Typical pressure drop – 0.3 bar

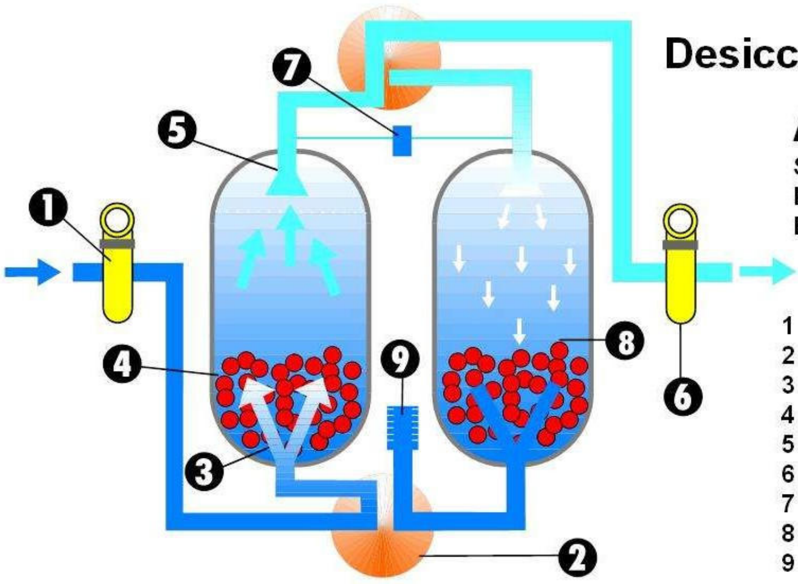
The effect of conditions on capacity





- **Multiply factors where several conditions vary**
- **Eg 100 cfm dryer at 7 barg, 35C, 25C ambient**
  = 70 cfm at 6 barg, 40C inlet, 30C ambient

Desiccant dryers



Desiccant drying - heatless

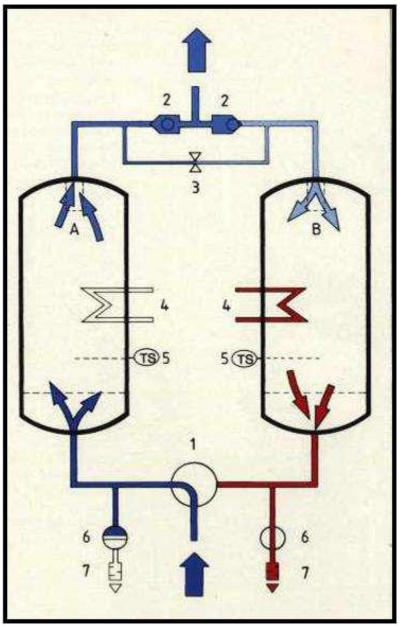
Application:

Systems subjected to freezing.
High ambient temperatures.
Extreme requirements of air quality.

1 microfilter (0.01 µm, 0.01 ppm)
2 changeover valve
3 flow diffuser
4 desiccant bed: moisture adsorption
5 outlet collector
6 particulate filter 1 µm
7 purge (regeneration) air valve
8 desiccant bed: regeneration
9 purge air exhaust silencer

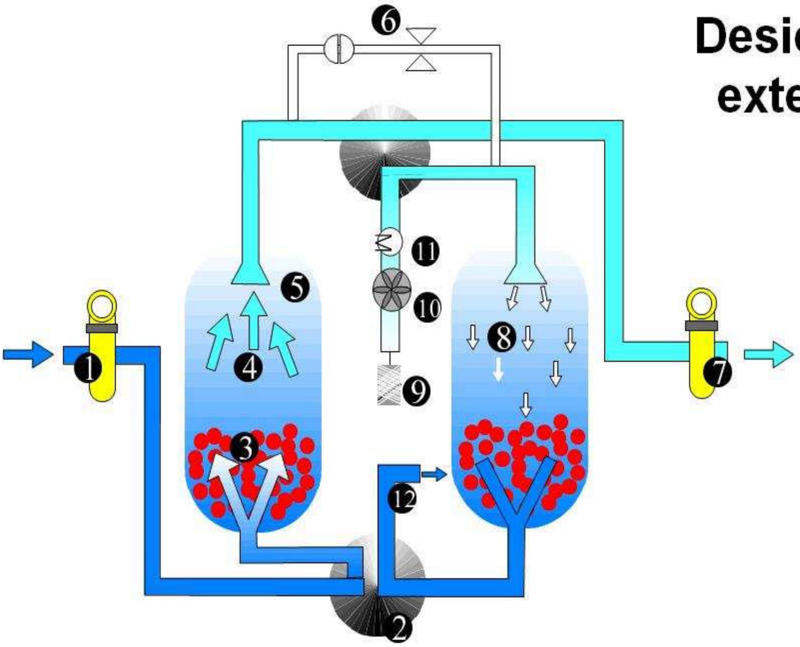
Desiccant drying - internally heated

- integrated heating rods (desiccant not heated evenly during regeneration)
- low purge air requirement (cooling, pressure build-up)
- constant dry, oil-free and clean compressed air



MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

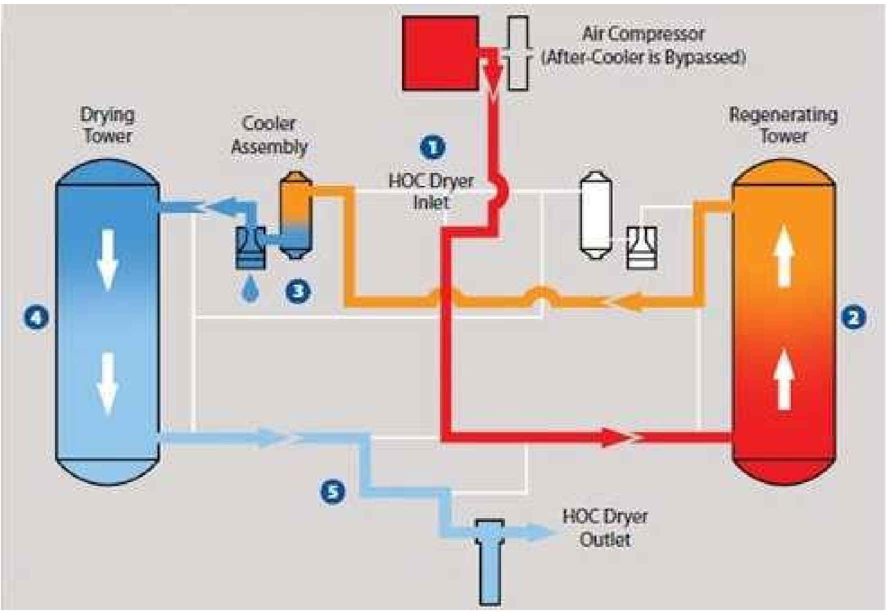
Compressed Air Systems



Desiccant drying - externally heated

1 microfilter (0.01 µm, 0.01ppm)
2 changeover valve
3 flow diffuser
4 desiccant bed: adsorption
5 outlet collector
6 regeneration (purge) valve
7 particulate filter
8 desiccant bed: regeneration
9 purge air inlet
10 purge air blower
11 purge air heating
12 purge air outlet

Heat of compression desiccant dryer



MINISTRY OF INDUSTRY AND TRADE
Global Gateway
Funded by the European Union
UNIDO
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

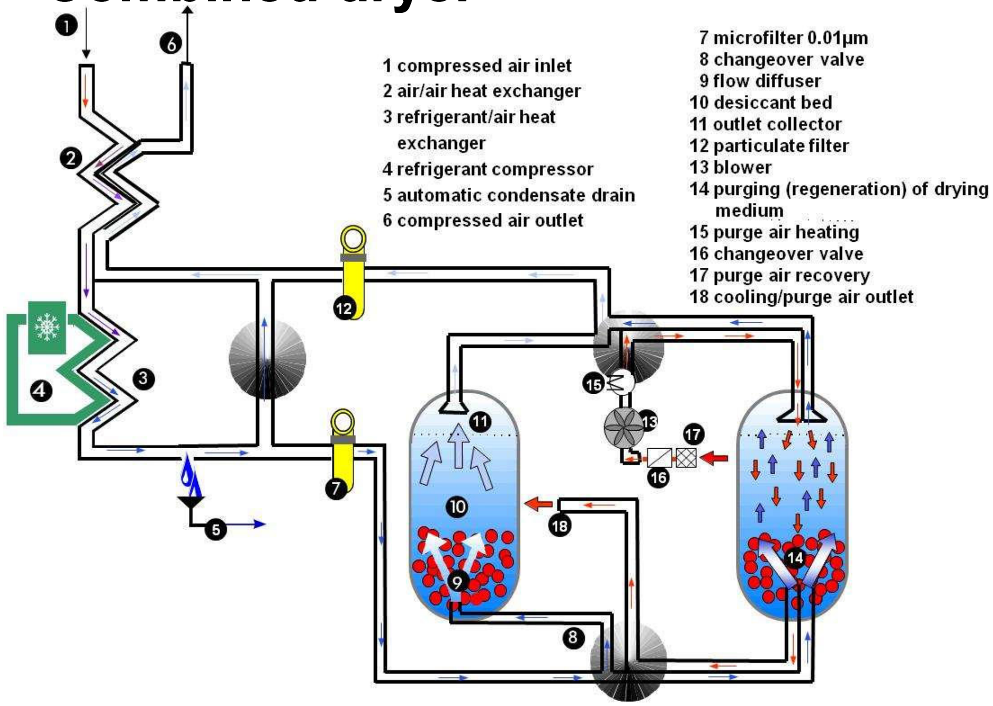
Compressed Air Systems

Applying Desiccant Dryers

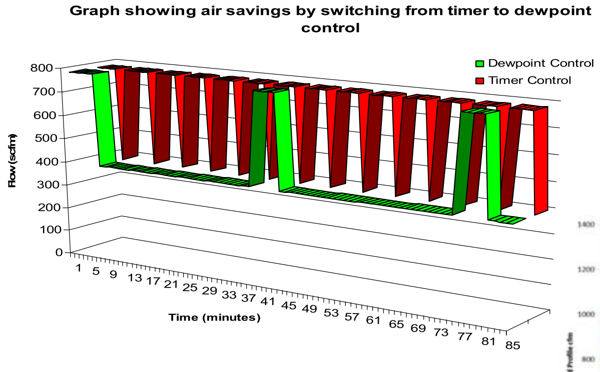
Desiccant dryers:

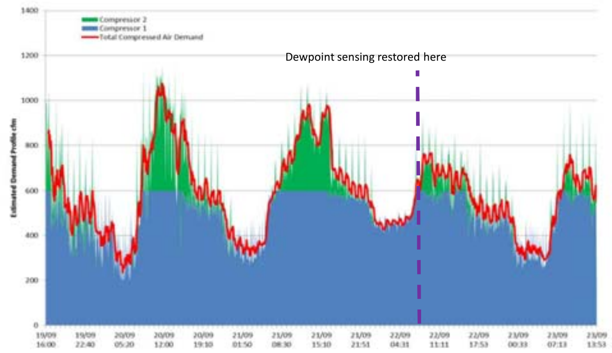
1) Pressure dew point to –70° C
2) Non-heated units require 15 – 17% purge air
3) Heated units require 7% purge air
4) Blower purge units require 0 - 2% purge air
5) Typical pressure drop – 0.2 to 0.3 bar

Combined dryer



Air dryers with dewpoint sensing control





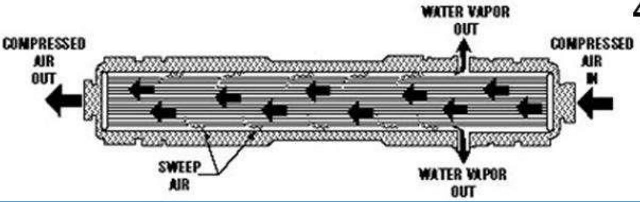
- **Savings up to 70%**
- **Systems can often be retrofitted to existing dryers**

Compressed Air Systems

Applying Membrane Dryers

Membrane dryers:

1) Pressure dew point to – 40° c
2) Require particulate and coalescing filters as pre-filters
3) Up to 30% purge air required
4) Excellent for point of use, very dry applications



MINISTRY OF INDUSTRY AND TRADE · Global Gateway · Funded by the European Union · UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Compressed Air Distribution

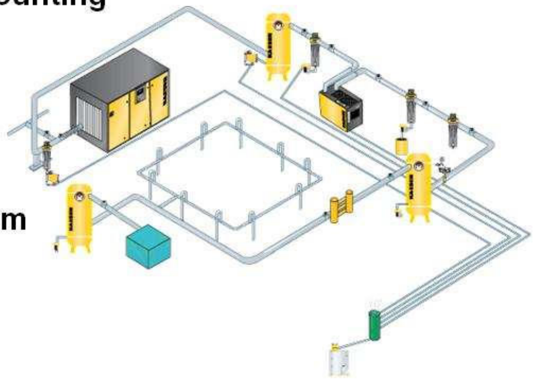
Minimum diameters of pipes

FAD m^3/min	working pressure 7.5 bar (g)			
	length of pipeline up to 50 m	up to 100 m	up to 200 m	over 200 m
up to 12.5	2 1/2"	2 1/2"	3"	see straight-line graph
up to 15,0	2 1/2"	2 1/2"	3"	
up to 17.5	2 1/2"	3"	DN100	
up to 20.0	3"	3"	DN100	
up to 25.0	3"	DN100	DN100	
up to 30.0	3"	DN100	DN100	
up to 40.0	DN100	DN100	DN 125	

Compressed Air Distribution

Rule of thumb:

A well designed piping system will have less than a 0.15 bar pressure drop in the entire system, not counting clean air treatment equipment.



Compressed air velocity should be kept to:

- **5 meters per second in the compressor room**
- **6 meters per second in the main header**
- **15 meters per second in the air drops**

Uses of compressed air

- Blowing
- Cleaning
- Processes
- Component ejection
- Ventilation - cooling of products
- Agitation of paint or cleaning baths
- Moving product around bends or on conveyors
- Keeping product in line
- Vacuum generation
- Instrumentation

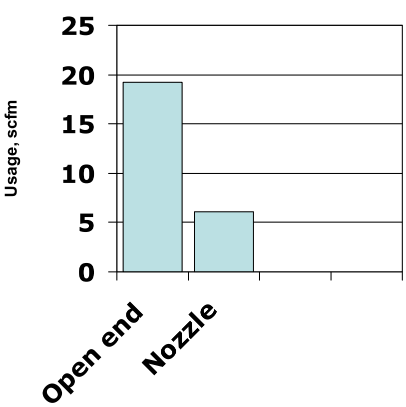
Energy saving air using devices

These include:

- Air intensifying nozzles
- Air knives
- Safety blow guns
- Low consumption solenoid valves
- Pressure boosters
- Multistage vacuum ejectors
- Local pressure regulators
- Local isolations of production machinery
- Double acting double power pneumatic cylinders
- Exhaust stroke air recovery from cylinders
- Reductions in local pressure losses
- Electronic zero loss drain traps
- Local receivers to reduce peak demands
- Electrical powder transfer vibrators

Air efficient nozzles

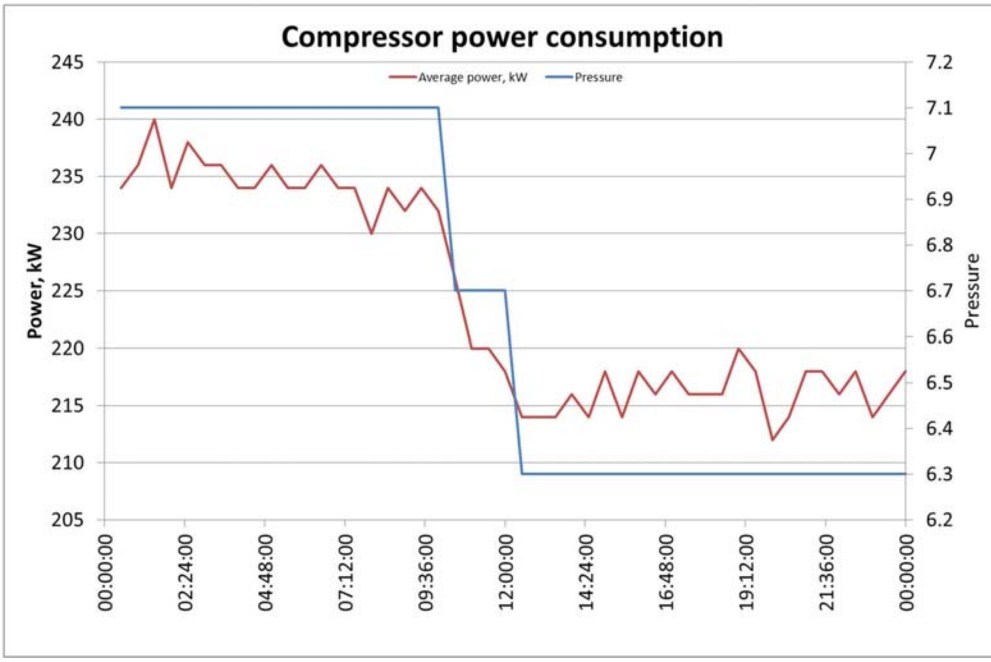
Copper pipe	19.2 scfm
Air efficient nozzle	6.1 scfm
Reduction	13.1 scfm



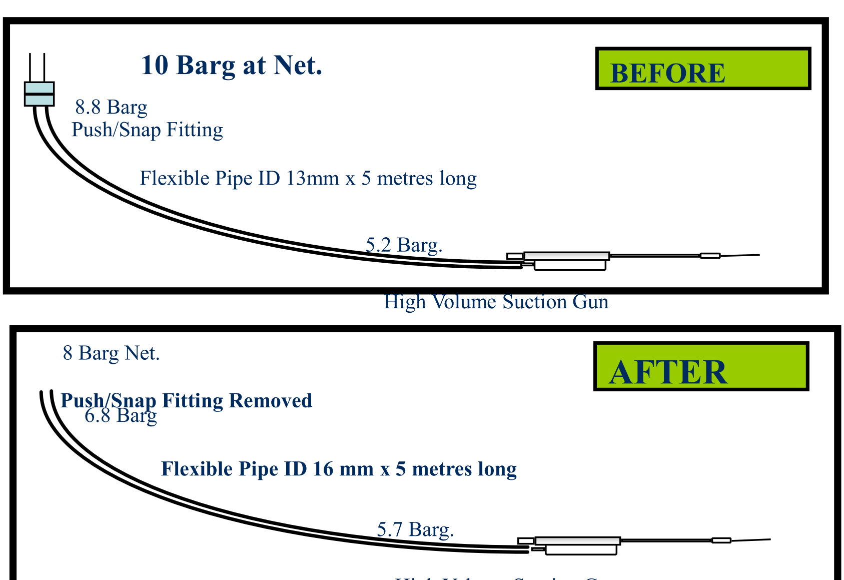
Specific energy = 0.122 kW/cfm
Energy saved = 1.6 kW/nozzle
Saving/nozzle = VND4,000,000 per year
(based on 2000 hours/year)

Cost VND350 - VND700,000 per nozzle
Payback < 2 months

Reducing pressure



Pressure reduction at the end user



Reducing pressure at the end user

- 4mm orifice Blow gun operating at 7 barg with safety nozzle
- Consumption: 40 cfm
- Reduce pressure to 2 barg
- Consumption = 40*3/8 (absolute pressure ratio)
- = 15 cfm
- Saving = 25 cfm*0.122 = 3 kW/gun
- 25 guns used for 2 minutes/hr = 25*3*2/60 = 2.5 kW average saving

Total saving = VND 12,000,000 per year (4000 hrs/yr)
Cost for preset regulator <d700,000
Payback 18 months

FIT REGULATORS!!

Safety blow guns

- Ergonomically designed body with patented valve design and KN nozzles produces considerably reduction in pressure losses.
- 2 connection options.
- Minimum actuation force required.

Local boosters

- Increases the main circuit pressure to an adjustable value.
- Major energy savings.
- No other energy source required
- Operating temperature: 2-50° C.
- Input pressure: 0.1-1 MPa.
- Mounting position: horizontal.

MINISTRY OF INDUSTRY AND TRADE
Global Gateway
Funded by the European Union
UNIDO
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Vacuum ejectors

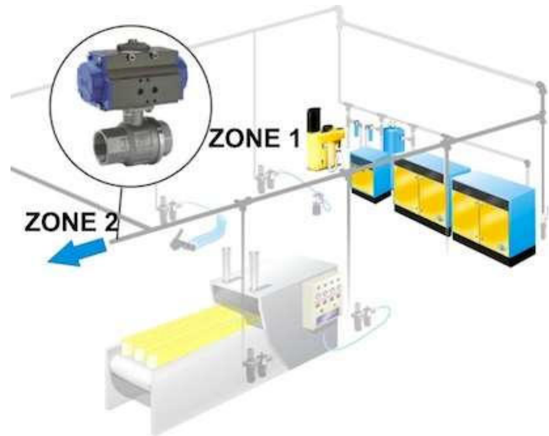
- Compact design.
- 3 different types:
  Ejector + vacuum switch.
  Ejector + vacuum gauge.
  Only ejector
- Vacuum built by 3 stage ejector therefore less air consumption, by the nozzle.

Zone & machine isolation

Isolate air using production machinery when not being used

Use local solenoid valves operated by:

- No product flow sensing
- Isolation switches
- No operator (burglar alarm mats)
- Turning off the air with the lights when everyone goes home

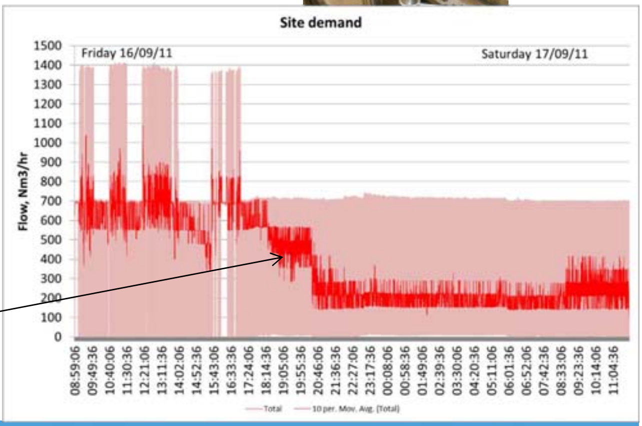


Machine isolation

A machine operates 8 hours a day with the air on 24 hours for users elsewhere on site
Air consumption in use: 20 scfm
Air consumption when stopped: 8 scfm
Power consumed when stopped: 0.976 kW

Annual cost = 0.976*16*3000*365
= VND17,099,520 per year

Typical cost of ½" solenoid valve VND1,700,000



Area 1 stops production and is isolated

Plant vibrators

Air consumption approximately 5 cfm = 1 kW for a 50cm unit at 4 barg

Power consumption less than 100W

MINISTRY OF INDUSTRY AND TRADE
Global Gateway
Funded by the European Union
UNIDO
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

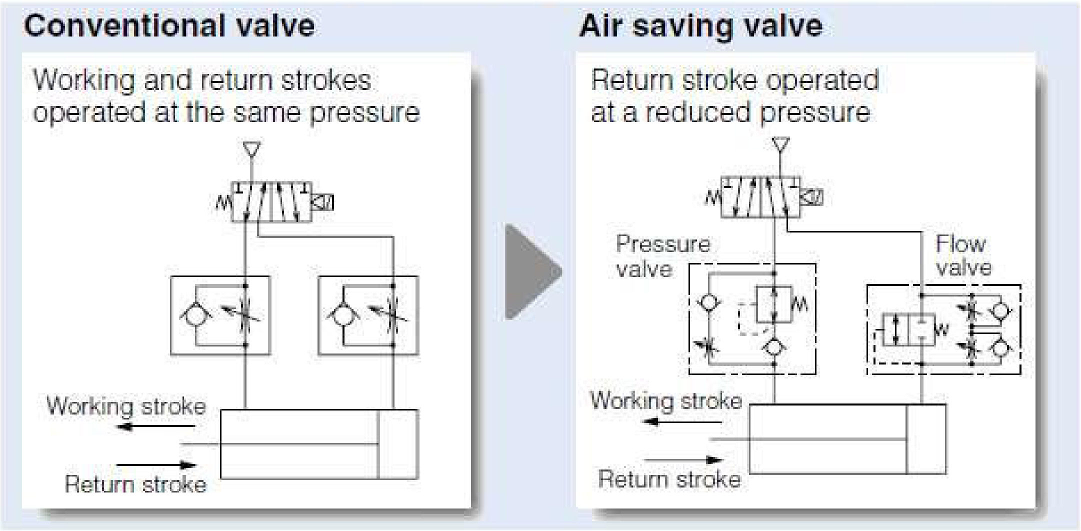
Quick release couplings

- Can be a major pressure loss component
- Ensure they are adequately sized
- Use low air loss quick release couplings
  - Two stage action prevents loss from pressurised side
  - Safer - no hose whip or sudden air release
  - Lower pressure loss so tools work better

Poverty Reduction through Productive Activities • Trade Capacity Building • Energy and Environment

Air saving valves

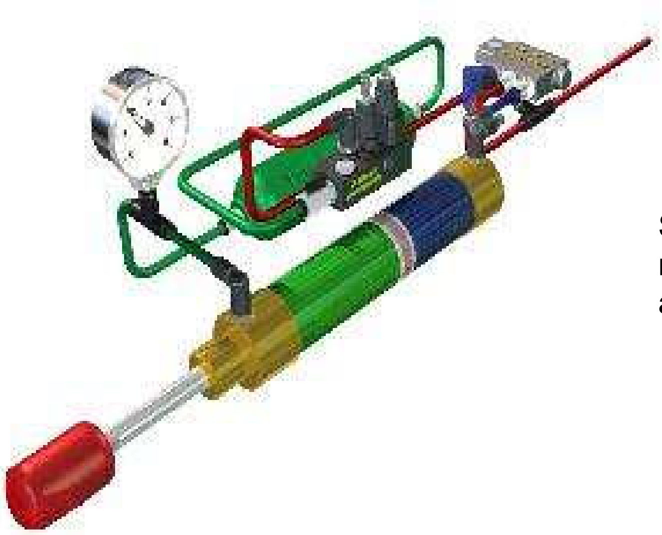
Cuts air consumption by operating the return stroke at a reduced pressure.



Double acting double power cylinders

- Double-acting double power cylinder.
- Highly loadable as a result of integrated slide bearing.
- Non-rotating rod (MGZ) - by slide bearing with built-in non-rotating mechanism.
- Double extension output power by "piston in piston construction".
- Approx. 30% reduced overall length compared with standard cylinders in tandem arrangement.
- Moment absorption is the same

Cylinder air recovery

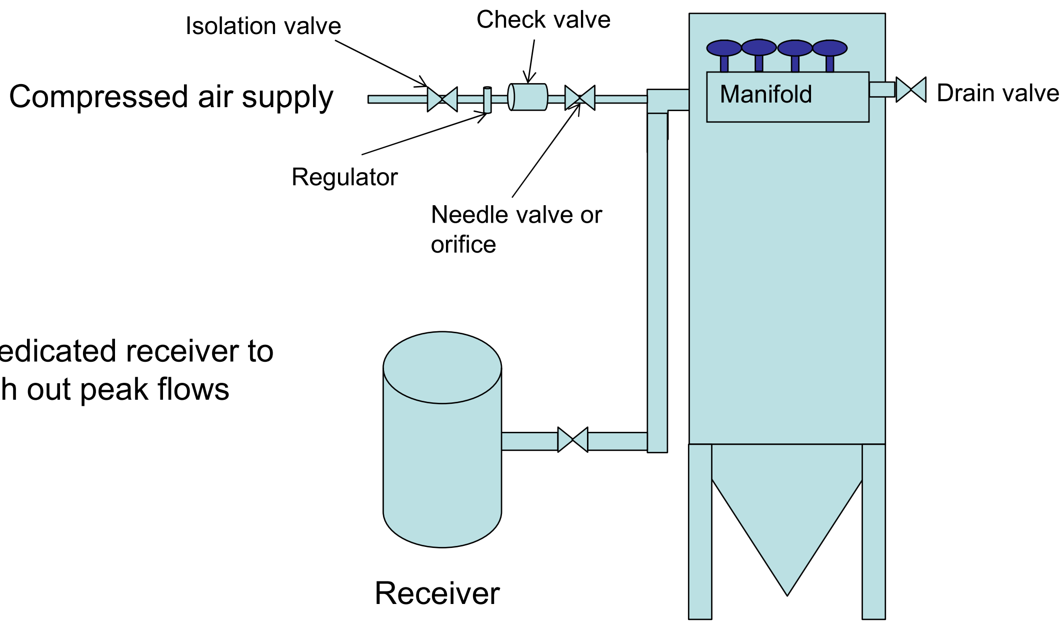


Store and reuse air normally discharged to atmosphere

Dust extraction plants

- Use local receiver to smooth out peaks
- Use differential pressure control not timed
- Isolate out of hours

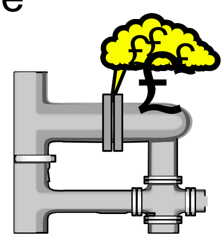
Dust Extraction plants



Use dedicated receiver to smooth out peak flows

Compressed air leaks

- Should not be more than 10% of the mean production demand in a normal factory
- Can be up to 20% for large sites, over 80% measured on occasion
- Leaks come back but seldom in the same place
- Regular ongoing leakage campaigns must be conducted
- Business opportunity for suppliers?



Leakage losses

Hole diameter	Air consumption at 6 bar (g) m^3/min	Loss kW
1 mm	0.065	0.3
2 mm	0.240	1.7
4 mm	0.980	6.5
6 mm	2.120	12.0

At D3000/kWh, a 4mm leak costs over VND170,820,000 /year in power plus additional service on the compressed air equipment.

Leak Detection

Many leaks can be heard, felt or seen.

Other techniques:

- **Using soapy water:**
  - **Tried and trusted, time consuming but sometimes the only way**
  - **Only suitable for small leaks**
- **Ultrasound**
  - **Very effective even in high background noise areas**

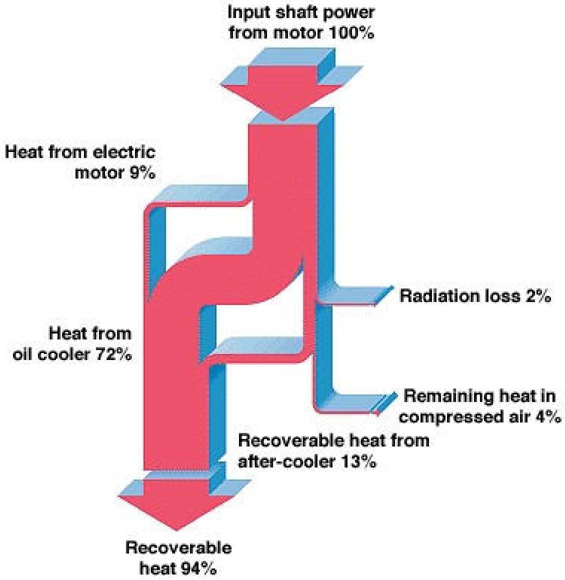
Common sources of leaks

- Filter, Regulator, Lubricator
- Manual Drain Valves
- Quick Disconnect (QD) fittings
- Hose clamps
- Push-on Hose fittings
- Cut or Punctured Hose
- Pipe fittings
- Pipe Unions
- Flange Gaskets
- Old Rusted Piping
- Pneumatic Cylinder Rod Packing
- Pneumatic Cylinder Body
- Directional Control Valves
- Valve Pilot Lines and Ports
- Valve Stems and Packing

Rubber hose with hose clamps make poor connections that often leak.

An open valve to drain water can cost more each month than the cost of an automatic drain that prevents air loss.

Waste heat recovery

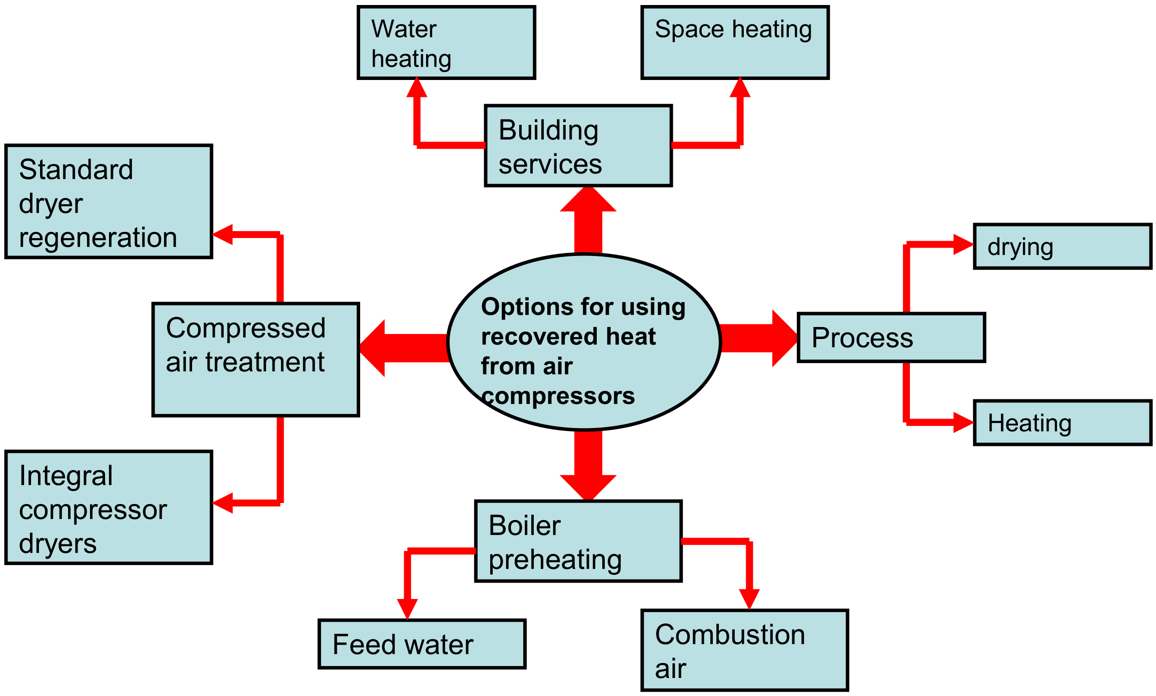


On average 85% of input energy can be recovered for heating applications.

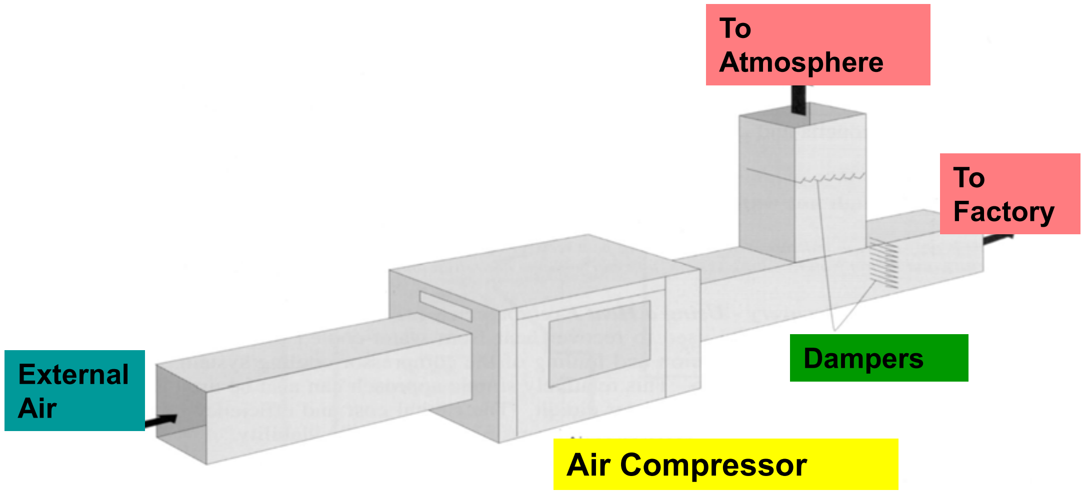
The possibility for heat recovery depends on:

- Heating demand of the factory
- Matching of compressor operation and heat demand
- Proximity of compressor station to heating distribution lines/consumers
- Available and usesable temperatures

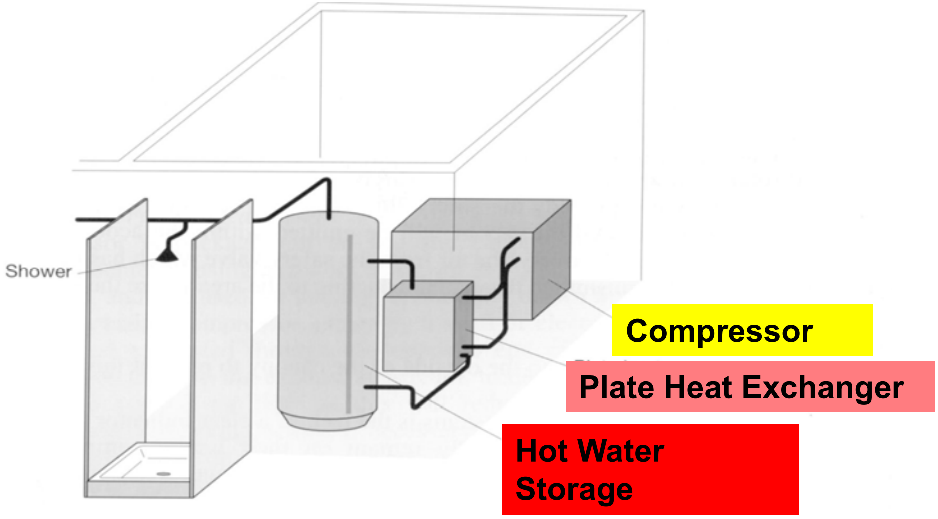
Heat recovery



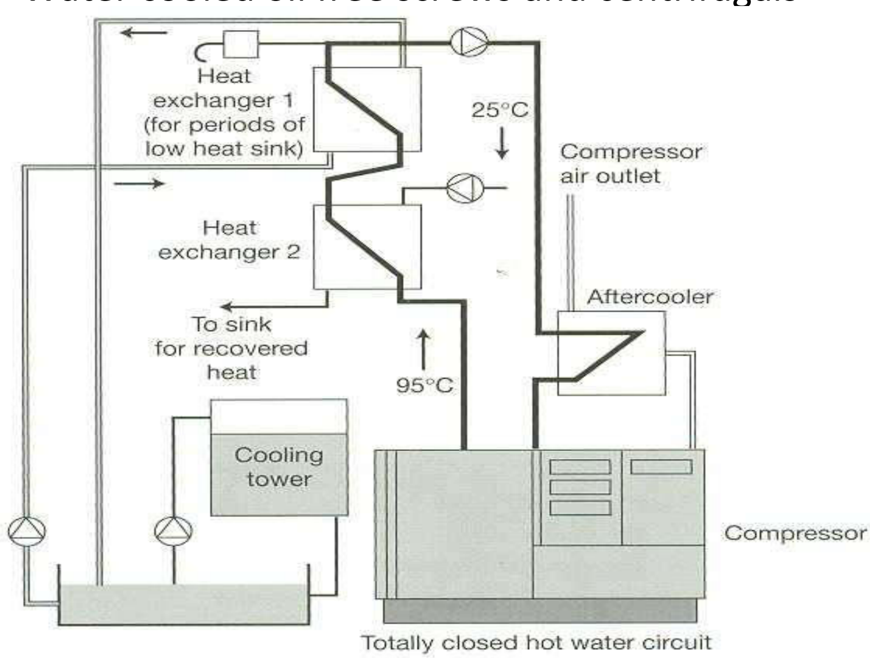
Collecting heat from air cooled packages



Collecting hot water from an air-cooled package



Water cooled oil free screws and centrifugals



END OF SESSION
ANY QUESTIONS?