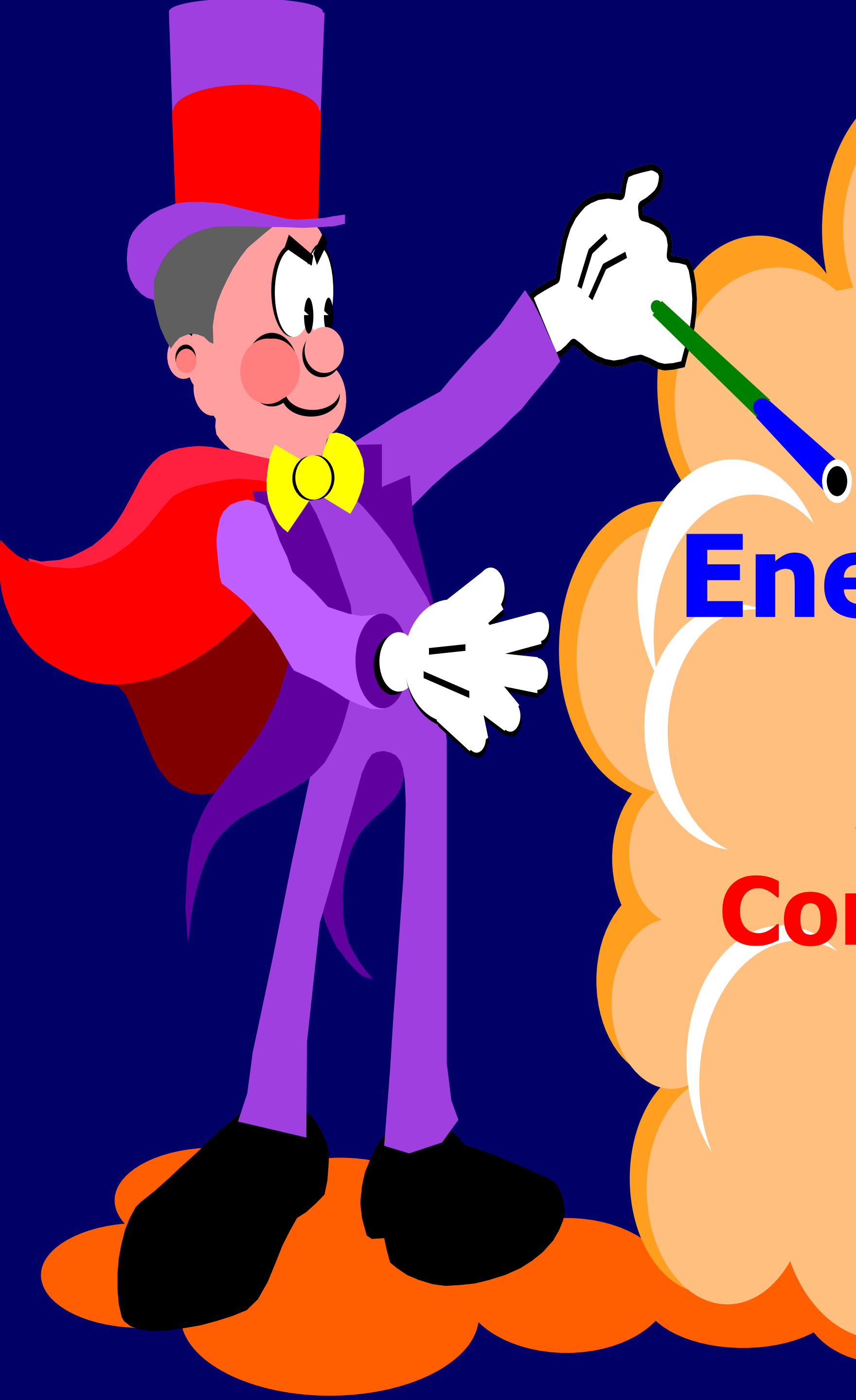
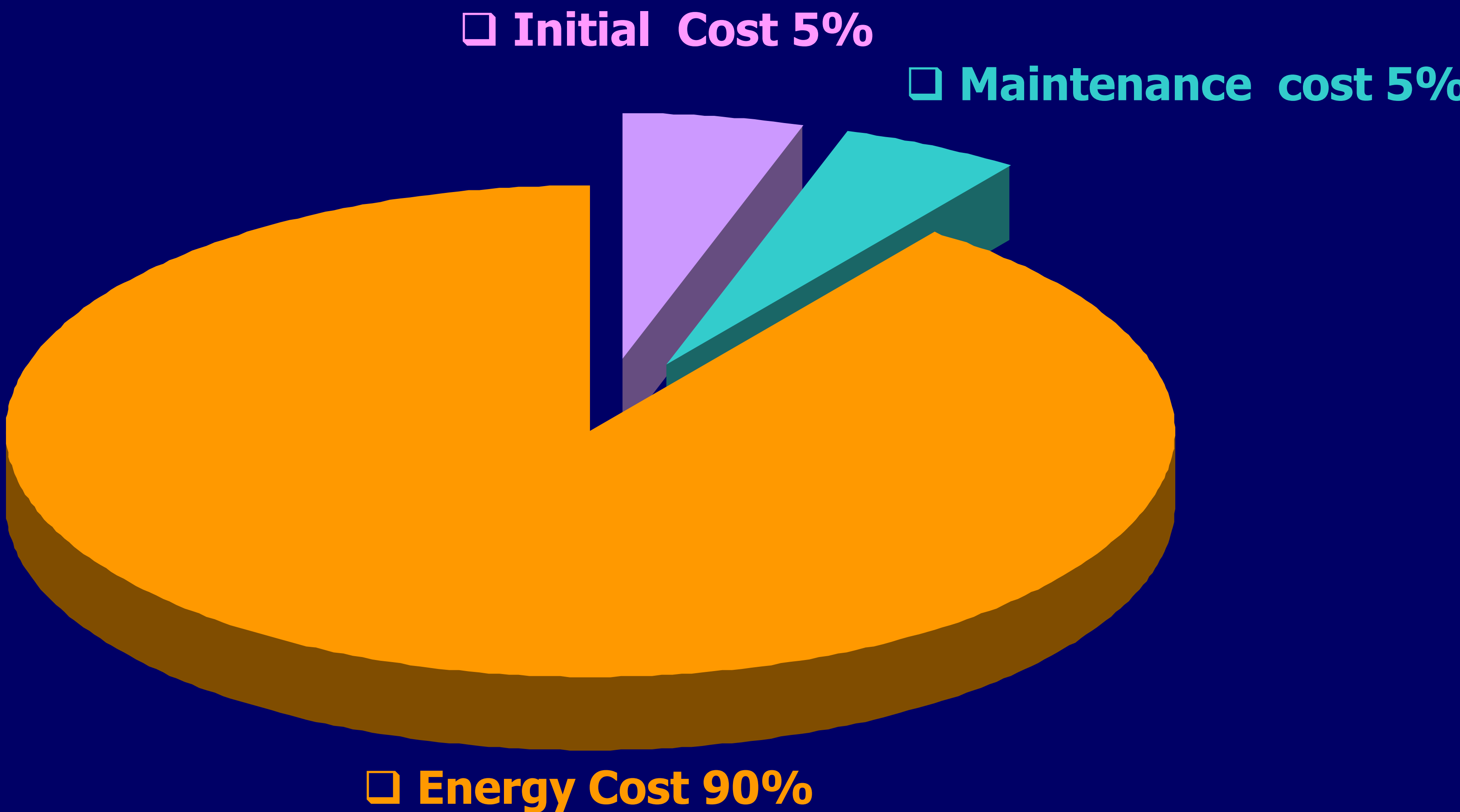


Energy Conservation

in

Air Compressors & Compressed Air System

Life Cycle Cost For A Compressor



Energy Cost!!

What is the operating cost/annum of a 500 cfm comp capacity?

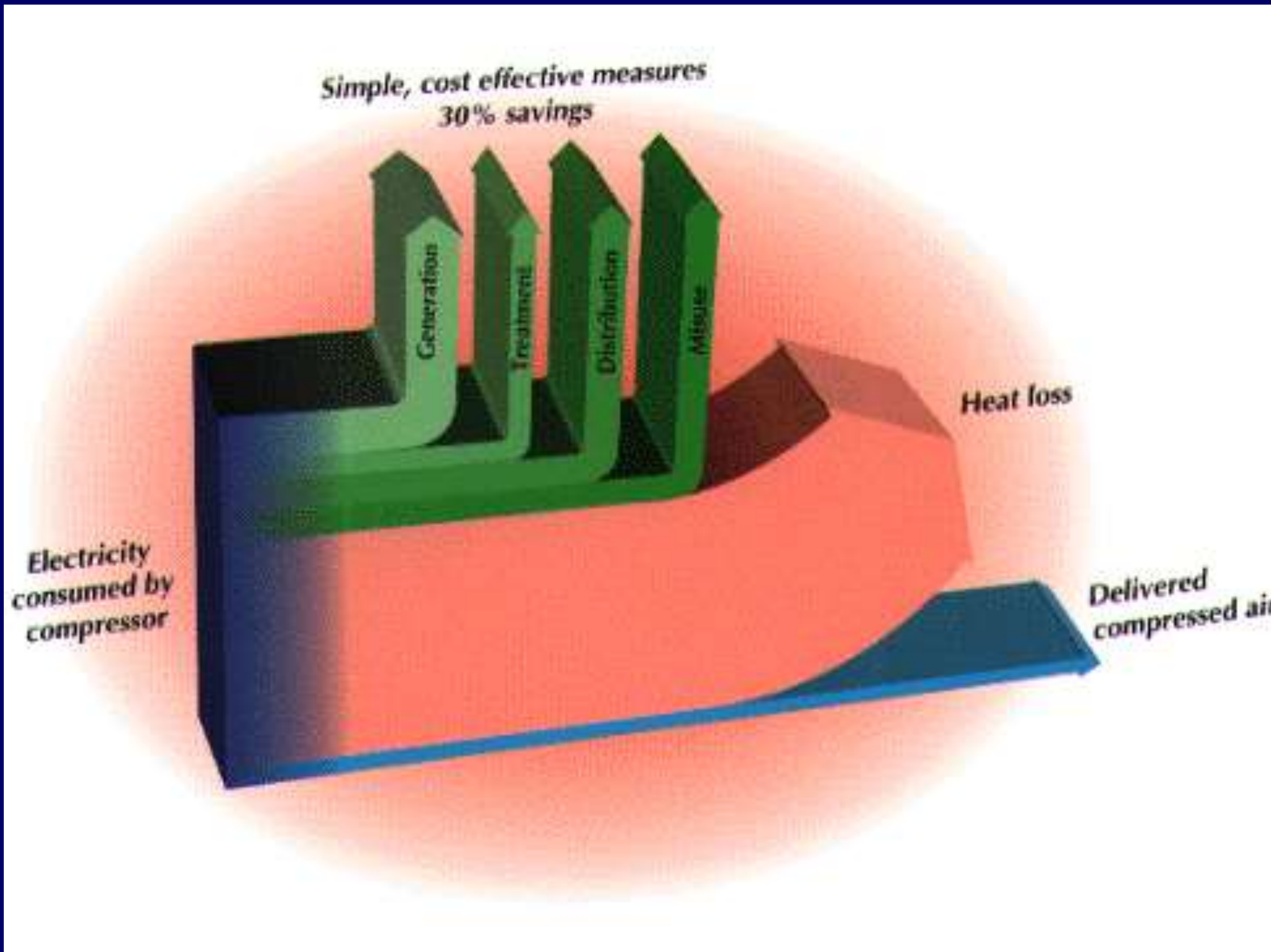
kW/100 cfm x Capacity of Comp (in CFM) x (operating Hrs/yr) x Unit Cost (Rs./kWh)

Benchmark –

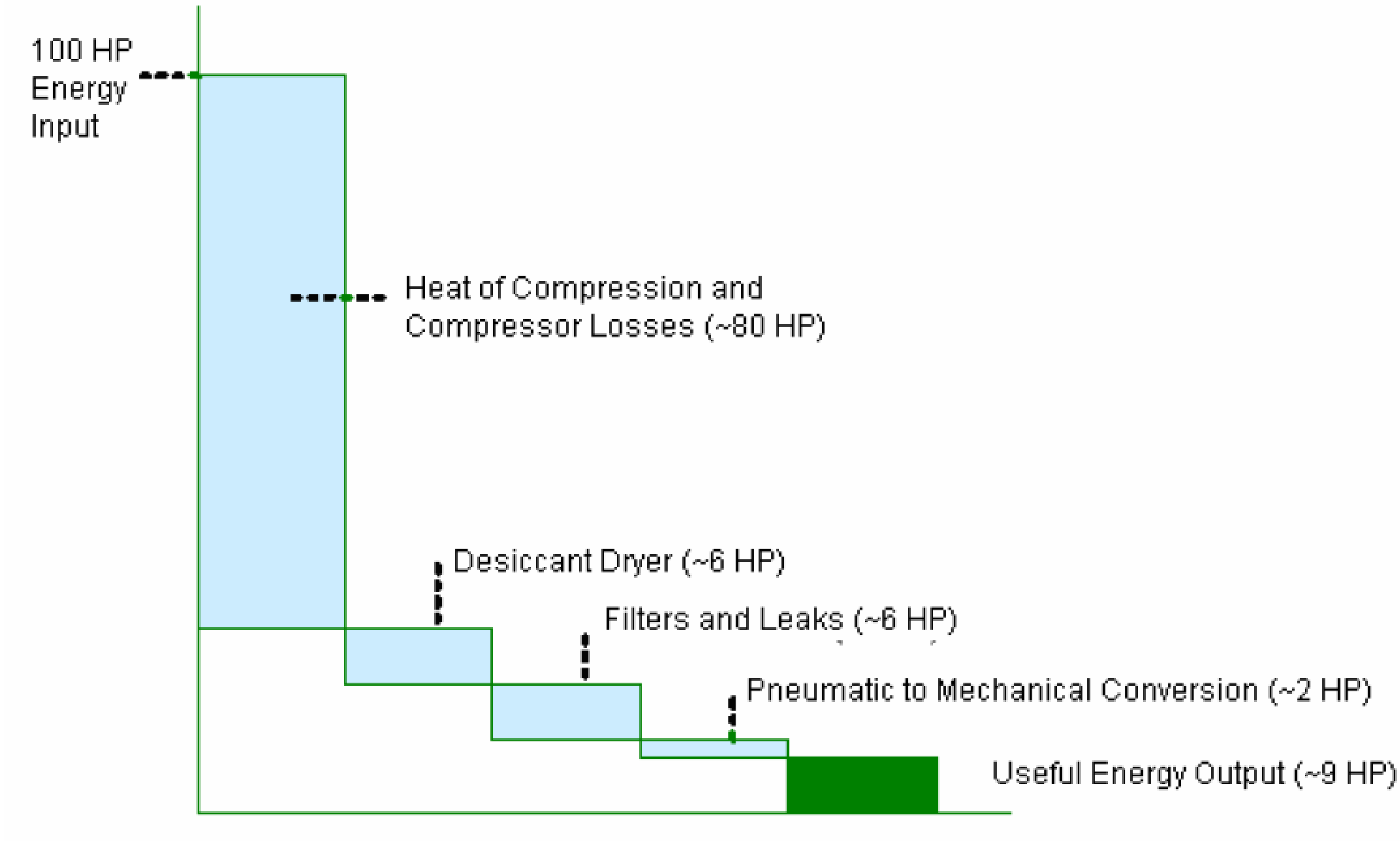
15-17 kW/100 cfm

Rs. 37.5 Lakhs @ Rs. 5.0/unit

Energy Balance for Air Compressor System



Approximately 10% gets to the point of use!!



Compressed Air Energy Input and Useful Energy Output

Air Compressors

Positive Displacement Type

Reciprocating

Vertical Type

(100-500 cfm)

Horizontal Balance Opposed

(200-5000 cfm)

Rotary

Screw (high speed)

Advantage: Intake air can also have some moisture

Disadvantage: Oil carry over

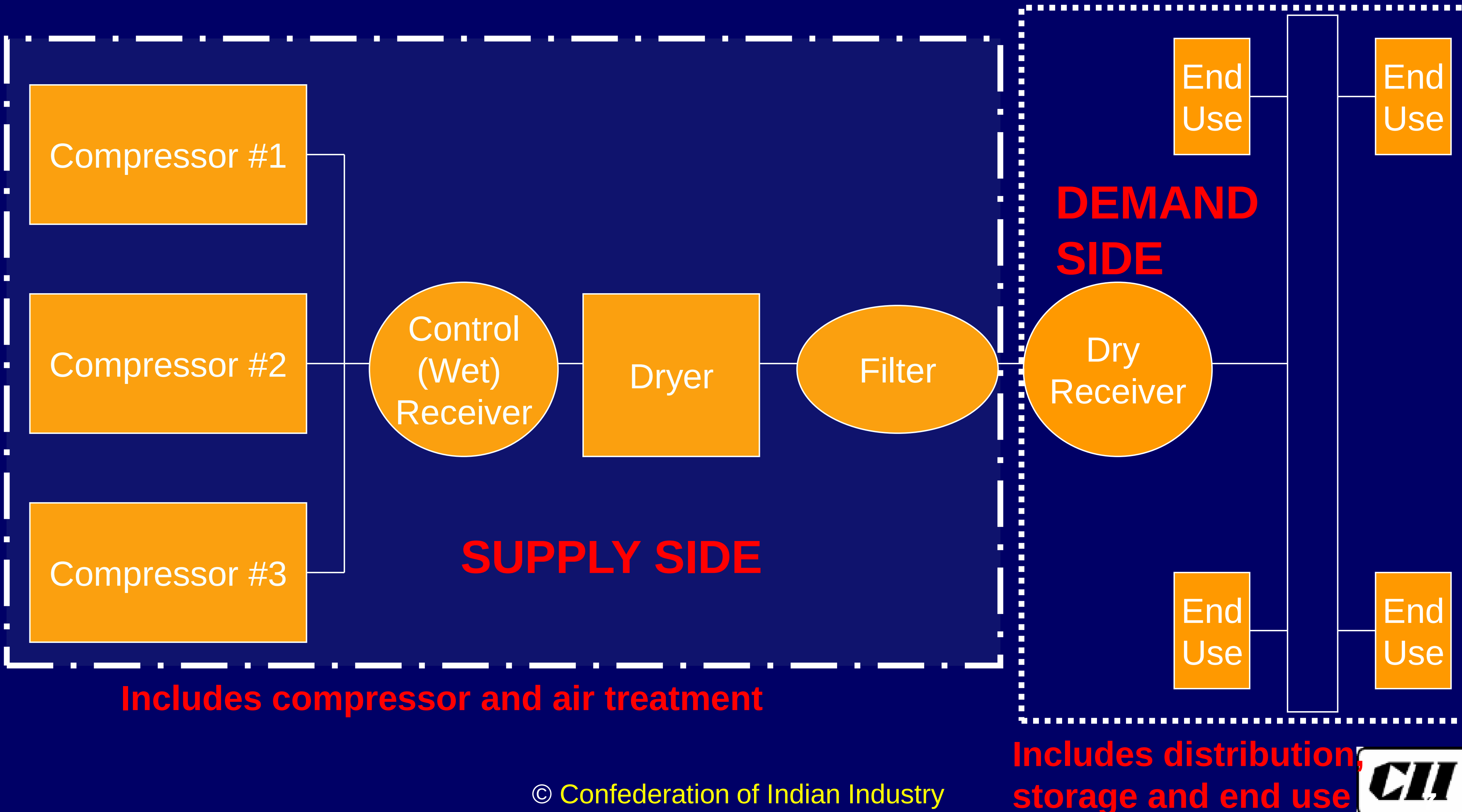
Centrifugal Type

Radial Flow

Axial Flow

> 12000 cfm

A Simplified Block Diagram

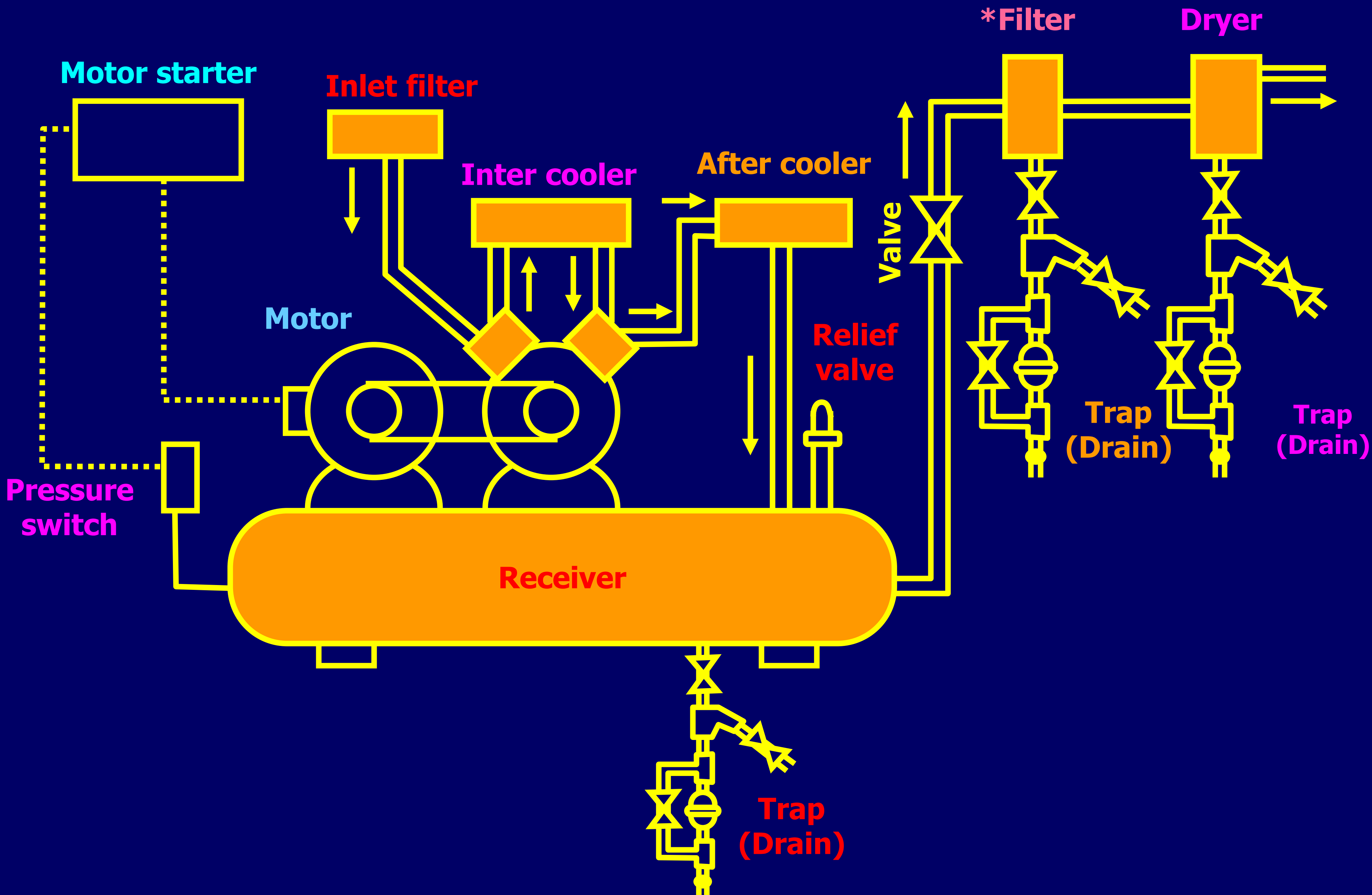


Applications

- Process air
- Operating pneumatic instruments
- Actuators
- Transportation of materials
- Drying
- Agitation
- Cleaning
- Nitrogen generation
- Cooling
- Press filters …

Positive Displacement Air Compressors

Single Acting, 2-Stage Reciprocating Compressor



Why Inter-cooler?

- Compressed air leaves at high temp.
  - Density is lower
  - Volumetric η decreases
- Inter-cooling reduces temperature & volume
  - Mass of air delivered increases
- Inter-cooler generally saves 7 %

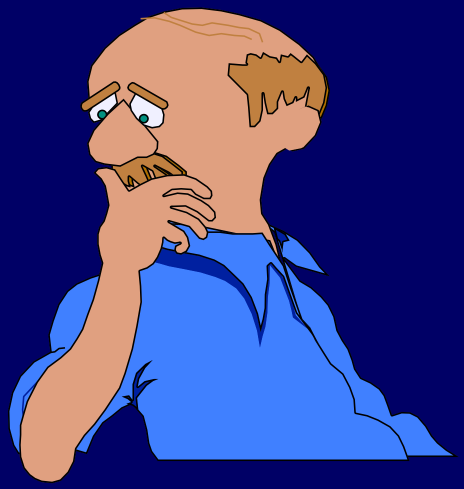
CII

Why After-cooler?
How much is the energy savings?

- Savings same as inter cooler - 7 %

- Higher than inter cooler

- Lesser than inter cooler



CII

Why After-Cooler?
How much is the energy savings?

- At higher temperature moisture carry over very high
- Condensed water moves with same velocity of air
  - Damage to instrument valves
  - Makes instruments sluggish
- After-cooler saves energy only when air dryers are installed

Methodology for Energy Audit

- Is the correct type and size of compressor being used?
- Is the system efficient?
- What is the required operating pressure?
- What is pressure drop between user and compressor?
- Is correct type of dryer used?

Methodology for Energy Audit

- Is compressor cooling water monitored?
- Are auto drain valves provided?
- Can compressed air be substituted?
- Are valves provided at the user points?

CII

Efficient operation of compressed air system

Location of air compressors

- **Cold air intake – Leads to more efficient compression**

  Every 4ºC reduction in inlet air temperature results in 1% reduction in power consumption

- **Dust free air intake – Results in less maintenance**

  Every 250 mm WC pressure drop across the inlet filter – Compressor power consumption increase by 2%

Efficient operation of compressed air system

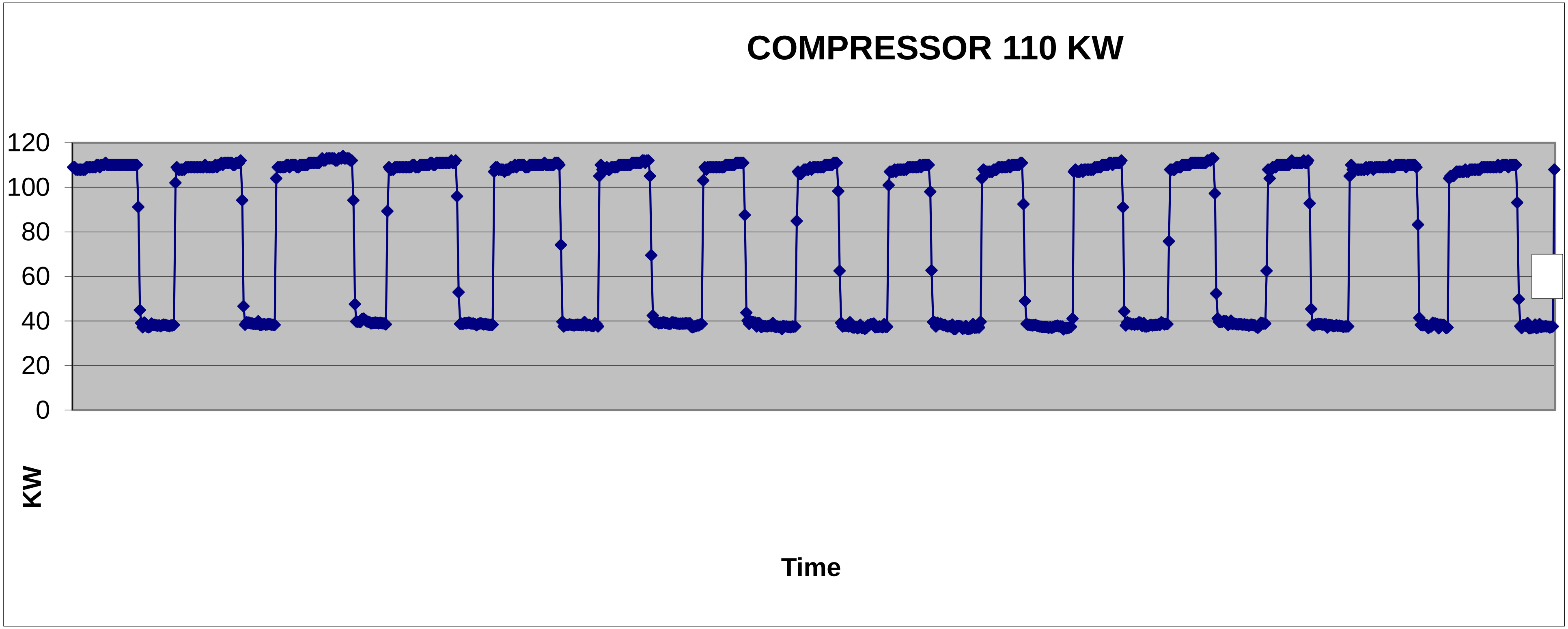
Location of air compressors

- Dry air intake – Vapour also get compressed and drained out in dryers

- Elevation (Height from sea level)
  - Impact on volumetric efficiency

Compressor located at higher altitudes consume more power

Air Compressor Running Pattern



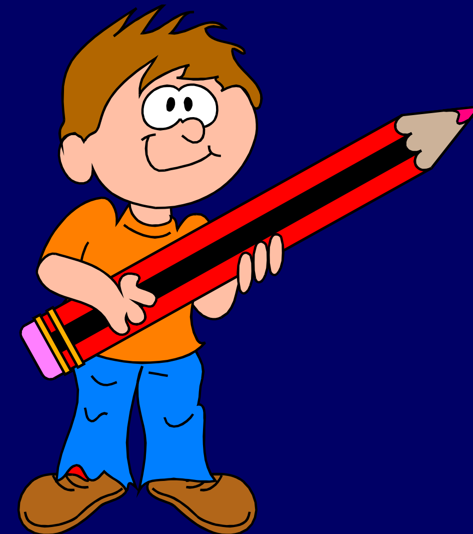
Optimal Utilisation of Compressors

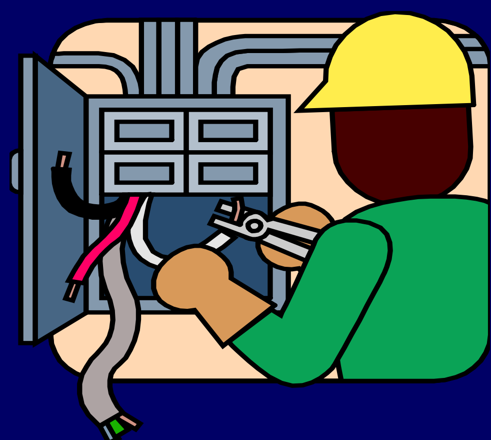
Background

110 kW compressor in operation

At present loading - 50%

Unloading - 50%





Power consumption

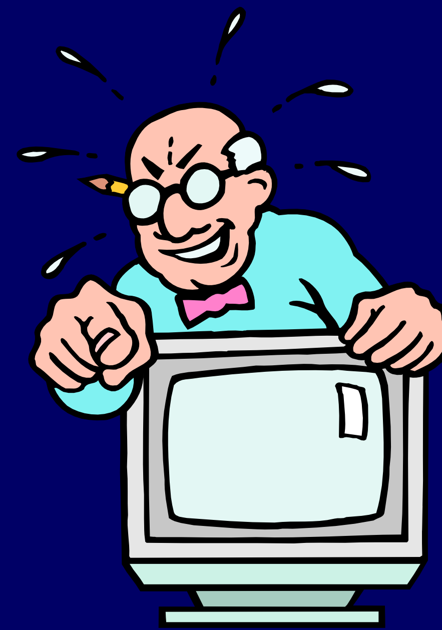
Unload – 40 kW

Loading – 115 kW

Optimal Utilisation of Compressors

Action

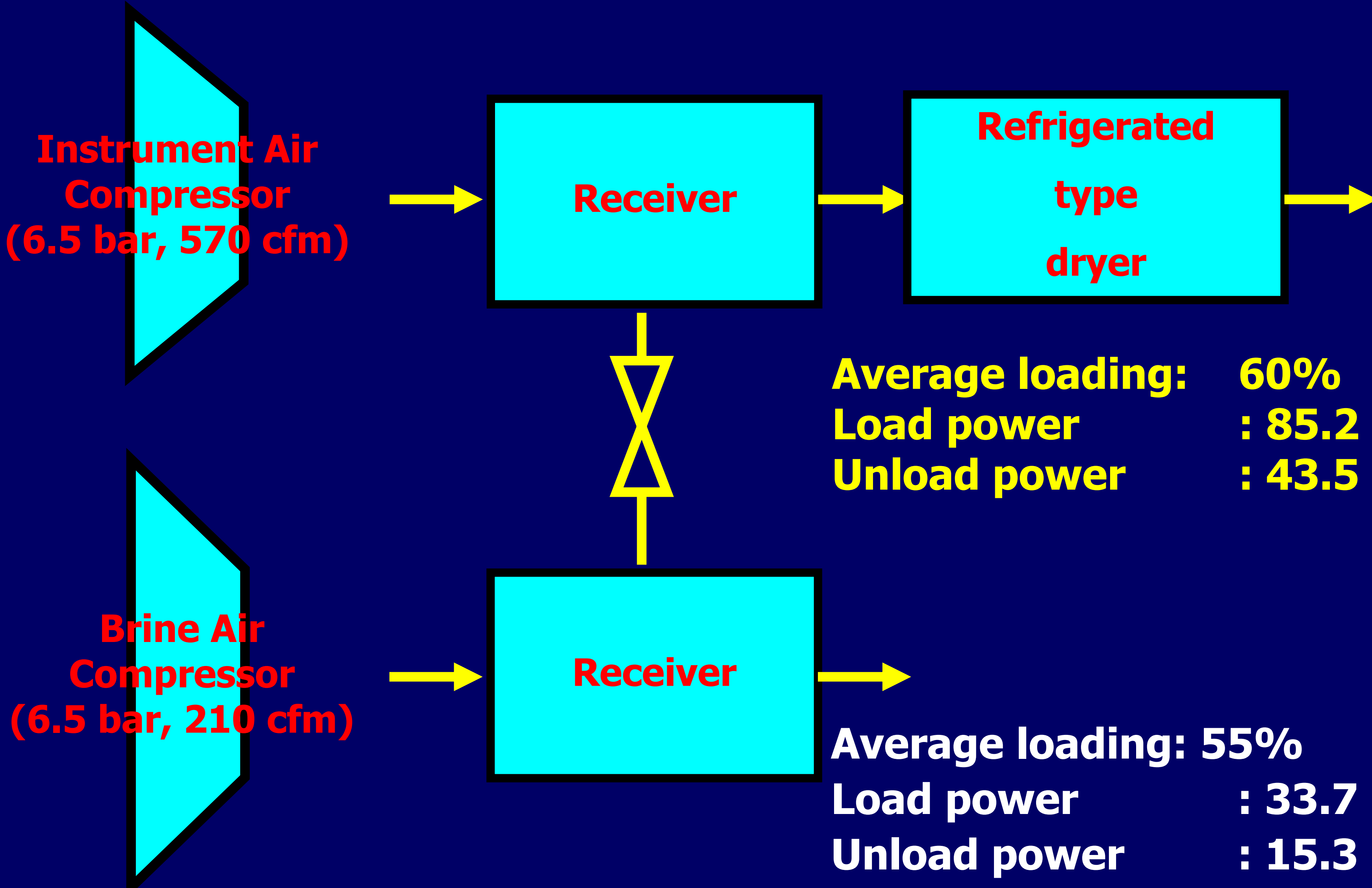
- ❖ **Install correct size air compressor**
- ❖ **Saves no-load power**
- ❖ **Use existing compressor as stand-by**



Annual Savings	**- Rs.12.0 Lakhs**
Investment	**- Rs.8.0 Lakhs**
Payback period	**- 9 months**

CII

Manage Available Facility Optimally



Average loading: 60%
Load power : 85.2 kW
Unload power : 43.5 kW

Average loading: 55%
Load power : 33.7 kW
Unload power : 15.3 kW

Manage Available Facility Optimally

- Interconnect the two receivers
- Stop Brine compressor

Annual Savings	: Rs. 4.28 lakhs
Investment	: Rs.0.02
Payback period	: < 1 month

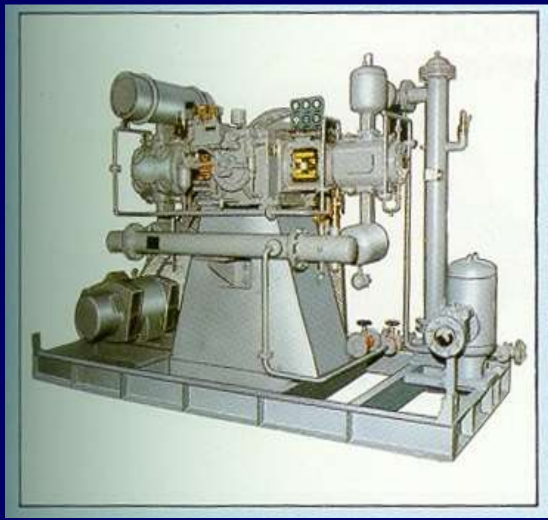
Utilise the Correct Type of Compressor

- **Battery of screw & reciprocating compressors – 200 kW capacity**
  - **2 Screw Compressors**
    - One 100% Load
    - Second 40% Load
  - **Reciprocating compressor stand by**

- **Screw compressor operation**
  - **Load power = 180 kW (40%)**
  - **Unload power = 60 kW (60 %)**

Utilise the Correct Type of Compressor

- **Reciprocating Compressor Operation**
  - Load power = 165 kW (40%)
  - Unload power = 25 kW (60%)



- **Operate Reciprocating Compressor on continuous basis**
  - Keep Screw as stand by

Annual Savings = Rs. 4.90 Lakhs

Pressure setting

- Compressor operates within a pressure range
  - Loading and unloading of compressor
    - Loading – compressor operate and deliver air
    - Unloading- Compressor operate and does not deliver air
  - Control by a pressure switch

Power consumption of air compressor increases with higher operating pressure

Pressure setting

- **Consequences of higher pressure setting**
  - **Wastage of power**
  - **Leads to excessive wear**
  - **Less volumetric efficiency**
- **Generation pressure of the air compressor should be optimally set**

Reduction of generation pressure by 1 bar would reduce the power consumption by 6-10%

Air Compressor power consumption @ 7.1 kg/cm2 pressure

Comp Number	Capacity (cfm)	Power Consumption
2	167	32
4	407	81
5	433	79
6	398	82
7	407	80
9	433	80
Total		**434 kW**

Air compressor power consumption @ 6.8 kg/cm2 pressure

Comp Number	Rated Capacity (cfm)	Power Consumption
4	407	77
5	433	75
6	398	62
7	407	77
9	433	80
Total		**371**

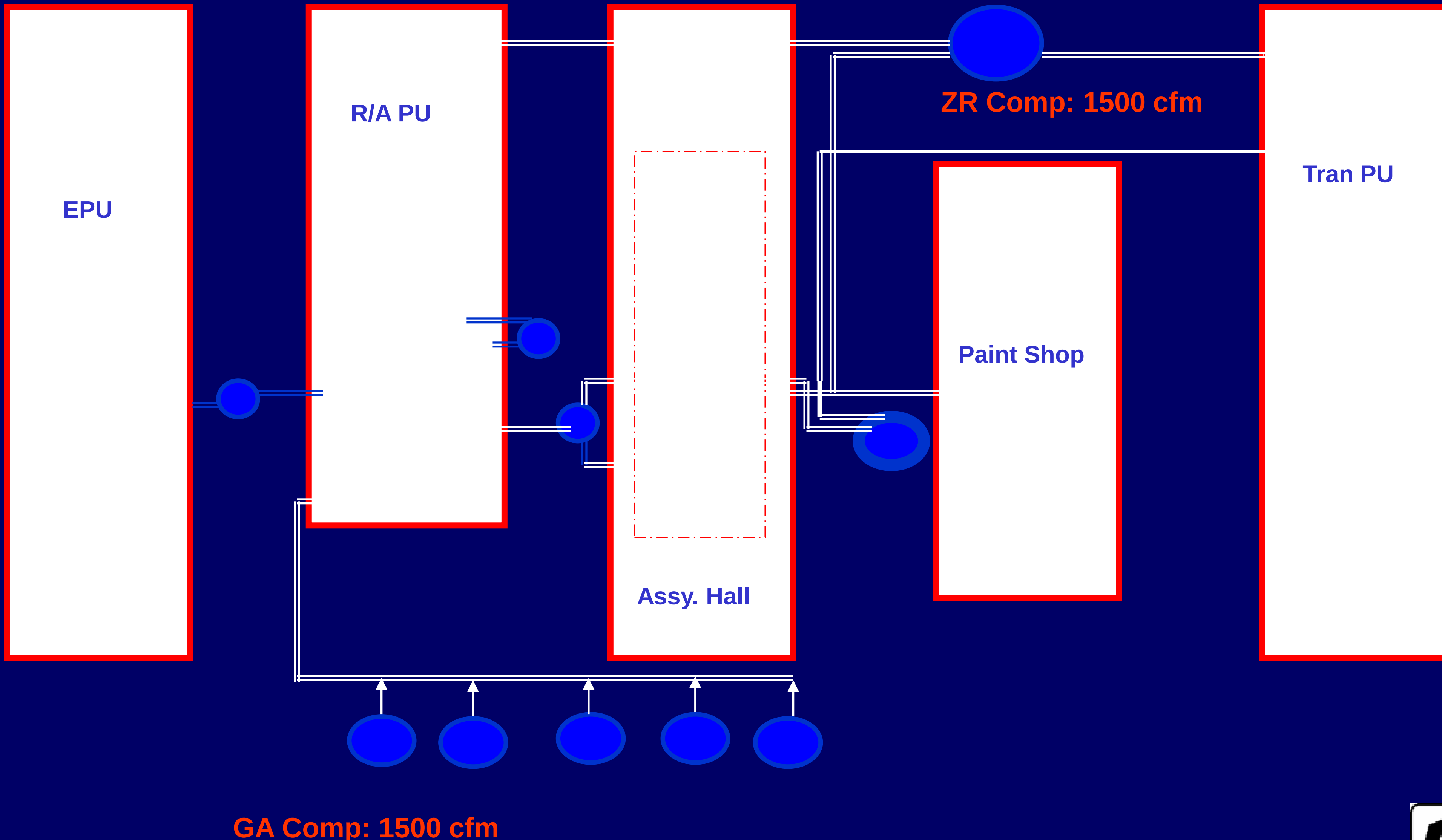
Shift loading/unloading pattern of air compressor & optimise generation pressure

- CII appreciates plant team for quick action
- Change over done after detailed discussion & analysis
- Results were continuously monitored for 4 days
- Results were monitored only for shift A & B as operation in shift C is very dynamic as production operation is varying

Shift loading/unloading pattern of air compressor & optimise generation pressure

- Present System – 3 compressors in operation
  - ZR Comp – 1500 cfm (240 kW, 90 kW)
  - GA Comp – 1000 cfm (180 kW, 70 kW)
  - GA Comp – 525 cfm (85 kW, 30 kW)

Shift loading/unloading pattern of air compressor & optimise generation pressure



Shift loading/unloading pattern of air compressor & optimise generation pressure

- **Present layout –**
  - One of the good distribution system
  - Compressor located at two ends
  - Results in uniform distribution of air
  - Pressure even at farthest end reaches well

Shift loading/unloading pattern of air compressor & optimise generation pressure

- **Present operation –**
  - GA Comp: 525 cfm comp: running on base load
  - GA Comp: 1000 cfm: also running on base load
  - ZR Comp: 1500 cfm: running on fluctuating load

Shift loading/unloading pattern of air compressor & optimise generation pressure

- **Present operating pressure –**
  - ZR Comp: 1500 cfm: 6.3 kg/cm^2– unloading & 5.8 kg/cm^2 loading
  - GA Comp: 525 cfm: pressure higher than 6.3 kg/cm^2
  - GA Comp: 1000 cfm: pressure higher than 6.3 kg/cm^2
  - Average operating pressure higher than 6.3 kg/cm2
  - GA 1000 cfm & 525 cfm – higher av. Power
  - unloading of bigger comp (1500) – consumes higher power without any useful work

CII

Shift loading/unloading pattern of air compressor & optimise generation pressure

- **After fine tuning & modifications –**
  - ZR Comp: 1500 cfm: 6.3 kg/cm^2– unloading & 5.8 kg/cm^2 loading
  - GA Comp: 525 cfm: 5.8 kg/cm^2 – 5.4 kg/cm^2
  - GA Comp: 1000 cfm: 6.0 kg/cm^2 – 5.5 kg/cm^2
  - Average operating pressure: 5.8 - 6.0 kg/cm^2 at the receiver at generation end
  - Average pressure at user end receiver: 5.5 – 5.0 kg/cm^2
  - ZR 1500: operated at base load

CII

Shift loading/unloading pattern of air compressor & optimise generation pressure

- **Results:** Shift A

Average unit consumption in May (Except Sunday & 2nd Sat.	4337 units
Average unit consumption in June (9 days)	4628 units
Average unit consumption after modifications (2 days)	3816 units

Shift loading/unloading pattern of air compressor & optimise generation pressure

- **Results:** Shift B

Average unit consumption in May (Except Sunday & 2nd Sat.)	**3898 units**
Average unit consumption in June (9 days)	**3884 units**
Average unit consumption after modifications (2 days)	3200 units

Shift loading/unloading pattern of air compressor & optimise generation pressure

❖ Results: Comparison Shift – A

Savings as compared to last month -May	**4337 – 3816 units = 521 units**
Average unit consumption in June (9 days)	**4628 – 3816 units = 812 units**
Minimum savings after modifications	500 units/shift A

Shift loading/unloading pattern of air compressor & optimise generation pressure

Results: Comparison Shift – B

Savings as compared to last month -May	**3898 – 3200 units = 698 units**
Average unit consumption in June (9 days)	**3884 – 3200 units = 684 units**
Minimum savings after modifications	650 units/shift B

Shift loading/unloading pattern of air compressor & optimise generation pressure

- **Results: Total Savings**

Per day savings	**500 + 650 = 1150 units**
Per year savings @ 300 days	**1150 units x 300 = 345000 units**
Annual savings @ Rs. 7.5/unit	Rs. 26.0 Lakhs

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Shift loading/unloading pattern of air compressor & optimise generation pressure

Annual Savings	**-**	**Rs 26.0 Lakhs**
Investment	**-**	**Nil**

- **This proposal has been successful implemented – results are being monitored regularly**

- Replacing spring loaded pressure switches with digital pressure is recommended to further fine tune control of generation pressure

Capacity Test

Capacity Test (Pumping Method)

$$\text{Average Compressor Delivery} = \frac{P_2 - P_1}{P} \cdot V_R \cdot \frac{1}{\Delta t}$$

P_1 = Initial pressure in receiver

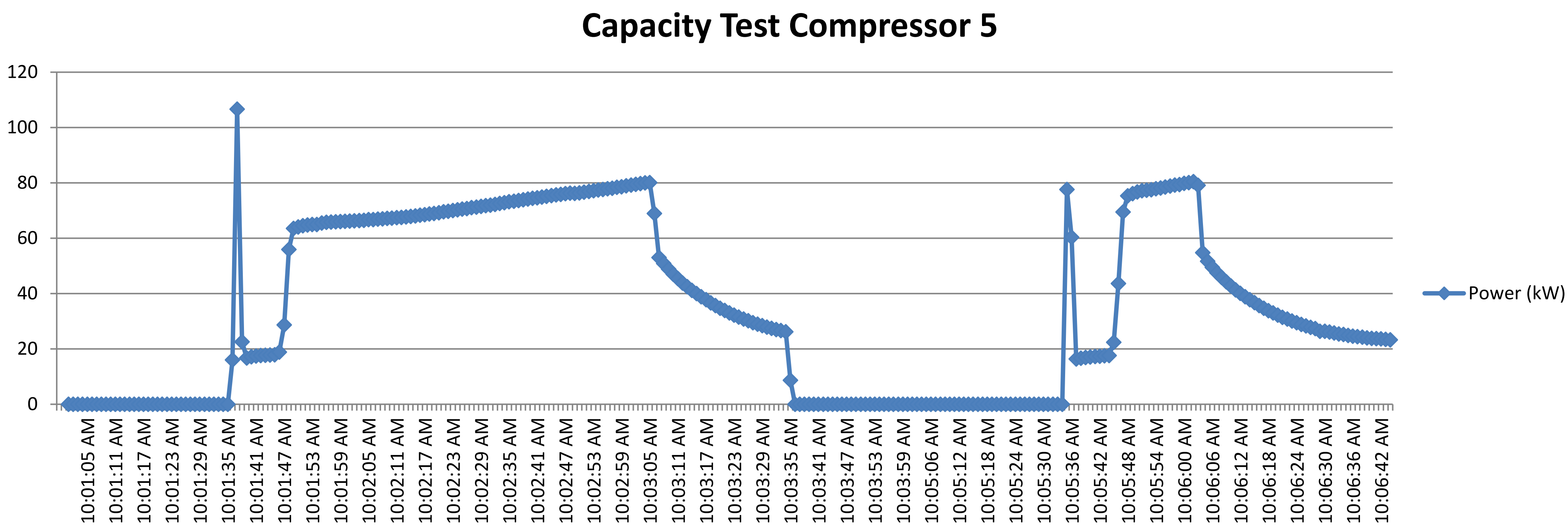
P_2 = Final pressure in receiver

P = Atmospheric pressure

V_R = Volume of air in receiver

Δt = Time taken for charging receiver from P_1 to P_2

Compressor No. 5, 75 kW – power consumption at different generation pressure



Replacement of Inefficient Compressors

- Compressor – For Instrumentation and Process air
- Design Specifications
  - Capacity (FAD) = 540 cfm
  - Pressure (Average) = 6 kg/cm2
  - Motor = 90 kW
- 8 year Old Compressor
  - Regular Maintenance Conducted
  - Overhauling done

Replacement of Inefficient Compressors

- **Capacity Test Conducted**
  - Actual volume (FAD) = 430 cfm
  - Power measured = 86 kW
  - Specific Power = 20 kW/100 cfm
- **Specific power consumption for reciprocation compressor should be around 15 - 16 kW/100 cfm**

CII

Replacement of Inefficient Compressors

- Excess power consumption – 5 kW/100 cfm
- Replaced with New Reciprocating Compressor

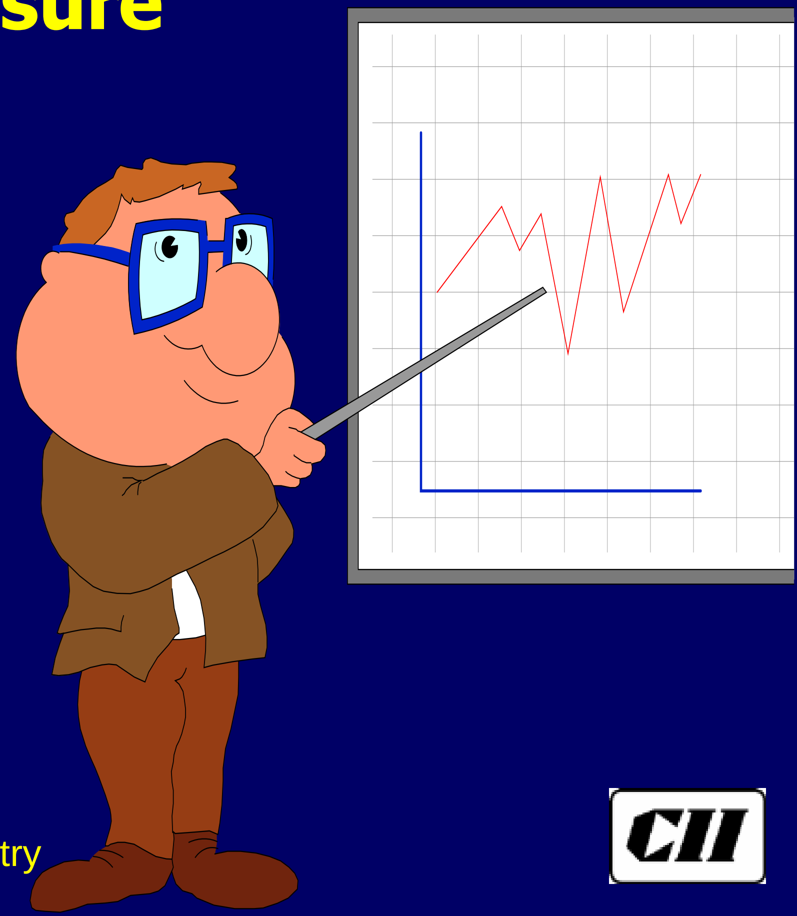
Annual savings	= Rs. 9.0 Lakhs
Investment	= Rs.10.00 Lakhs
Payback period	= 14 months

CII

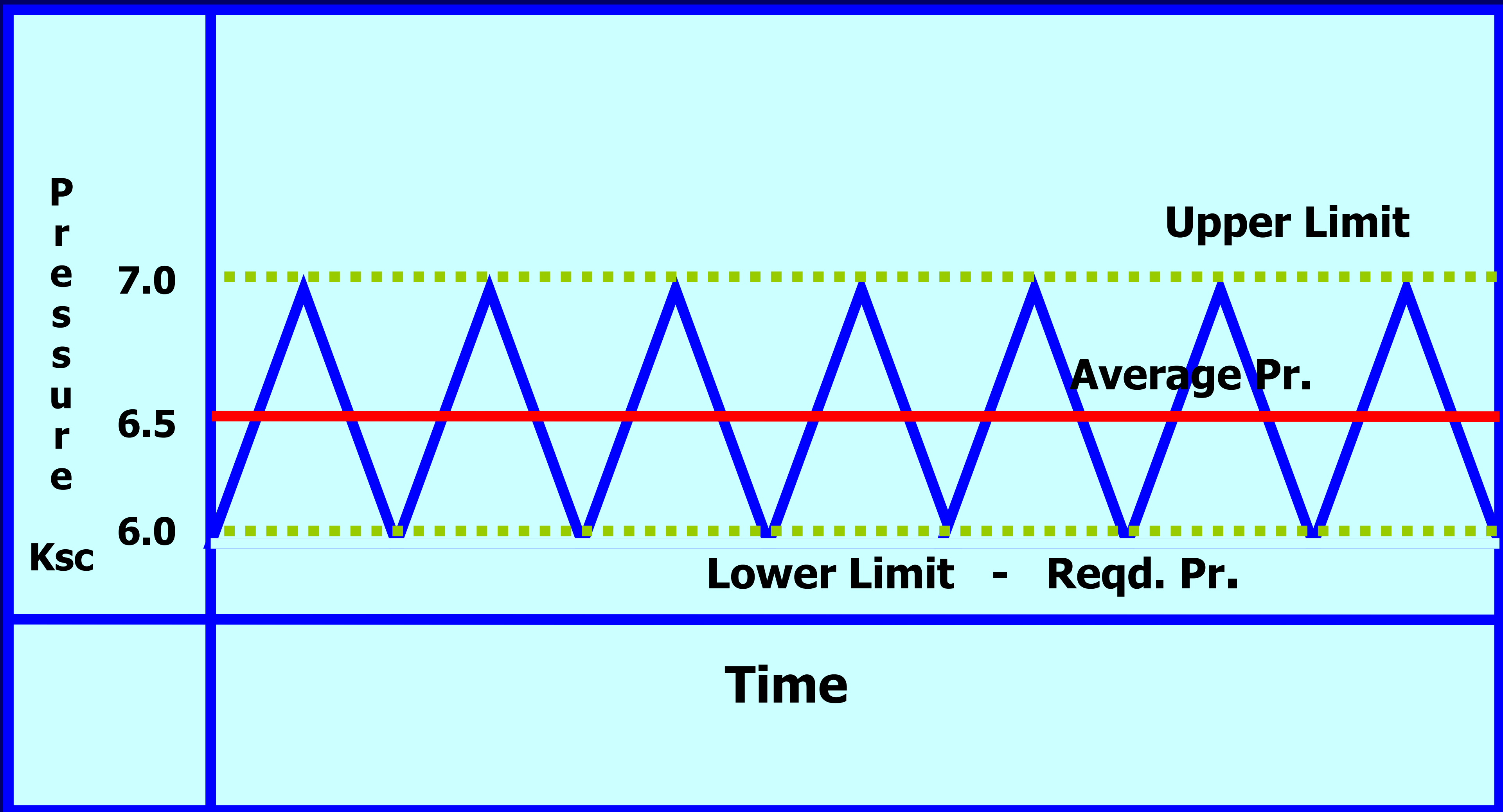
VFD - Concept

Advantages

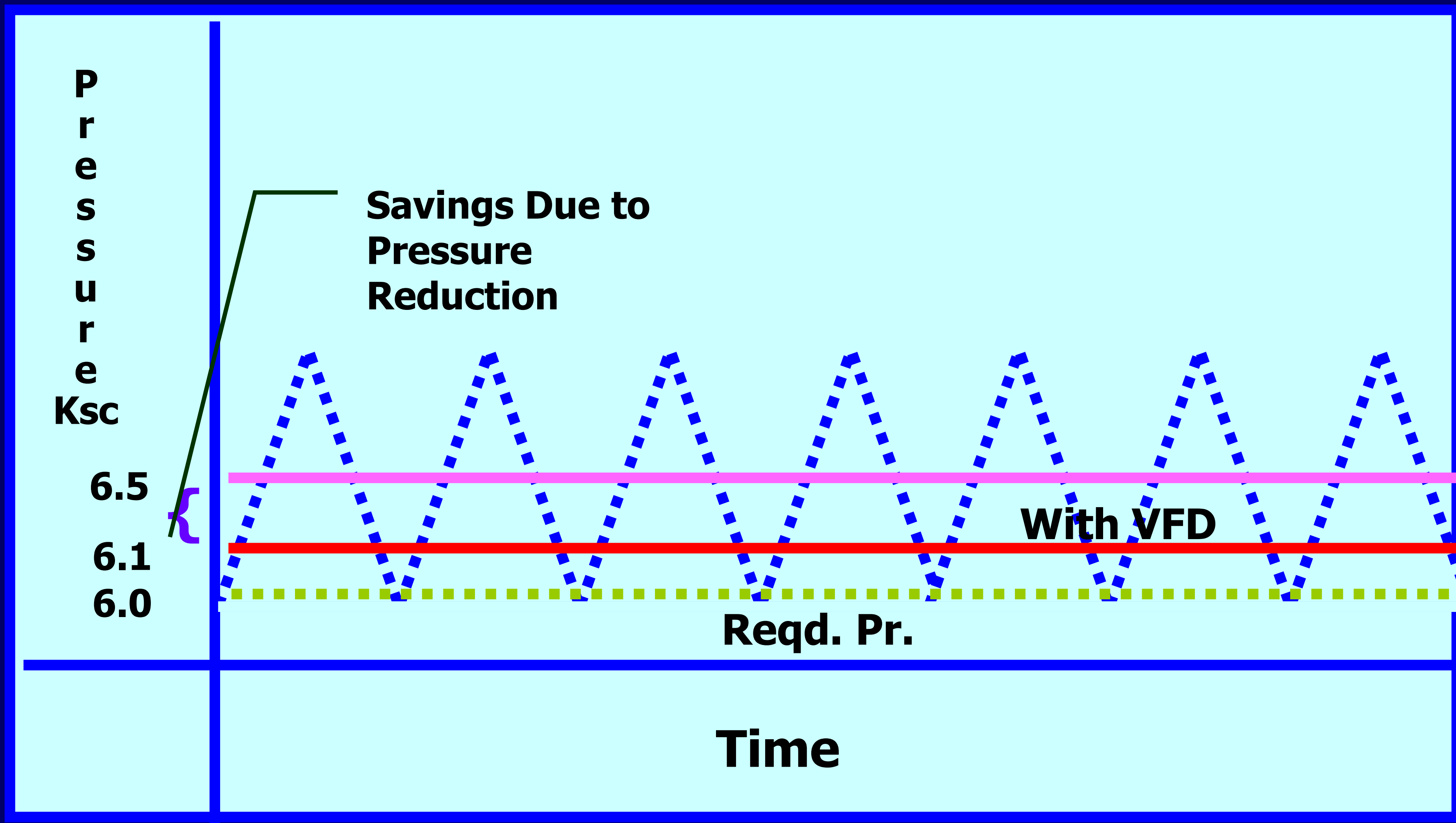
- Operates at Lower Avg. Pressure
  - Proportional Savings
- No Unloading
- Less Leakages
  - Lower Pressure
- Better Motor Efficiency



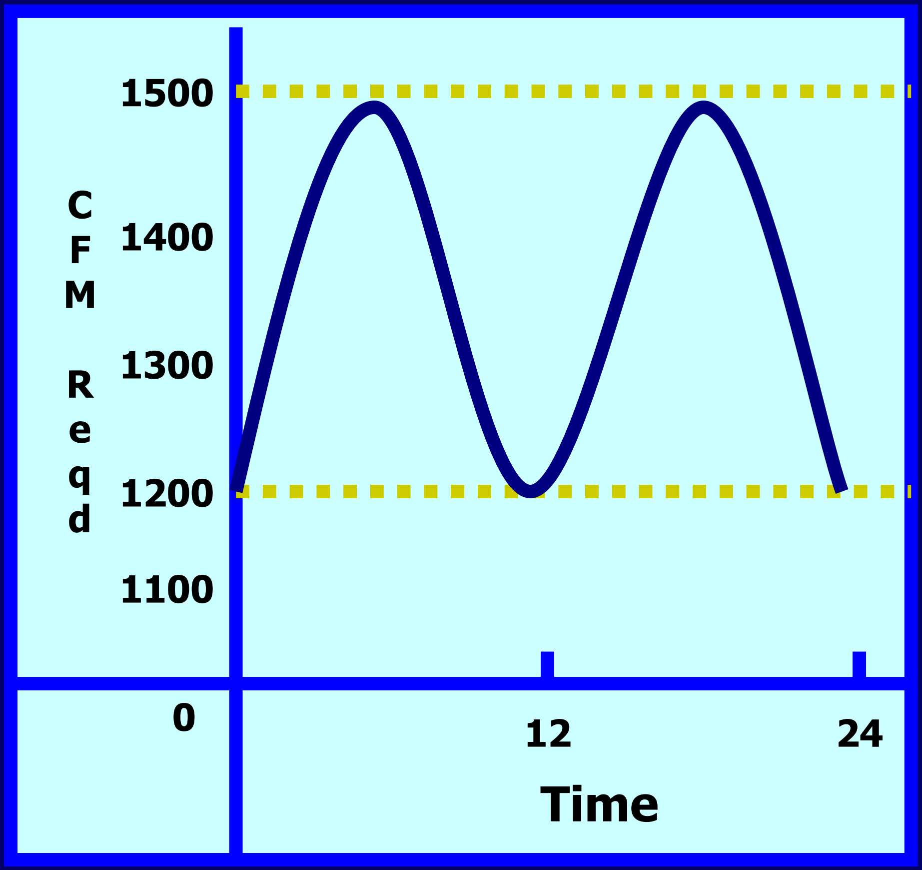
Concept - Conventional Control



Concept - VFD Control

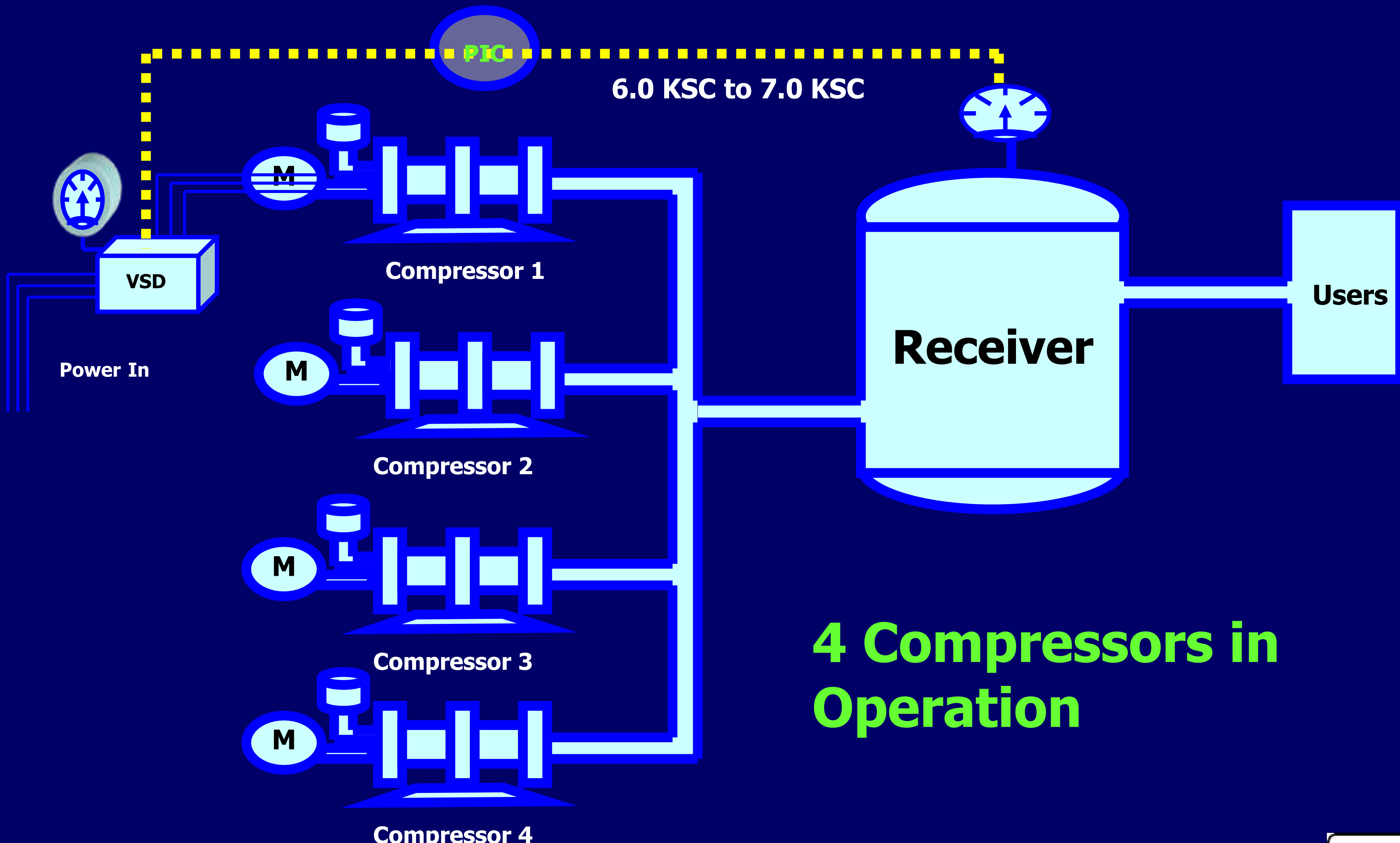


Savings in Unload Power



- Compressors Designed to meet Fluctuating Load
- Fluctuating Load Leads to Load / Unload
- Lean Time - Unload
- Unload power 15 - 40%
- No useful work
- VSD Avoids Unloading of Compressors

Case Study



4 Compressors in Operation

Install VFD for One Compressor

- VFD For One Compressor
- Constant Pressure of 6.0 ksc
- 4% Savings in all compressors

Annual Savings	= Rs.12.00 Lakhs
Investment	= Rs. 12.00 Lakhs
Payback period	= 12 Months

Optimise power consumption of compressed air

- Present System – 5 compressors installed in the plant
  - Comp 1 – 204 cfm
  - Comp 3 – 735 cfm
  - Comp 4 – 735 cfm
  - Comp 5 – 900 cfm
  - Comp 6 – 850 cfm (new comp with VSD)

Optimise power consumption of compressed air

- Present Operation– 2 compressors running
- Case – I (at average load)
  - Comp 1 – 204 cfm
  - Comp 6 – 850 cfm (new comp with VSD)
- Case - II (at higher load)
  - Comp 5 – 900 cfm
  - Comp 6 – 850 cfm (new comp with VSD)

Optimise power consumption of compressed air

❖ **Present Demand Pattern –**

- Base load – around 800 cfm
- Average load – around 1000 cfm
- Peak load – around 1100 – 1200 cfm

Optimise power consumption of compressed air

- **During base load & average load –**
  - Comp 1 & Comp 6 in operation
  - Comp 1: 200 cfm
  - Comp 6: 850 cfm
  - Both compressor runs at full load
  - supply = demand
  - Best system

Optimise power consumption of compressed air

❖ **During peak load & average load – 1100 – 1200 cfm**

- Comp 1 & Comp 6 in operation
- Comp 5: 900 cfm
- Comp 6: 850 cfm
- Compressor no 5: runs at full load
- Comp no 6: runs at part load (800-900 rpm)

Optimise power consumption of compressed air

- **During base load & average load**

Lowest unit consumption in July	2900 units
Lowest unit consumption in Aug (12 days)	3000 units

Optimise power consumption of compressed air

- **During peak load & average load – 1100 cfm – 1200 cfm**

Peak unit consumption in July	4180 units
Average unit consumption in Aug (12 days)	3900 units

What should be my bench mark?

Optimise power consumption of compressed air

- **Action Plan –**
  - Install new compressor of 400 cfm with VFD
  - Operate Comp 6: 850 cfm on base load
  - Operate New Comp: on variable load

Bench mark -2500 – 2700 units/day

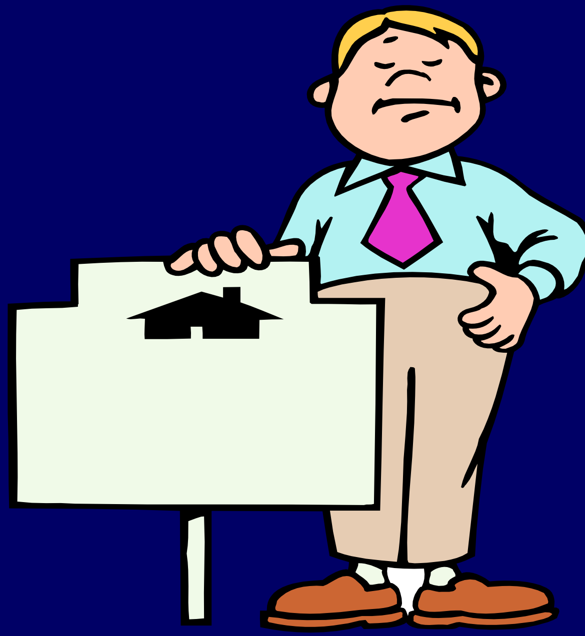
Optimise power consumption of compressed air

Annual Savings	-	Rs 10.0 Lakhs
Investment	-	Rs. 7.0 Lakhs
Simple Payback	-	9 months

Compressor Layout

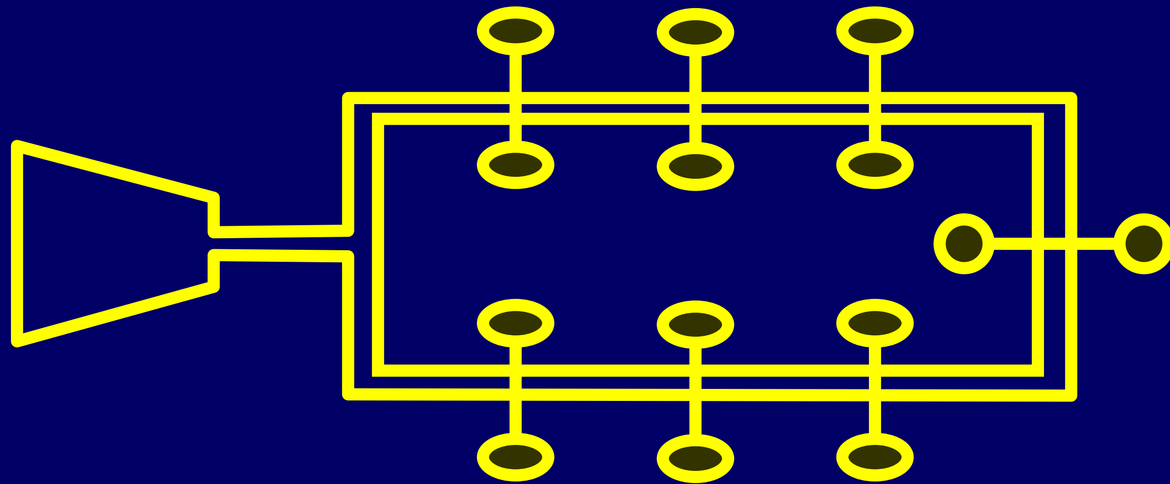
Loop header most efficient

- Pressure losses are lesser
- Easier to add/delete user points

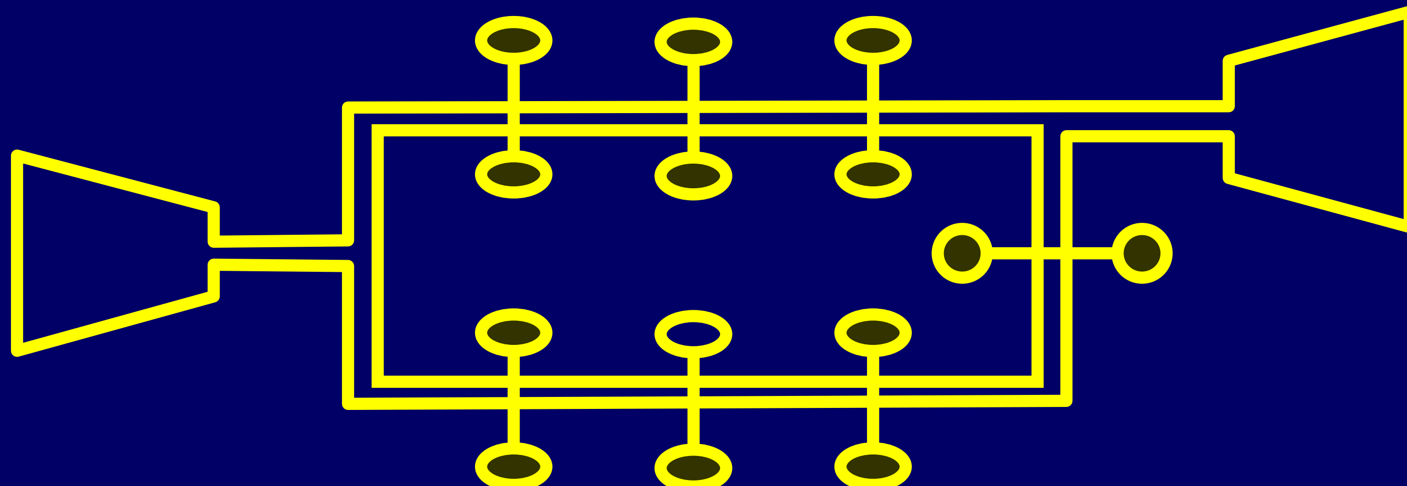


Compressor Layout

Loop

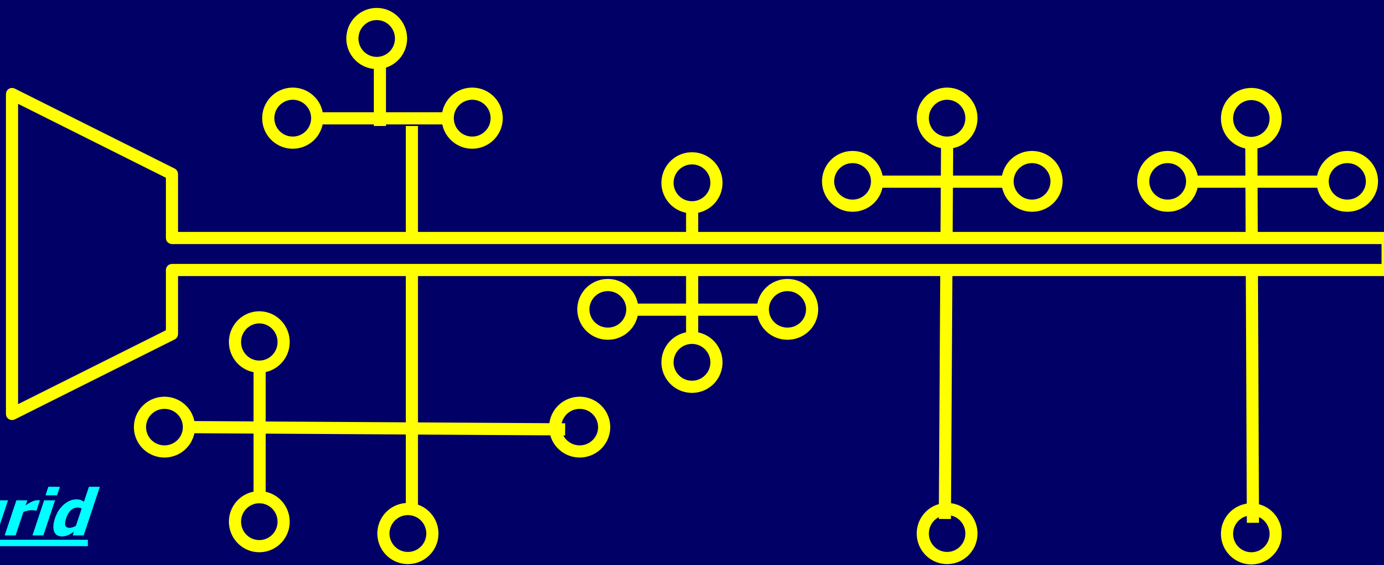


Unit loop

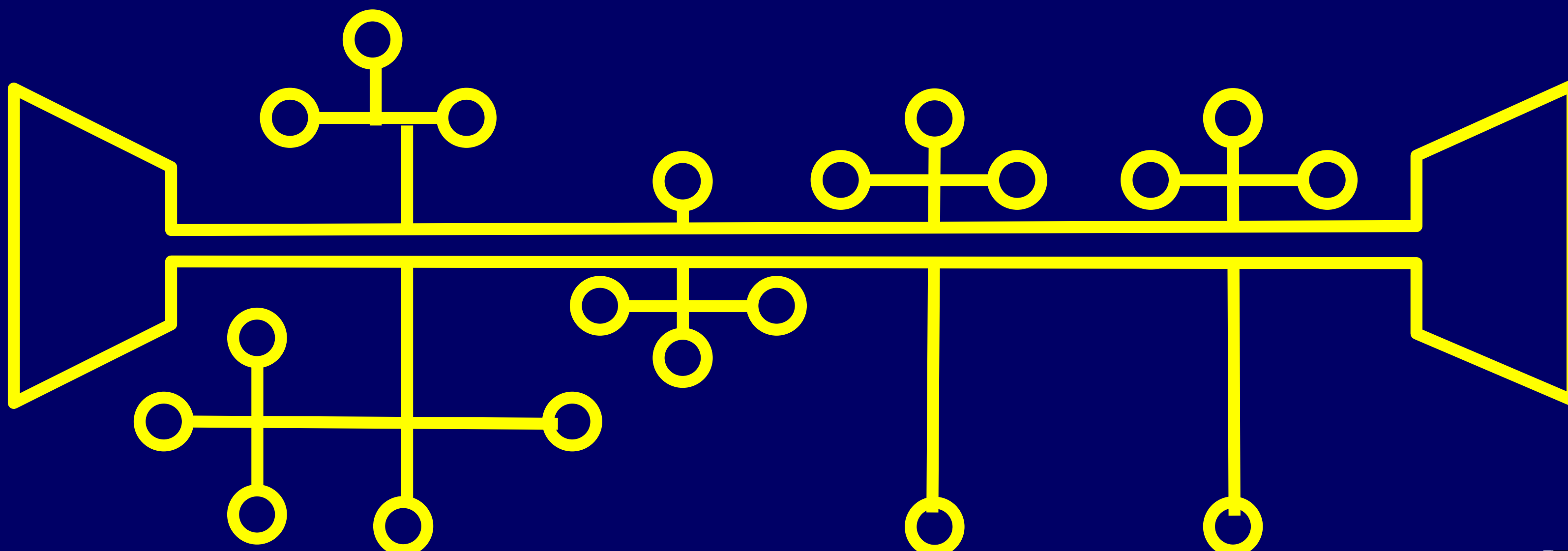


Compressor Layout..

Grid



Unit grid



Pressure drops in lines

- Excessive pressure loss in lines leads to power loss

TYPICAL ENERGY WASTAGE DUE TO SMALLER PIPE DIAMETER FOR 100 CFM FLOW		
Pipe nominal Bore (mm)	**Pressure drop (bar) per 100 meters**	**Equivalent power losses (kW)**
40	1.8	9.5
50	0.65	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

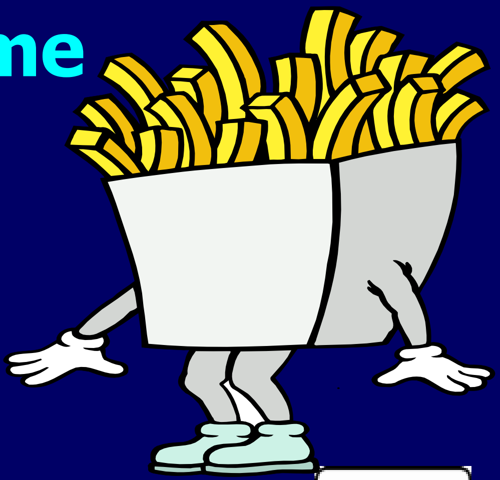
- ***Acceptable pressure drop:***
  - ✓ ***0.3 bar in main header at farthest point***
  - ✓ ***0.5 bar in distribution system***

Minimise Leakages

- Common in all industries
- Tricky
- Quantification

Quantification

- Allow compressor to run normally
- Allow compressed air to flow in the system
- Close all the user points
- Measure the loading and unloading time
- % of loading time is % of leakages



Leakage Test

- Close all the user points & Charge all the lines
- Note the Load time of compressor (T)

  and

  Unload time of compressor (t)
- % air leakage (L) = [T/ (T + t)] x 100
- Qty. of leakages = L x Compressor Capacity (Q)

Cost Of Leakage At 7kg/cm^2

Orifice dia (mm)	Air Leakage (cfm)	Power Wasted (kW)	Annual Savings @ Rs.5.0/kWh.
1.6	6.5	1.26	Rs.65,000
3.2	26.0	5.04	Rs.2,00,000
6.4	104.0	20.19	Rs.6,25,000

CII

Replace Compressed Air with Blower Air for Agitation in ETP

- ETP – Agitation Very Important
- Compressed air used in several industries
  - Highly energy intensive
- 7 ksc pressure utilised for 8' depth tank
  - Required pressure 0.5 ksc only
  - Quantity consumed – 120 cfm
- For Agitation - Quantity is Criteria, Not Pressure!!

Replace Pneumatic Tools With Electric Tools

Background

- Compressed air costlier
  - Theoretically - 25% more
- In practice much more than that
- 40 pneumatic grinders in a plant

Action

- Replaced 40 pneumatic grinders

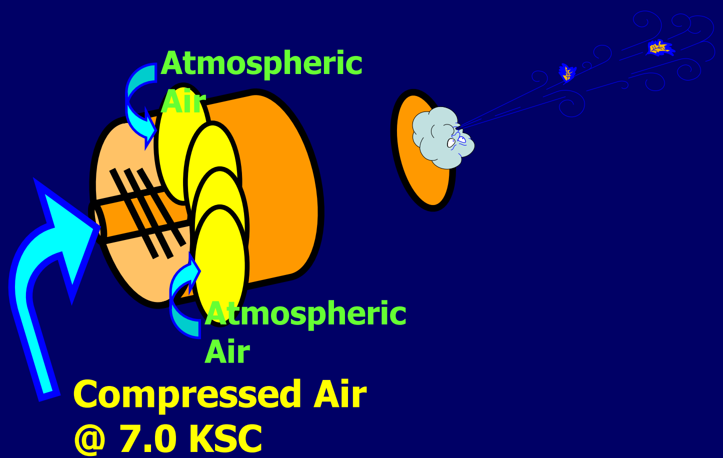
Annual Savings	- Rs. 6.50 lakhs
Investment	- Rs. 11.00 lakhs
Payback period	- 21 months

CII

Use Transvector Nozzle In Air Hose

- Sucks atmospheric air along with air jet
  - Reduces air consumption by 50%
- Compressed air used for cleaning the burrs
- Provided transvector nozzles at the end users

Annual Savings	**- Rs. 0.48 Lakhs**
Investment	**- Rs.0.25 Lakhs**
Payback period	**- 6 months**



Compressed Air Dryers

- Adsorption Type
  - Dessicant Heatless Type
  - Dessicant Heated Type
  - Dessicant Heat of Compression Type
- Refrigeration Type

Why Air Dryer?

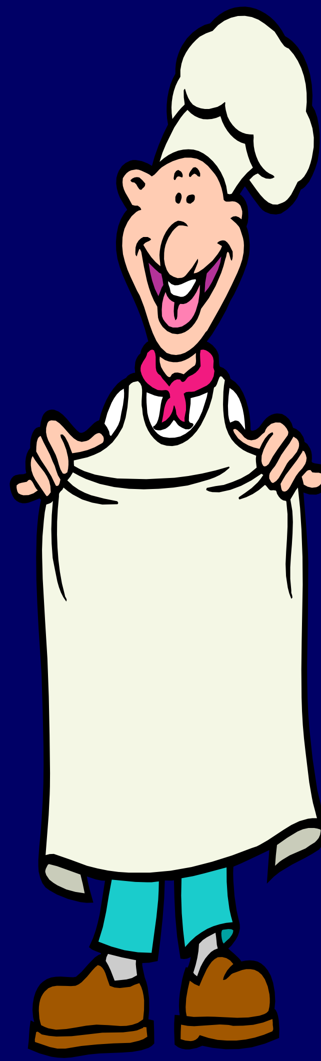
- Water carryover damaging instruments
- Possible corrosion of receiver and air lines

Comparison of Air Dryers

Type of Dryer (cfm)	Capital Cost	Running Cost	Atmospheric Dew Point oC	Pressure Drop	Best Suitable for
Dessicant Heatless	Low	High	-40	Medium	150
Dessicant Heated	High	Medium	-40	High	100-750
Dessicant HOC	High	Very Low	-40	High	>500
Refrigeration Dryer	Medium	Low	-20	Low	100

List Of Energy Saving Ideas In Compressed Air System

- **Select correct size air compressor**
- **Operate compressor at required pressure**
- **Install VFD**
- **Minimise system losses - Proper line sizing**
- **Replace compressed air with blower air for agitation**
- **Replace pneumatic tools with electric tools**



List Of Energy Saving Ideas In Compressed Air System

- **Provide ball valves at the user point to avoid compressed air wastage**
- **Use transvector nozzles in air hoses**
- **Cool inlet air to the compressor**
- **Provide sensors to sense unloading and switch off**
- **Replace inefficient compressors**
- **Install high efficiency dryers**

The Challenge

- Reduce energy consumed by compressed air system in your plant by 20 - 50%
- provide a more reliable and stable platform of supply to all users - and most specifically to the critical users
- This must be accomplished at a reasonable cost with a less than two year pay back or less.

Thank you

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