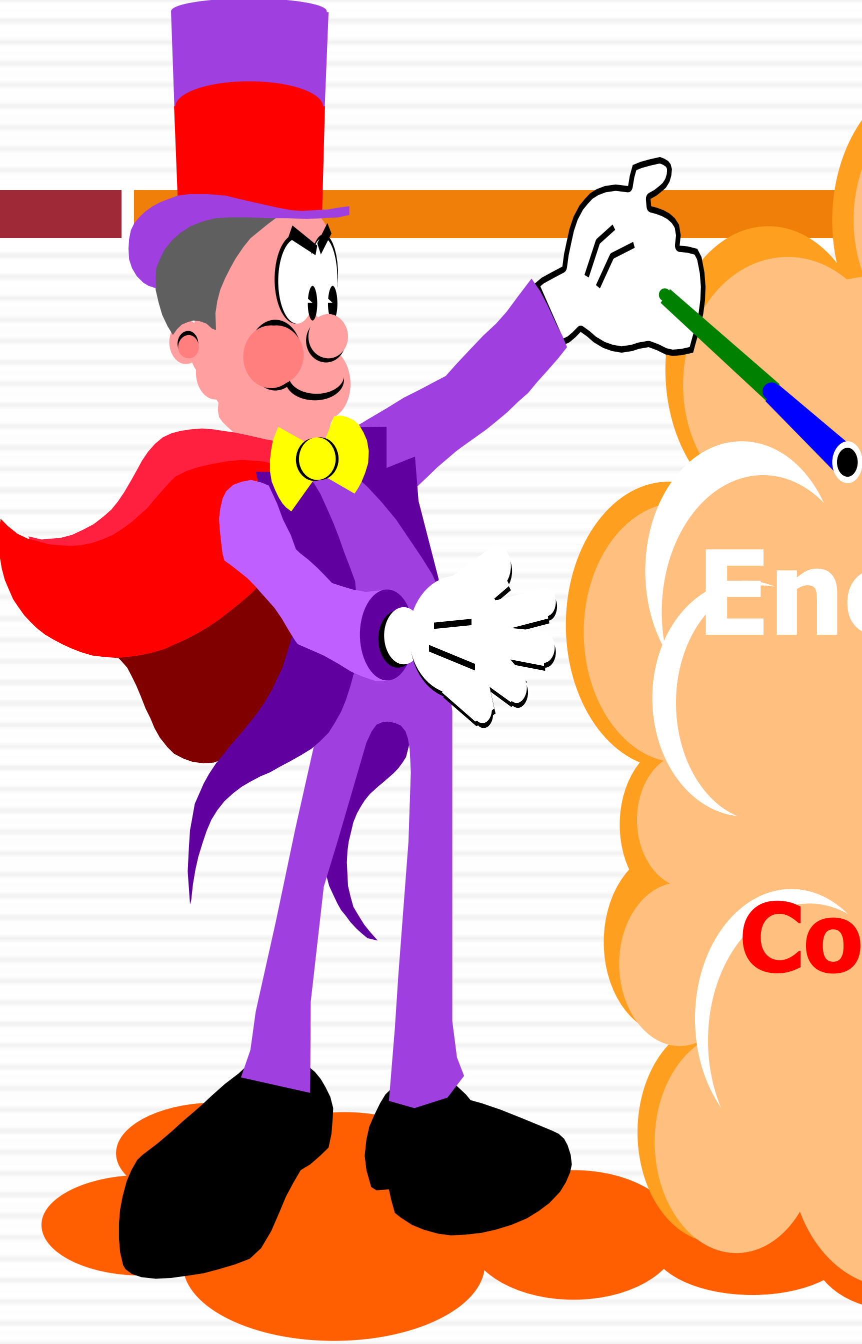
Which is the least energy efficient Equipment is your plant?

- Electrical Motor
- Transformer
- Pumps
- Compressed air system



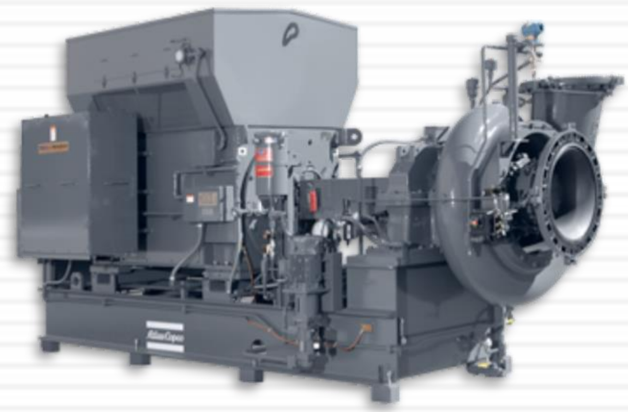
Energy Conservation

in

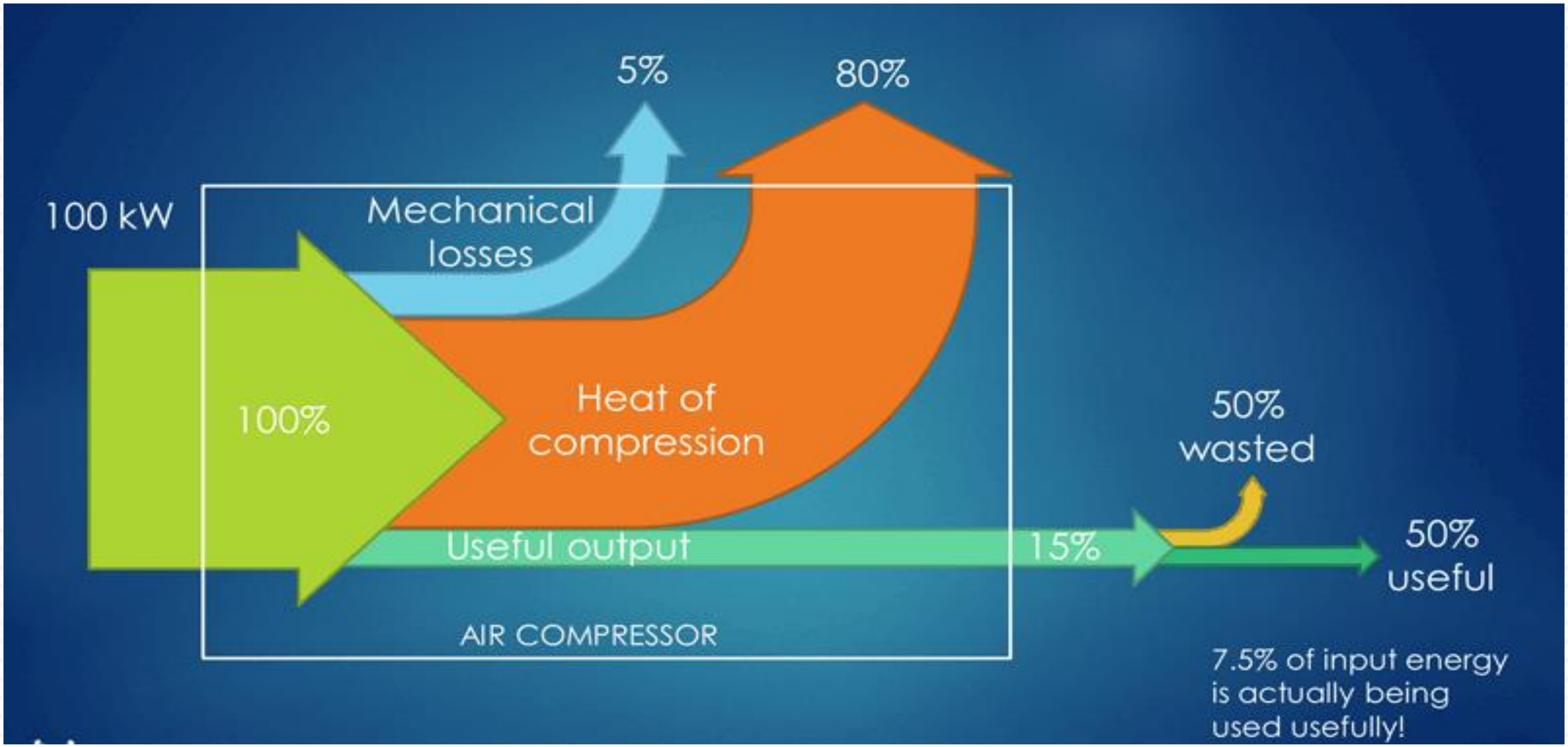
Air Compressors & Compressed Air System

Air Compressors

- Compressors
  - Positive Displacement
    - Reciprocating Type
    - Rotary Screw Type
  - Centrifugal Type
    - Radial Flow
    - Axial Flow

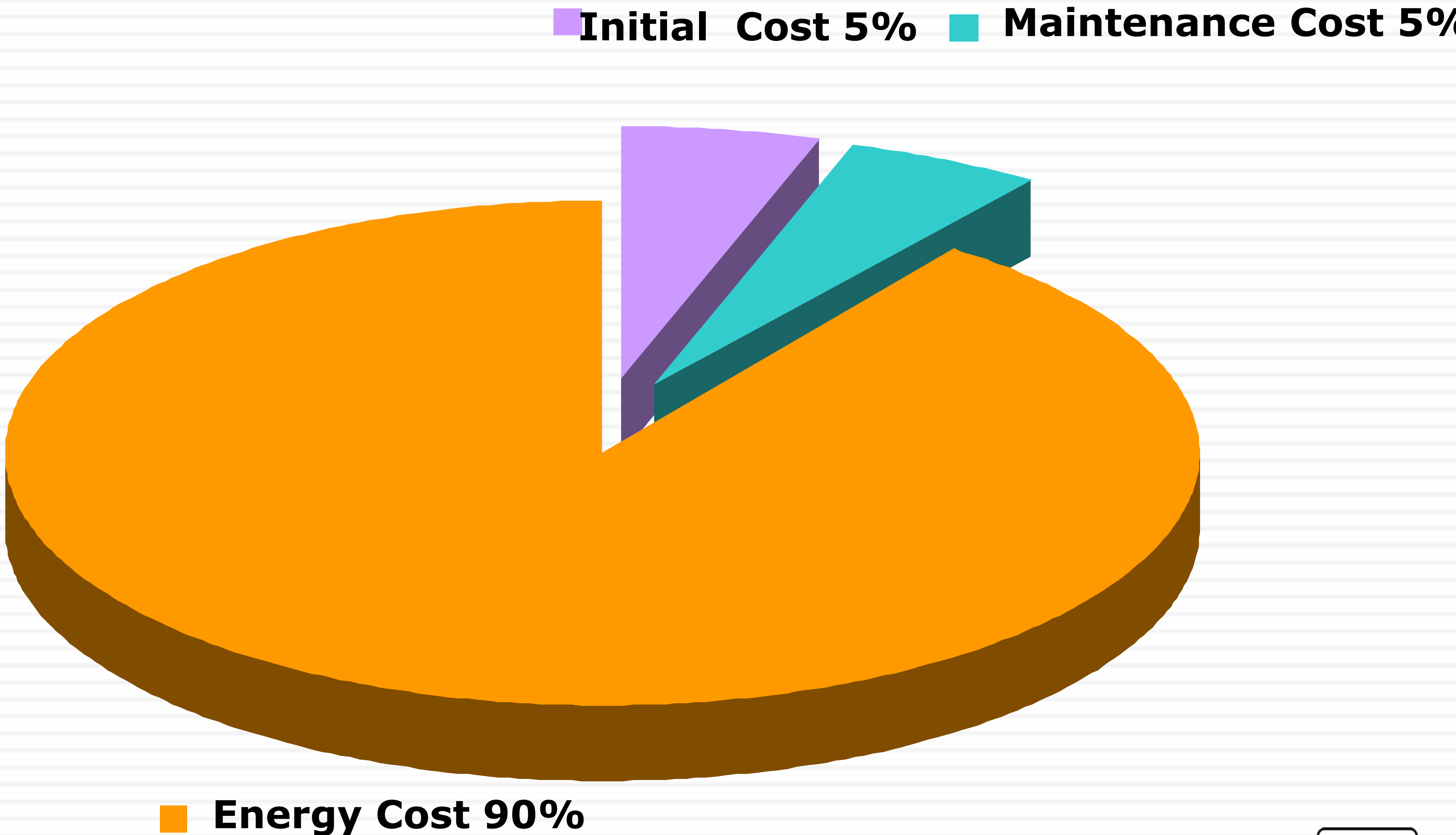


Sankey Diagram of Compressed Air System



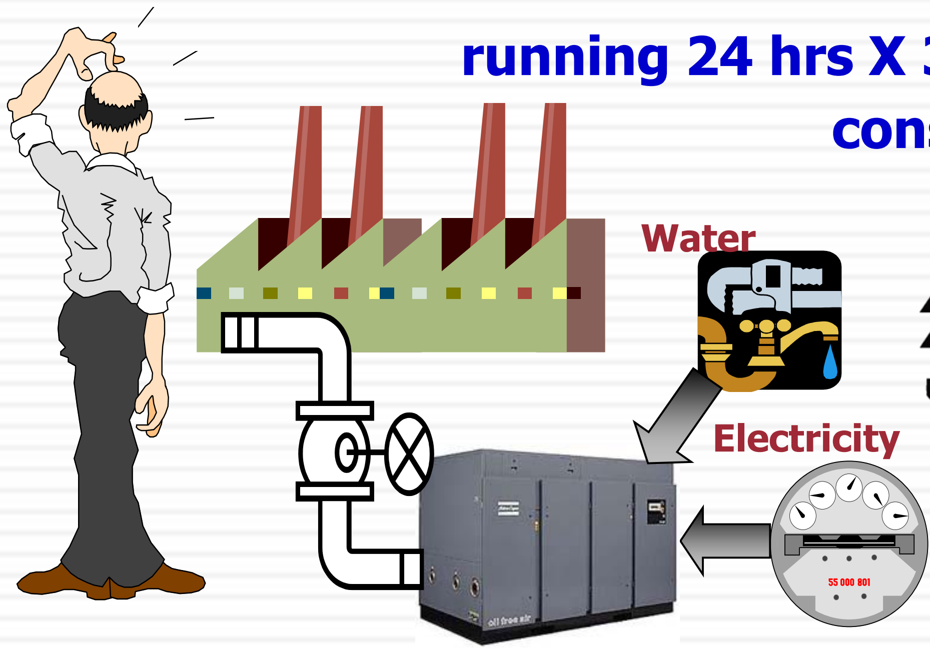
Compressed Air: Most Expensive Form of Energy!

Life Cycle Cost For A Compressor



Energy Cost of Running Air Compressor

500 cfm, 100 psi(g) Air Compressor
i.e. 120HP / 90kW Motor
running 24 hrs X 350 days with 70% Load Factor
consumes ~ 600,000 kWh annually

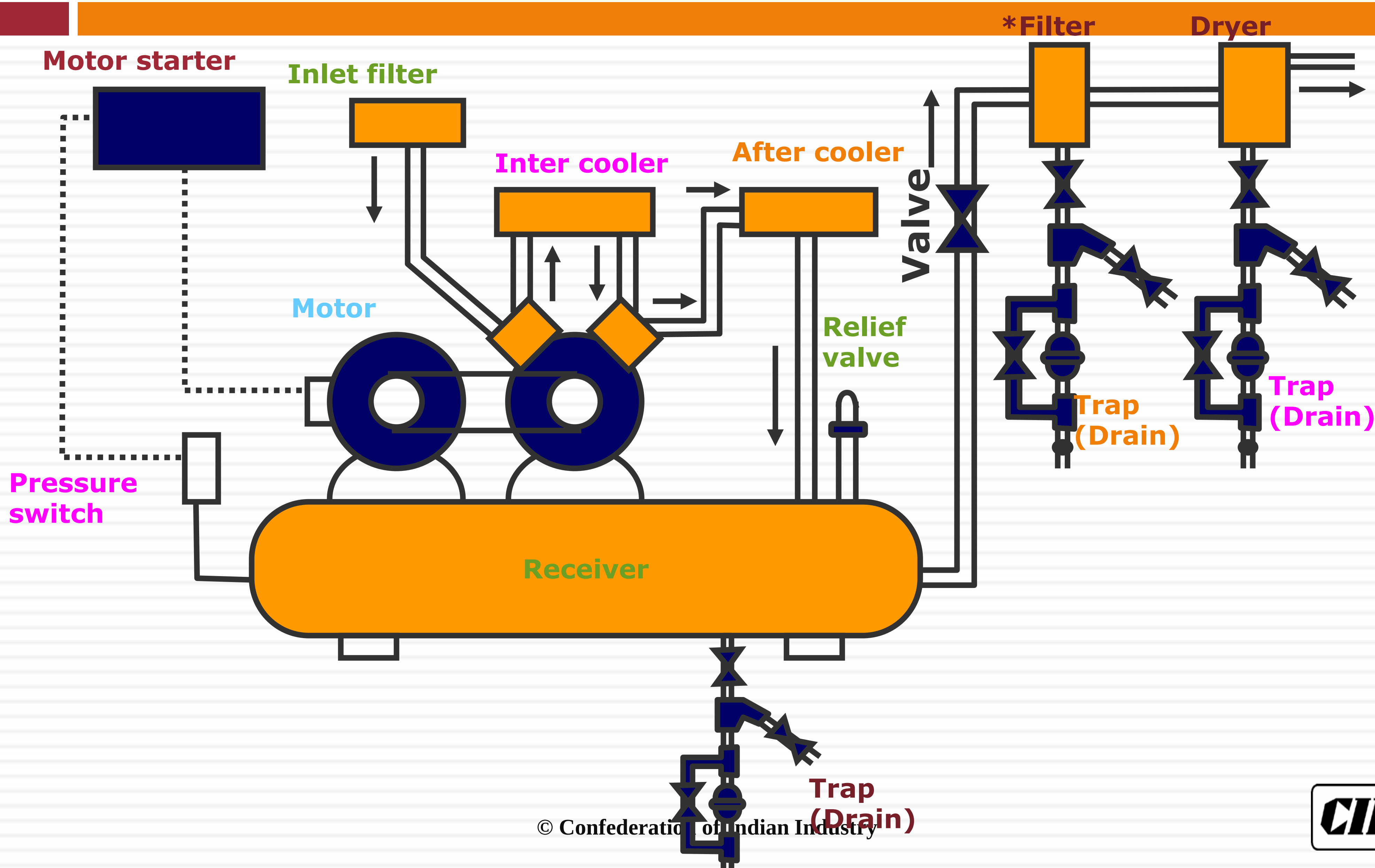


₹ **@ rate of Rs. 6/kWh,**

Costs Rs. 36 Lacs/year

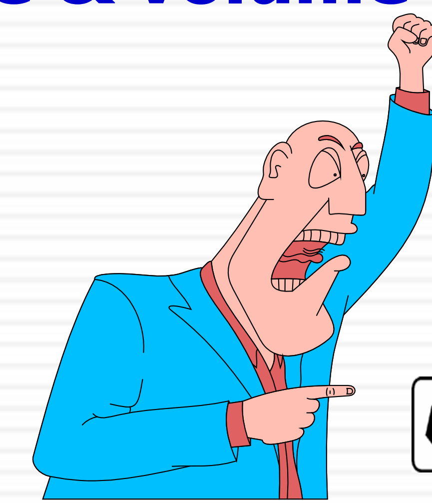
Which is 4 times the cost of Compressor itself !!

Two Stage Reciprocating Compressor



Why Inter-cooler?

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



Why After-Cooler?

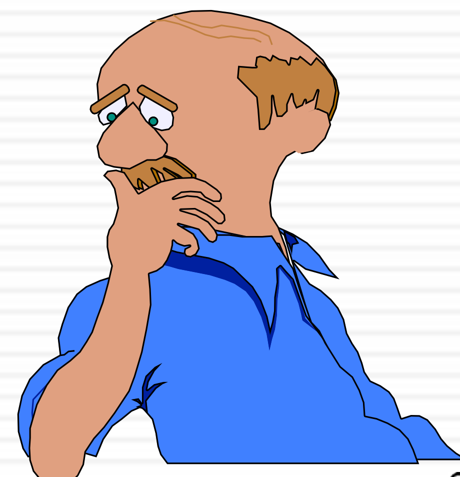
- At higher temperature moisture carry over very high
- Condensed water moves with same velocity of air
  - Damage to instrument valves
  - Makes instruments sluggish
- After-cooler saves energy – higher when air dryers are installed

How much is the energy savings?

A) Savings same as inter cooler - 7 %

b) Higher than inter cooler

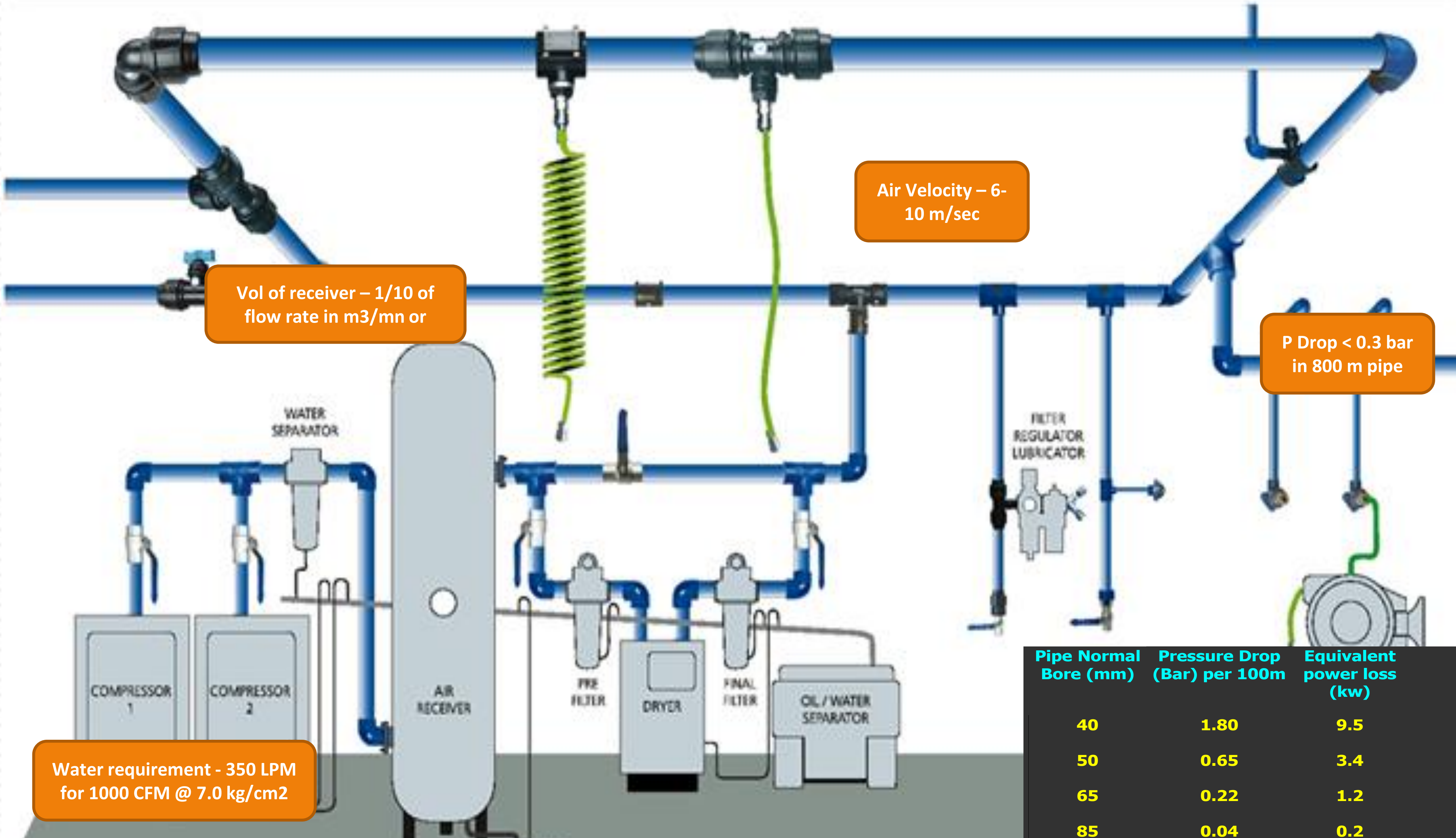
c) Lesser than inter cooler



CII

Check list for efficient operation of Compressor

Rules of Thumb



Pipe Normal Bore (mm)	Pressure Drop (Bar) per 100m	Equivalent power loss (kw)
40	1.80	9.5
50	0.65	3.4
65	0.22	1.2
85	0.04	0.2

Dry Air Intake

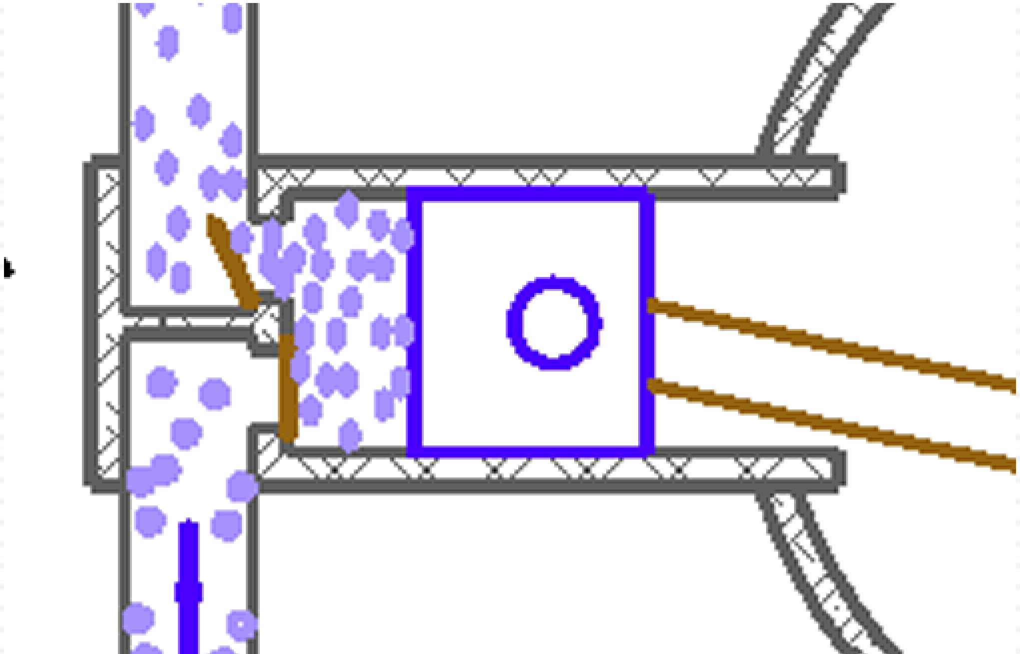
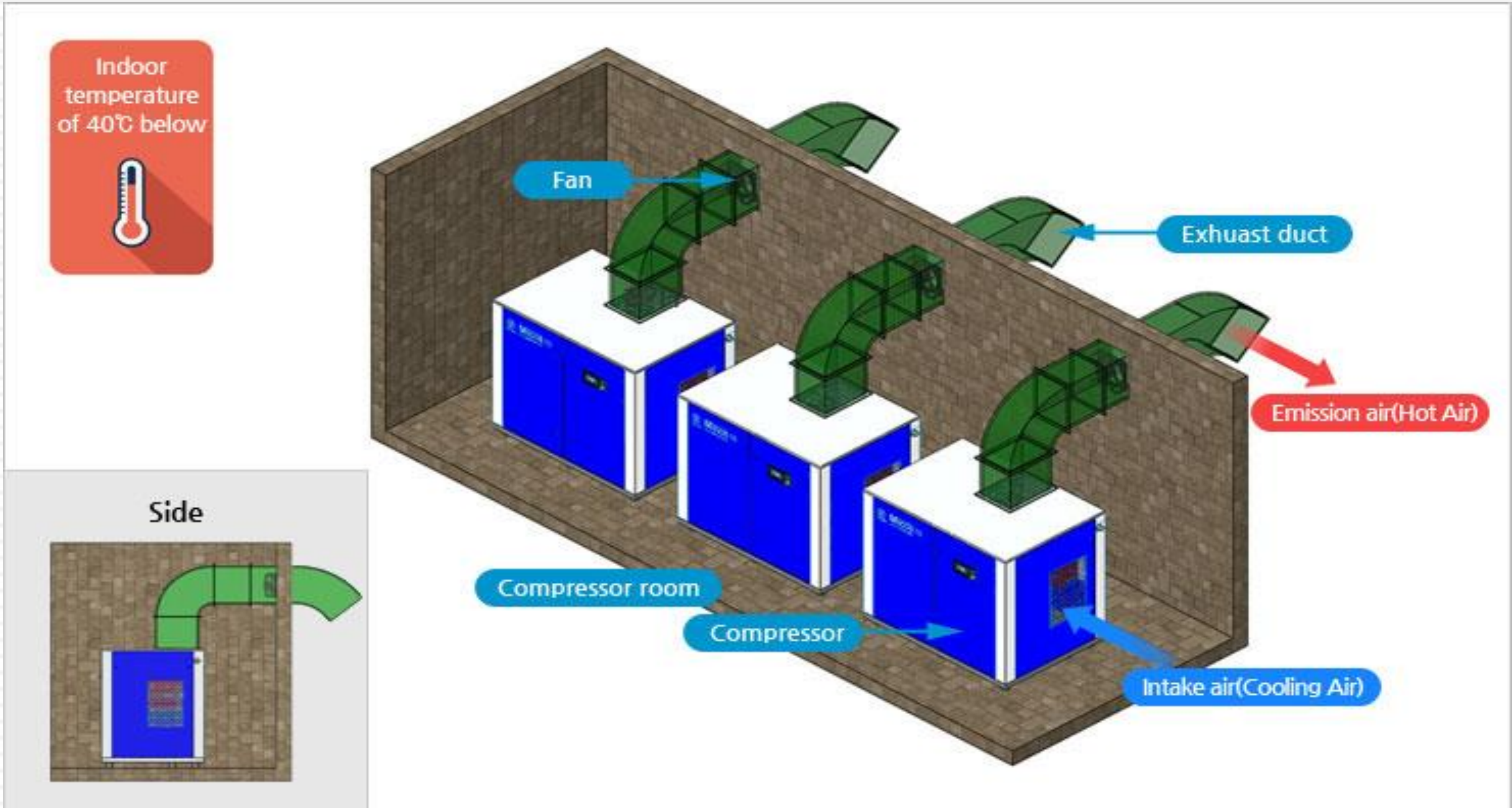


TABLE 3.2 EFFECT OF INTAKE AIR TEMPERATURE ON POWER CONSUMPTION		
Inlet Temperature (°C)	Relative Air Delivery (%)	Power Saved (%)
10.0	102.0	+ 1.4
15.5	100.0	Nil
21.1	98.1	– 1.3
26.6	96.3	– 2.5
32.2	94.1	– 4.0
37.7	92.8	– 5.0
43.3	91.2	– 5.8

Every 4°C rise in inlet air temperature results in a higher energy consumption by 1 % to achieve equivalent output

Compressor Room



CII

Pressure settings

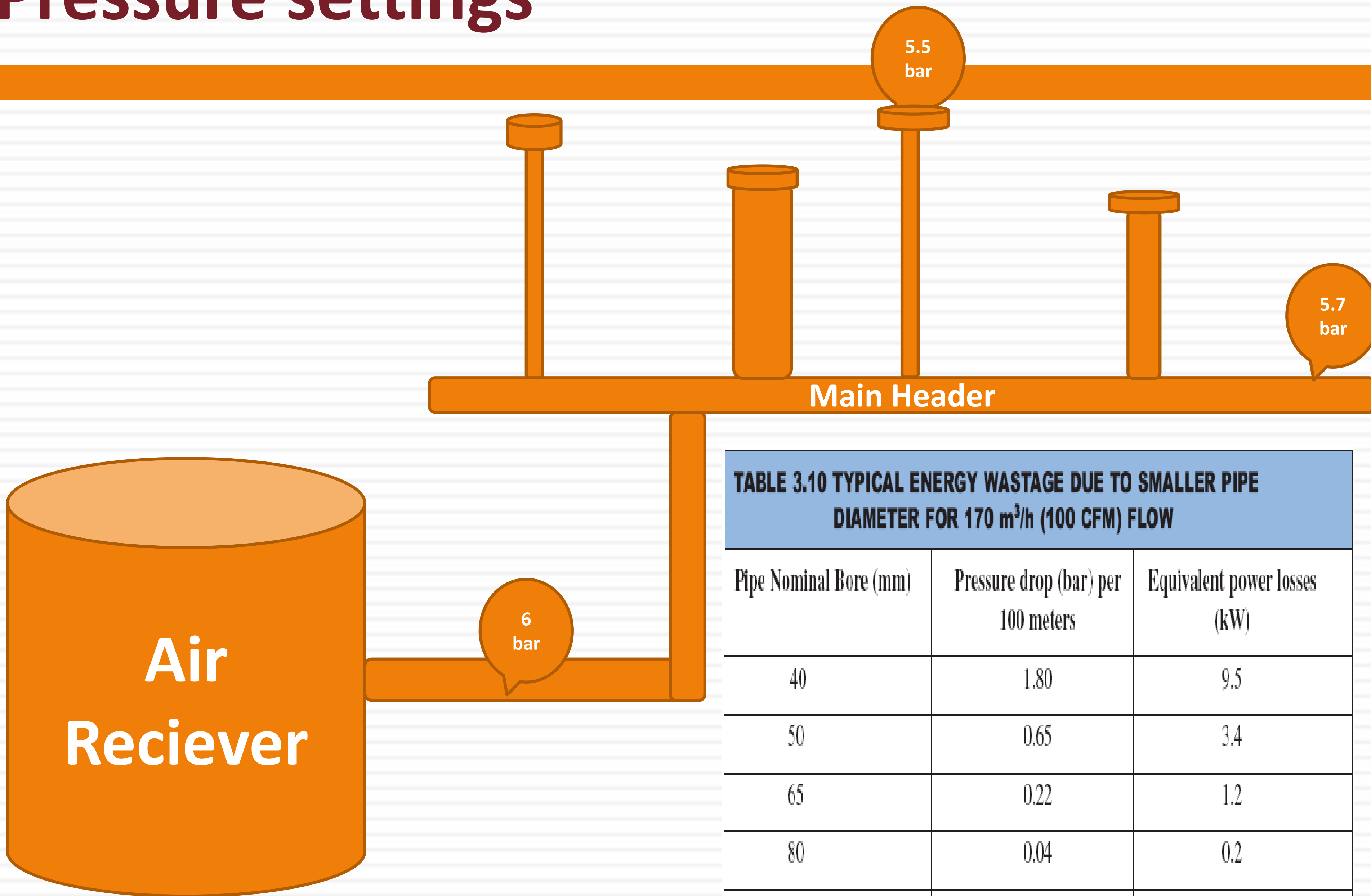


TABLE 3.10 TYPICAL ENERGY WASTAGE DUE TO SMALLER PIPE DIAMETER FOR 170 m^3/h (100 CFM) FLOW		
Pipe Nominal Bore (mm)	Pressure drop (bar) per 100 meters	Equivalent power losses (kW)
40	1.80	9.5
50	0.65	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

Capacity Test (Pumping Method)

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 receiver
Δt	=	Time taken for charging the receiver from P_1 to P_2

Operation of compressors

- 5 compressors available
  - 660 CFM, 7.5 bar, 110 kW
- 3 compressors are required to be operated

Operation of Compressors

No			
CP1			
CP2			
CP3			
CP4			
CP5			

Operation of Compressors

No	kW		
CP1	110		
CP2	90		
CP3	100		
CP4	105		
CP5	95		

Operation of Compressors

No	kW	FAD	
CP1	110	660	
CP2	90	500	
CP3	100	600	
CP4	105	645	
CP5	95	470	

Operation of Compressors

No	kW	FAD	kW / CFM
CP1	110	660	0.17
CP2	90	500	0.18
CP3	100	600	0.17
CP4	105	645	0.16
CP5	95	470	0.20

Always select compressor based on SEC (kW/CFM) not on kW and CFM separately

CII

Comparison of Specific Power Consumption

	Reciprocating	Centrifugal	Screw (Single stage)	Screw (Multi stage)
FAD	3950 CFM at 7kg/cm^2			
kW	549	515	632	510
Specific Power (kW/CFM)	0.139	0.130	0.162	0.129

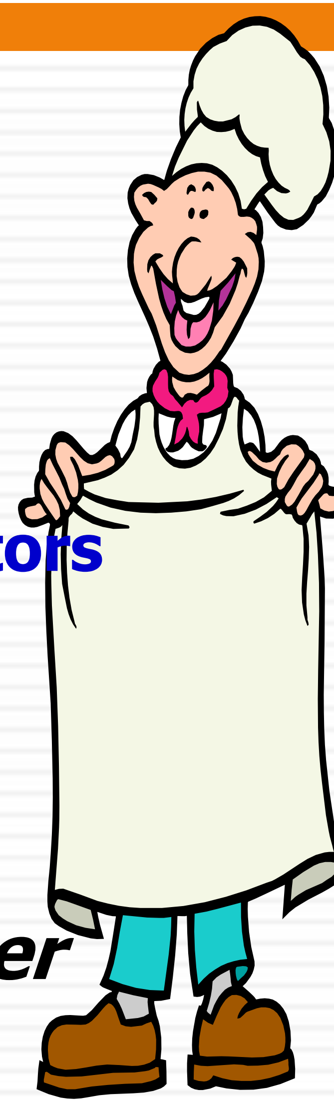
CII

Energy Losses

System Losses waste 20%!!

- **Pressure Loss in Pipelines, Bends & Valves**
- **Air Leakages from Corroded Pipe**
- **Pressure Loss in After Coolers, Moisture Separators**
- **Air leakages in joints & end connections**
- **Pressure Loss across Filters & Dryers**

Leading to Compressor operation at Higher Pressure to overcome these losses!



Minimise Leakages

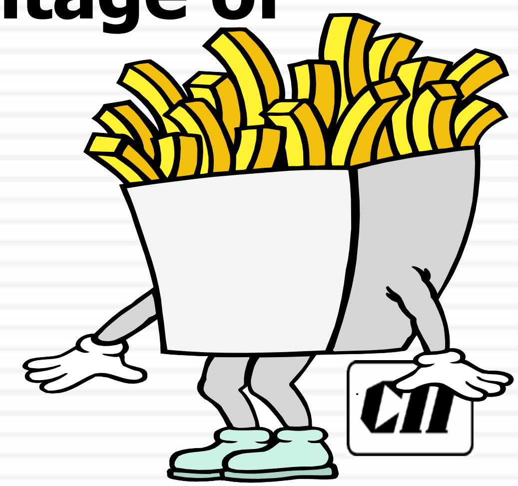
- **Common in all industries**
- **Tricky**
- **Quantification**

God has given abundant air, which is free!!

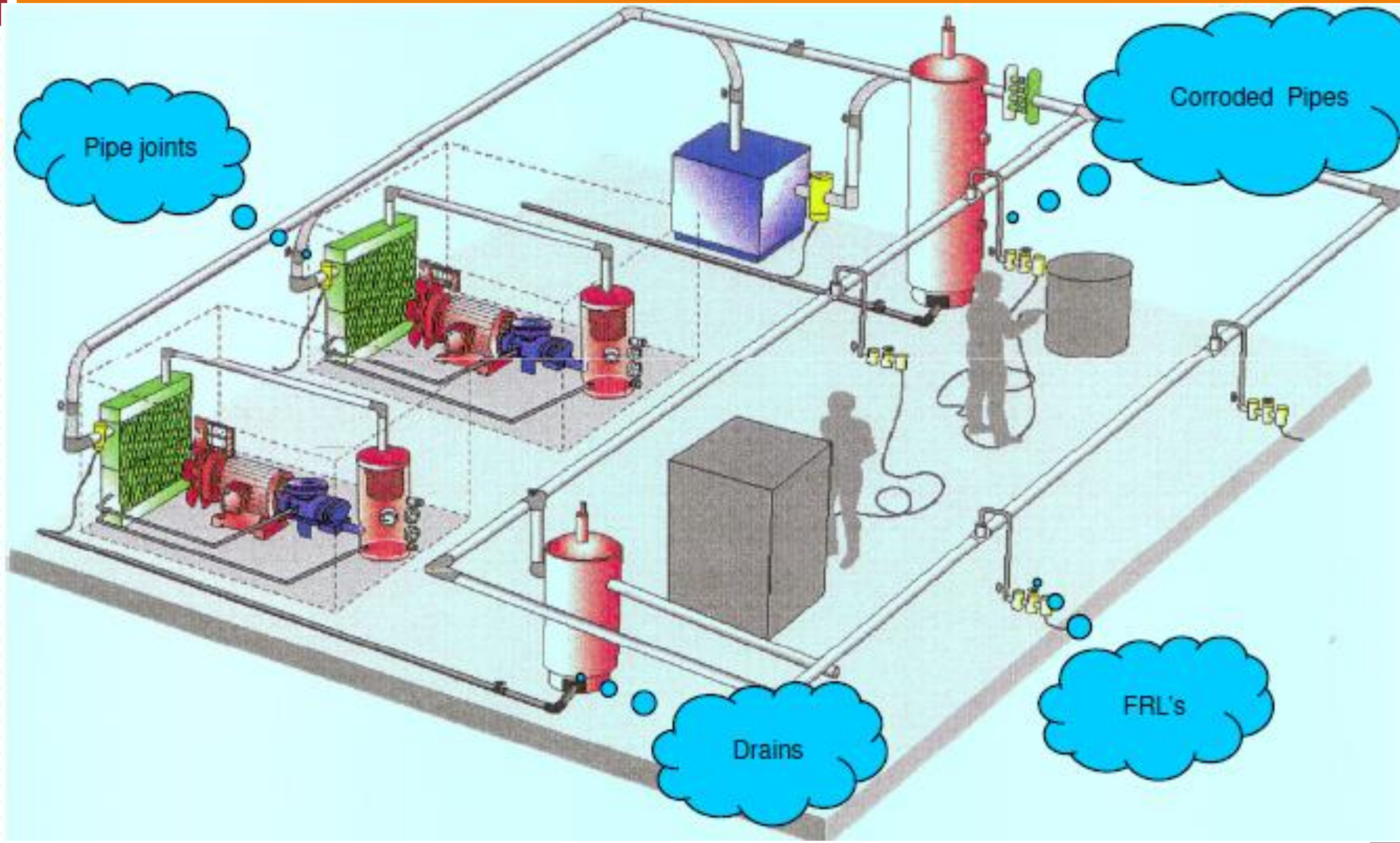
But … compressed air is not free!!

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
- Percentage of loading time is percentage of leakages



Common Leak Locations



Leakage Test

- Close all user points
- Charge the lines
- Note: On-load time of compressor (T)
  Off-load time of compressor (t)
- Q : Capacity of compressor

$$\text{Air leakage : L} = \left(\frac{T}{T + t} \right) \cdot Q$$

$$\text{\% air leakage} = \frac{\text{Air leakage}}{\text{Compressor capacity}} \times 100$$

CII

Cost Of Leakage At $7 kg/cm^2$

Orifice (mm)	Air Leakage (CFM)	Power Wasted (kW)	Annual Savings @ Rs 5/kWh
1.6	6.5	1.26	Rs 0.60 Lakhs
3.2	26	5.04	Rs 2.40 Lakhs
6.4	104	20.19	Rs 7.25 Lakhs

CII

Case Studies

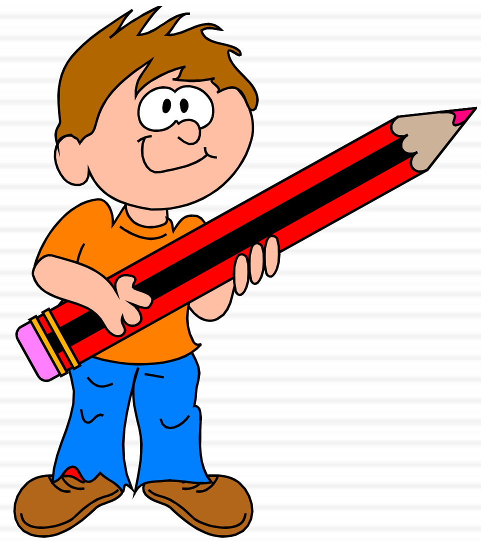
Optimal Utilisation of Compressors

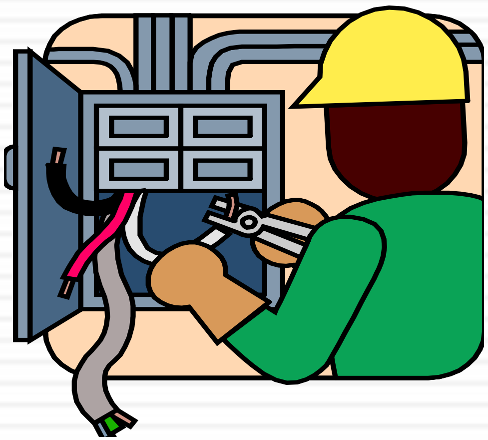
Background

37 kW compressor in operation

At present loading - 30%

Unloading - 70%





Power consumption

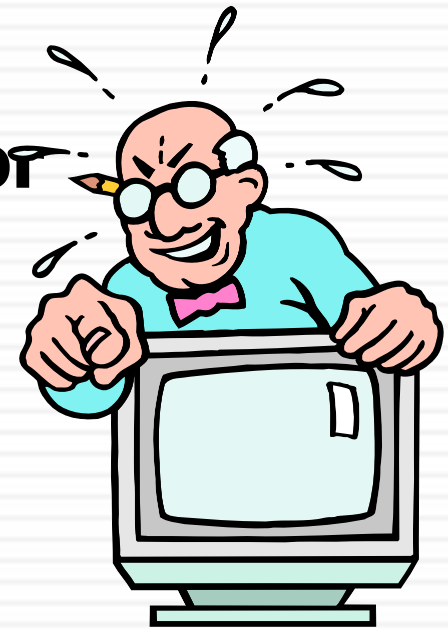
Unload - 9 kW

Loading - 27 kW

Install 15 kW ON/OFF Air Compressor and Use Existing 37 kW Air Compressor as Standby

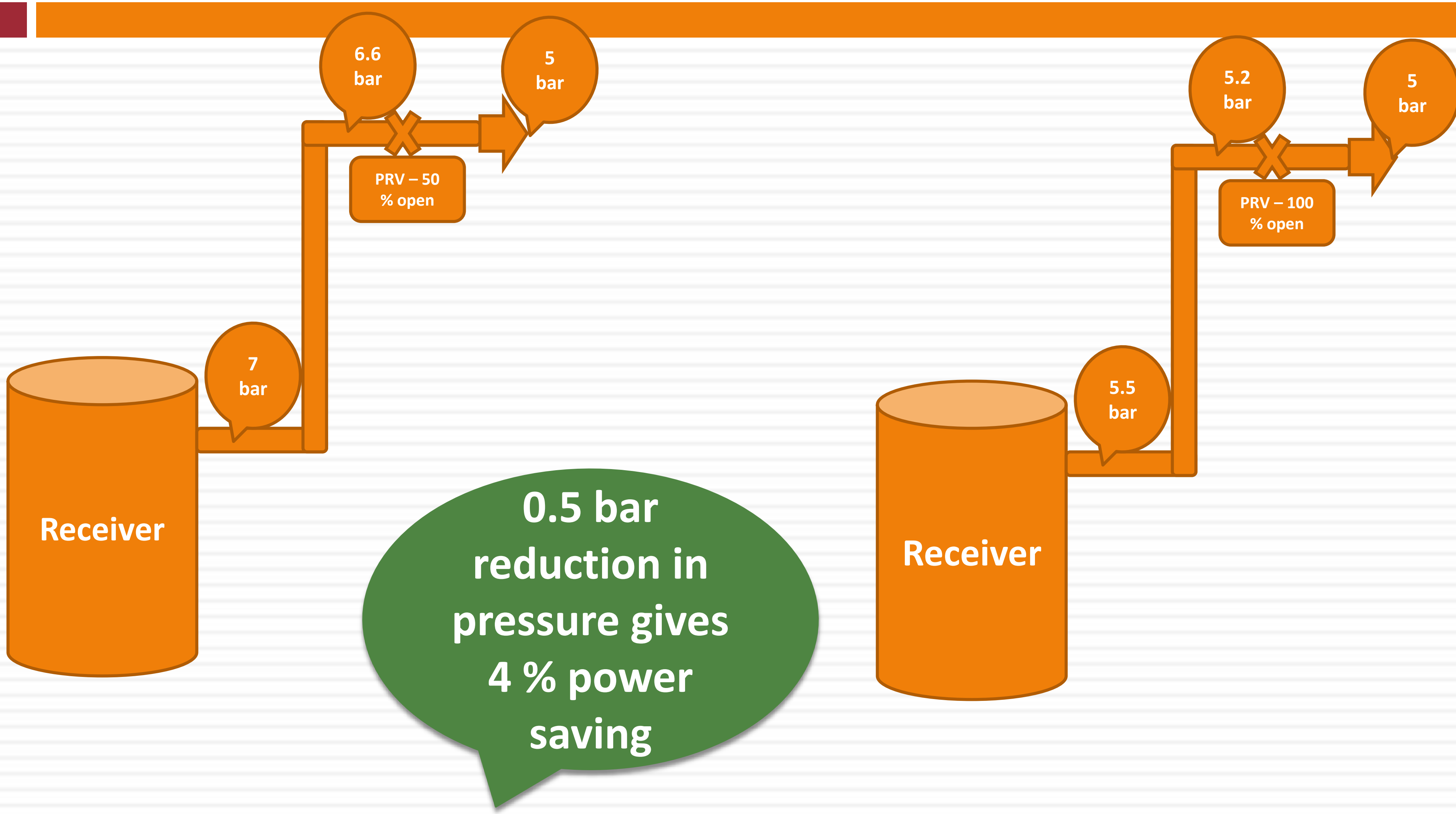
Action

- **Install 15 KW package air compressor**
- **Saves no-load power**
- **Use existing compressor as stand-by**



Savings - Rs.59,000
Investment - Rs.50,000
Payback - 11 months

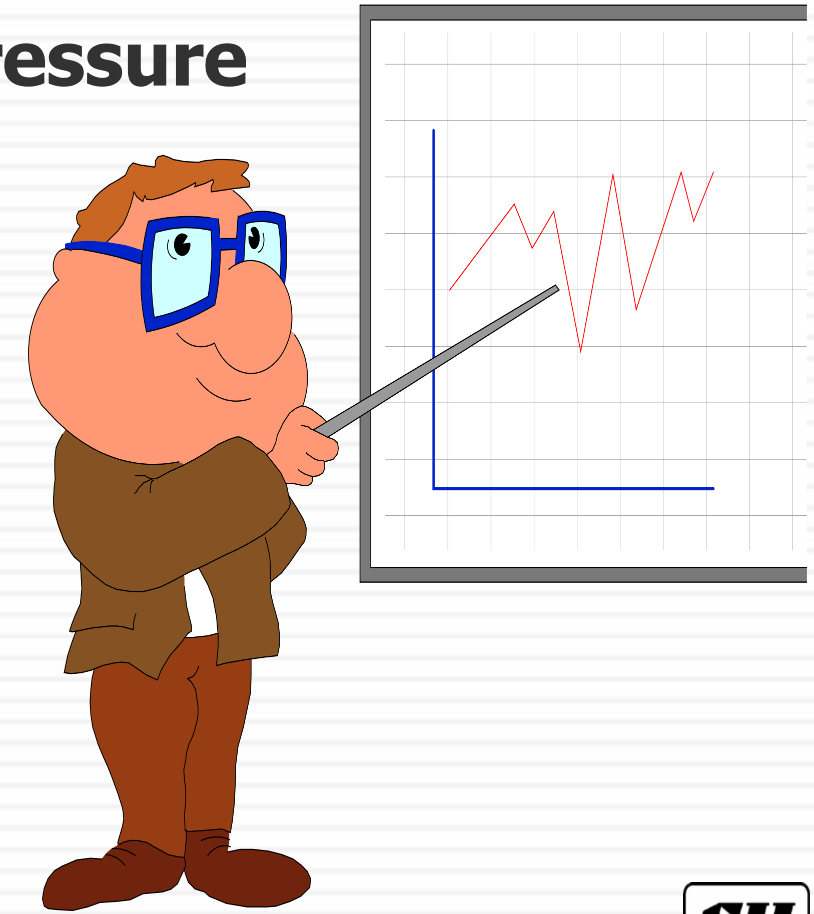
Pressure Reduction



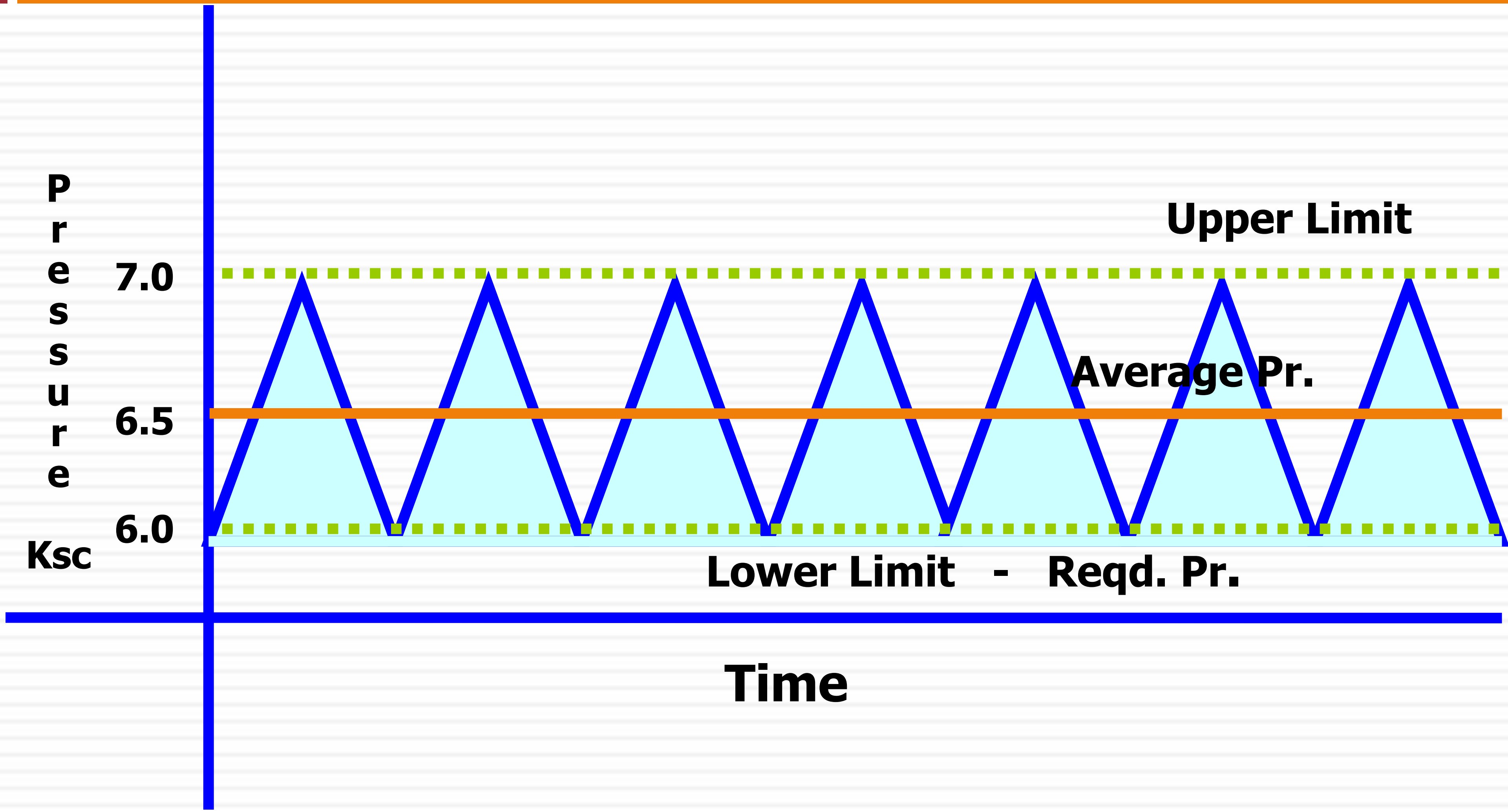
Concept of VFD

Advantages

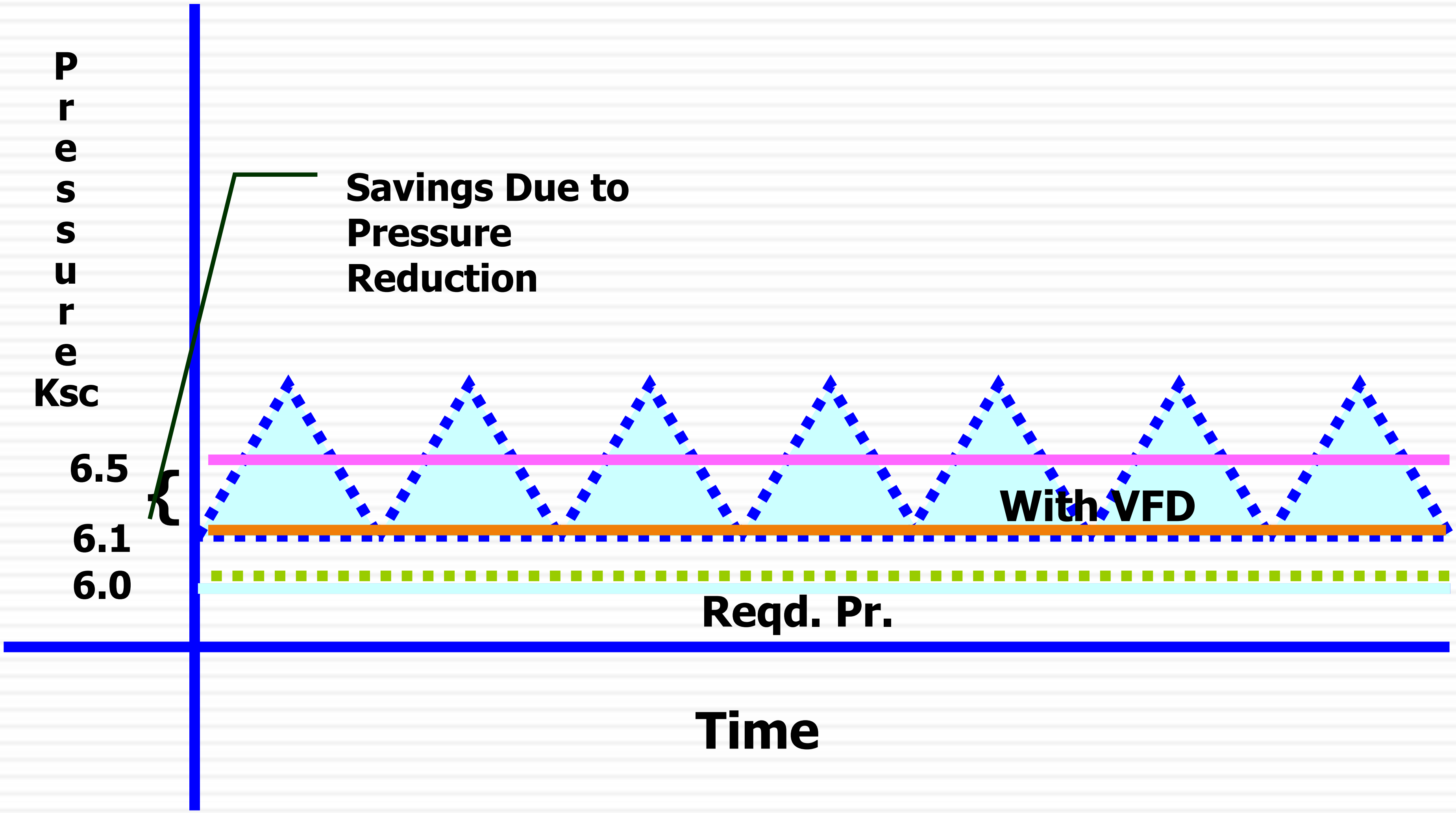
- Operates at Lower Avg. Pressure
  - Proportional Savings
- No Unloading
- Less Leakages
  - Lower Pressure
- Better Motor Efficiency



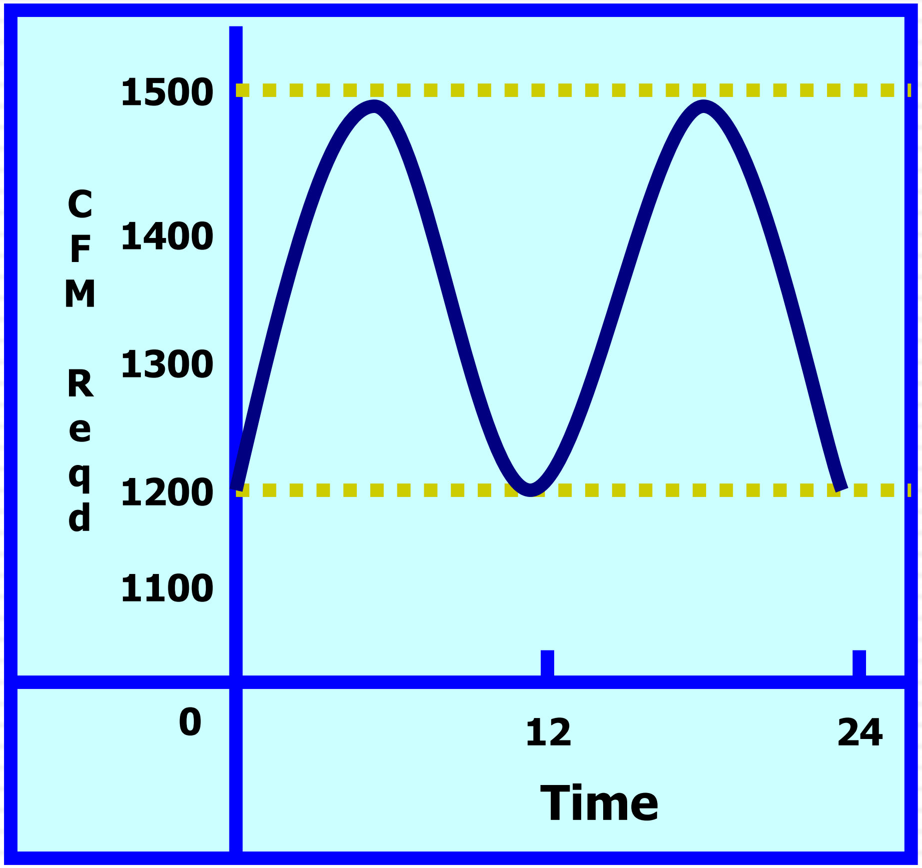
Concept - Conventional Control



Concept - VFD Control

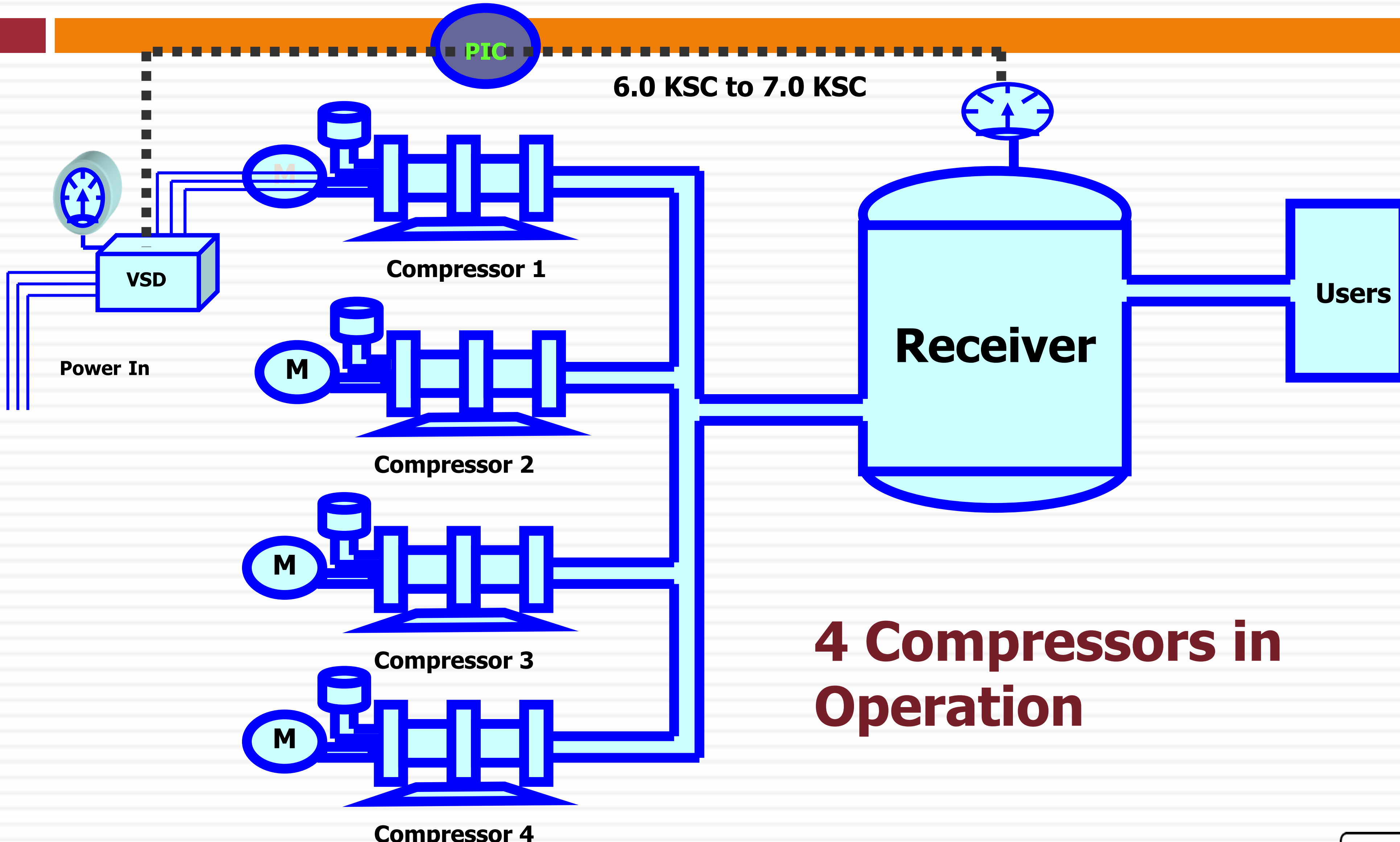


Savings in Unload Power



- 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

Install VFD for One Compressor



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

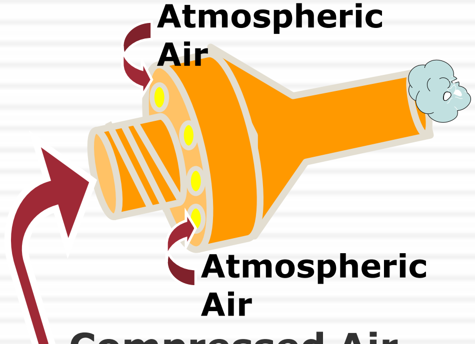
CII

Use Transvector Nozzle In Air Hose

- Sucks atmospheric air along with air jet
  - Reduces air consumption by 50%

- Compressed air used for cleaning application
- Provided transvector nozzles at the end users

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



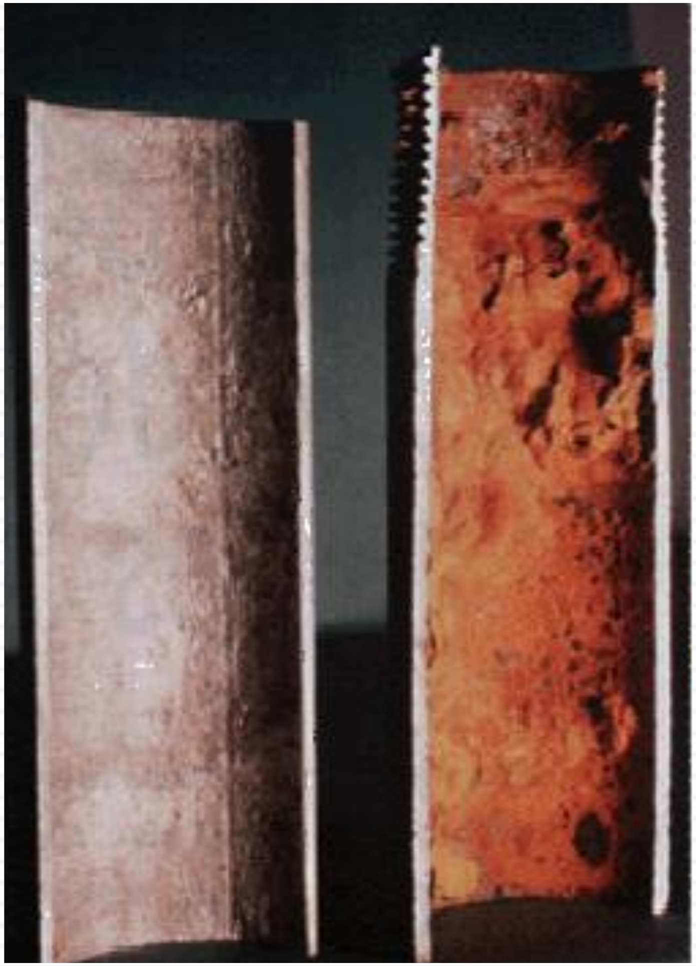
CII

Disadvantage of Carbon steel Piping

- Pollutant
- Pressure Drop
- Leakage
- Short Life span
- Product Damage

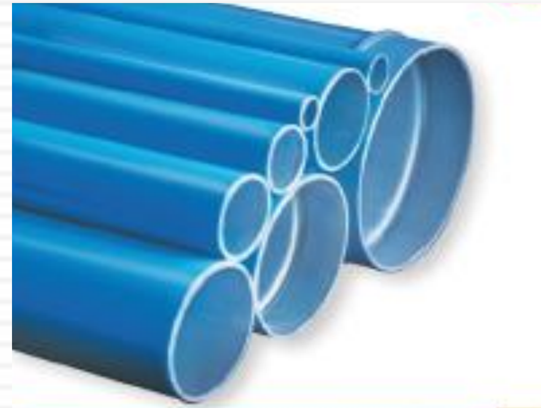
Black pipe corrosion creates air turbulence, i.e. pressure drop

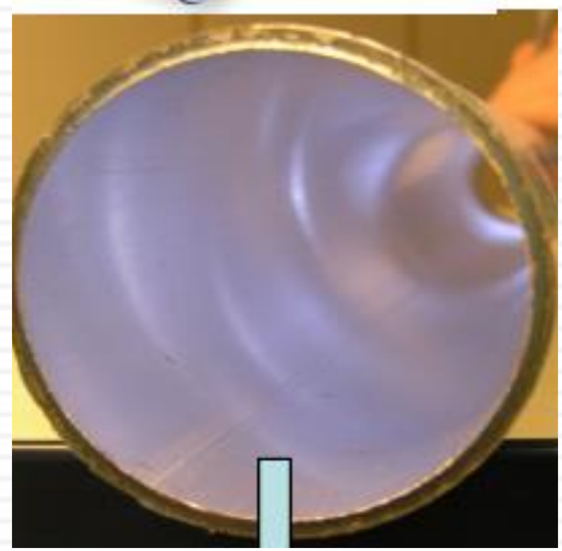
M.S. Pipe v/s Aluminium Pipe



M.S. Pipe gets thick and rough by Getting oxidized with particles. Oil, water, leading to Decrease in air quality and higher energy consumption

Aluminium eliminates risk of pollution as time goes

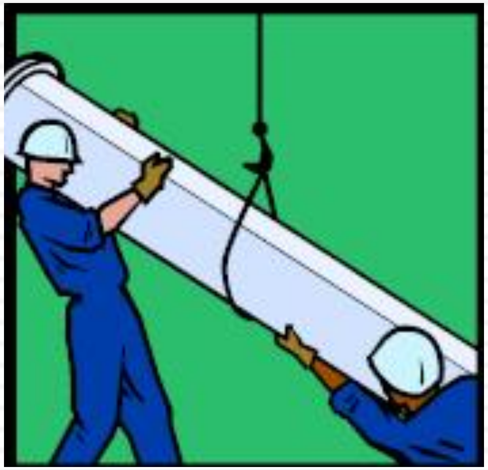




Comparison between Aluminium and Conventional Piping

	Carbon Steel Pipe	Stainless Steel Pipe	Aluminium Pipe	Remark
Installation Time	Slow	Slow	Quick	No. Welding, over 50% quicker
Modification	Hard	Hard	Easy	Quick to install
Modification Time	Long	Long	Short	Add a compressed air branch within 10min.
Inner Roughness	1.9µm	1µm	0.2-0.4µm (N4)	Extruded formation, smooth inner wall
Pressure Loss	Bigger	Big	Small	Low roughness, small pressure drop
Leakage	10% - 30%	5% - 10%	0%	O seal ring
Corrosion after Long time	Terrible	Few	No	Inner wall without chromium anticorrosive treatment
Impact on air quality	Big	Small	No	N0 harm to the air equipment.
Initial investment	Low	High	High	
Running Fee	Very High	High	Low	

Comparison: Diameters and weight of MS Pipe and Aluminium Pipe with comparable flow



Steel Pipe	Aluminium Pipe
Steel Pipe Dia. 48.3mmx6m length=19.5 kg	Aluminium Pipe Dia. 40mmx6m length=4 kg
Steel Pipe Dia. 76.1mmx6m length=34.5 kg	Aluminium Pipe Dia. 63mmx6m length=6.4 kg
Steel Pipe Dia. 88.9mmx6m length=40.5 kg	Aluminium Pipe Dia. 76.1mmx6m length=9.4 kg

List Of Energy Saving Ideas - Compressed Air System

- Turn off compressors when not needed
- Select correct size air compressor
- Operate compressor at required pressure
- Install VFD
- Conduct leakage testing regularly and minimise system losses
- Replace compressed air with blower air for agitation
- Replace pneumatic tools with electric tools

List Of Energy Saving Ideas - 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

Thank You….

PUMPING SYSTEM

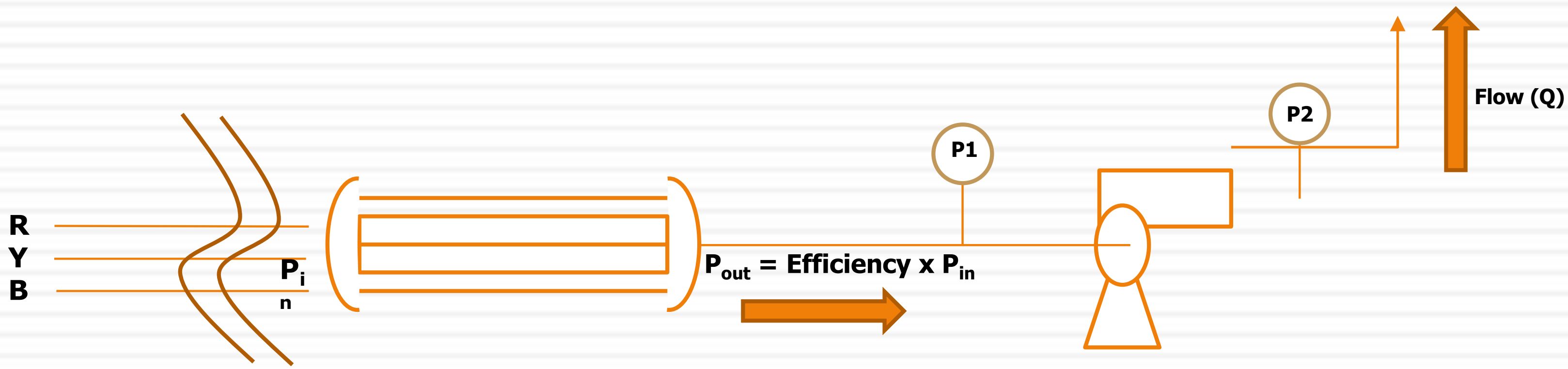
Energy Parameters

Capacity or Flow

Head or Pressure

Efficiency

Efficiency of Pump



$$\text{Pump } \eta\ (\%) = \frac{\text{Flow (lps) } \times \text{ (h2-h1) (m)} \times \text{ Sp. Gr.}}{102 \times P_{out}}$$

Pumps Formulae

- Capacity α (RPM)
- Head α $(RPM)^2$
- Power α (Capacity x Head)

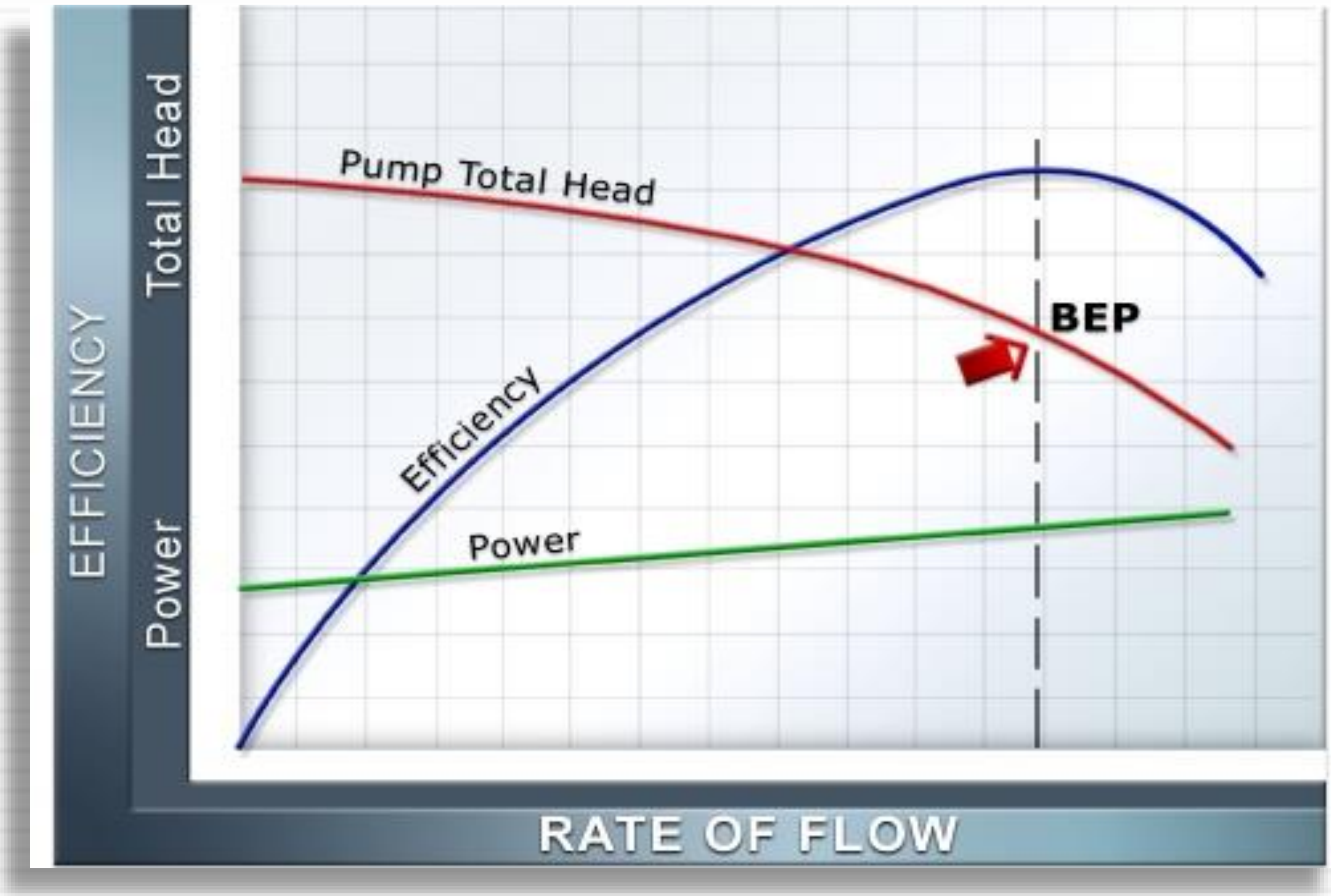
α $(RPM)^3$

Pumps Formulae

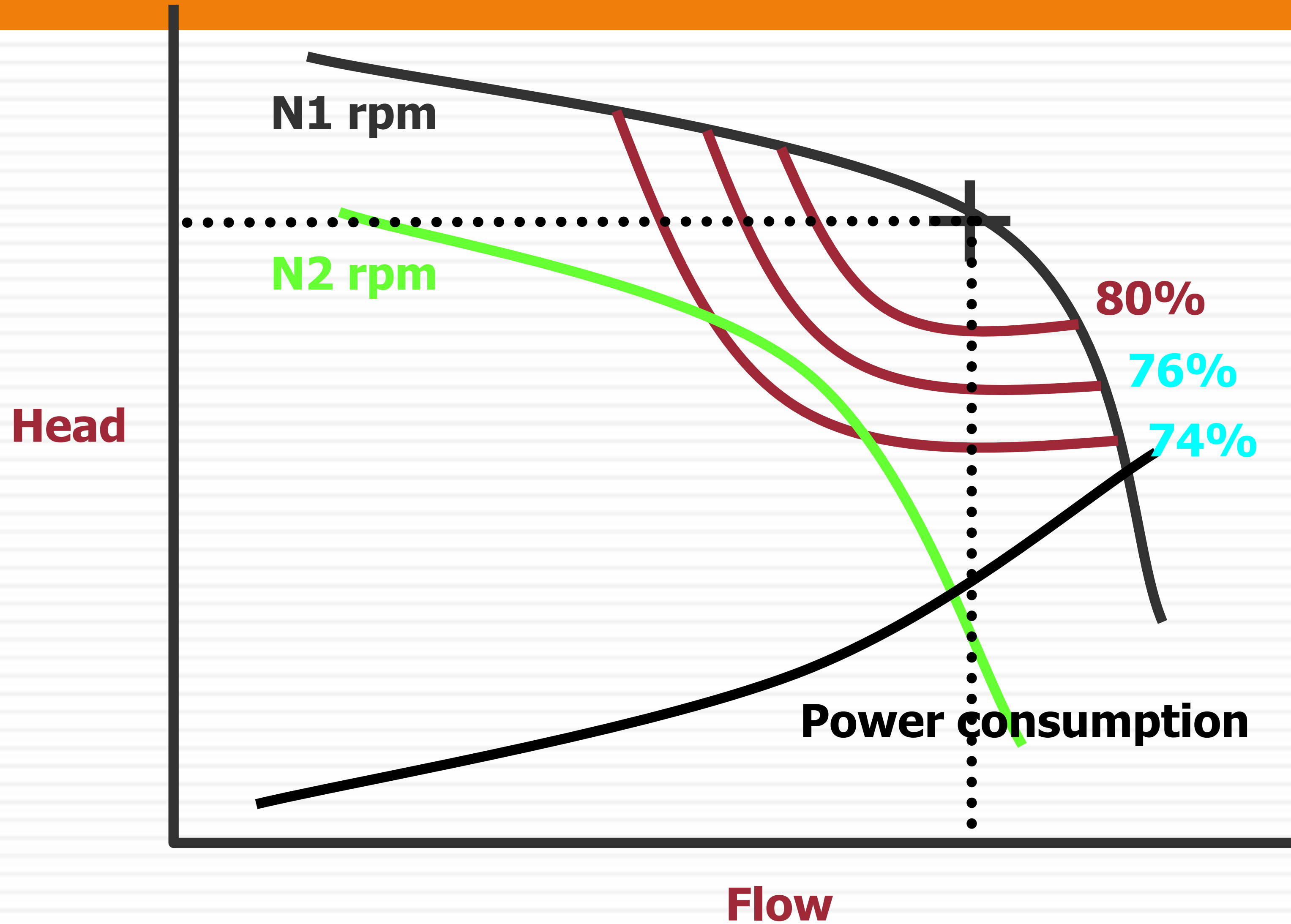
If the RPM is reduced by say 10%, what will happen to the

- **Capacity : reduces by 10%**
- **Head : reduces by 19%**
- **Power : reduces by 27%**

Characteristic Curve of Pump

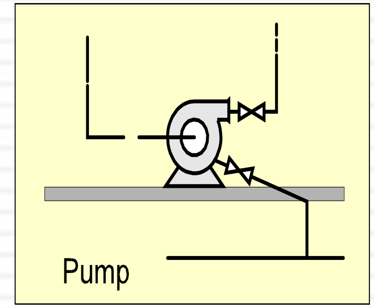


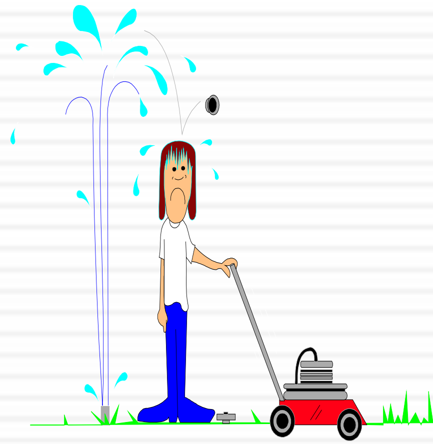
Characteristic Curve of a Pump



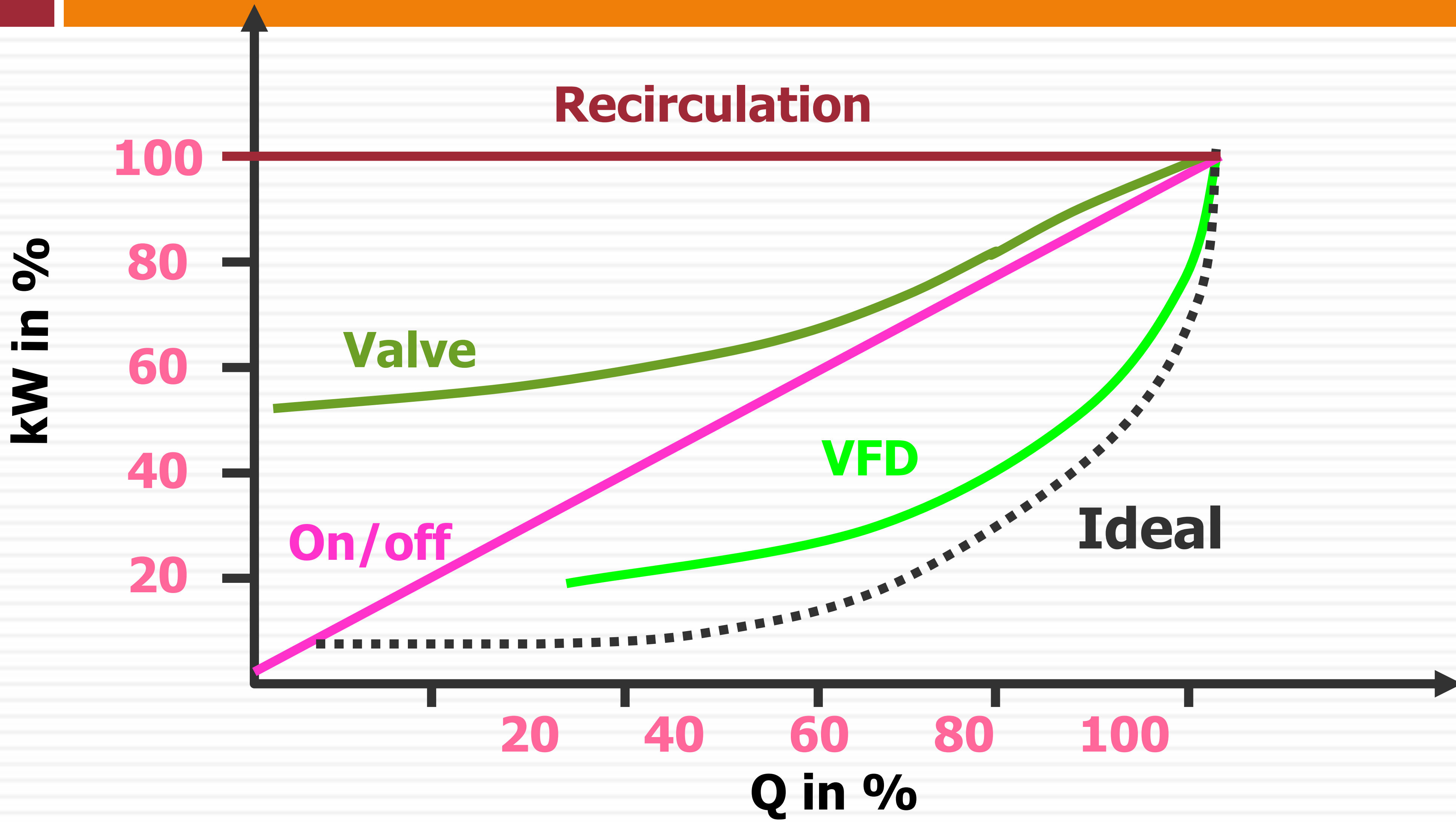
Reasons for excess power consumption

- Wrong Selection
- Over Design
- Improper Layout
- Old inefficient pumps
- Multiple smaller size pumps
- Ad-hoc decisions

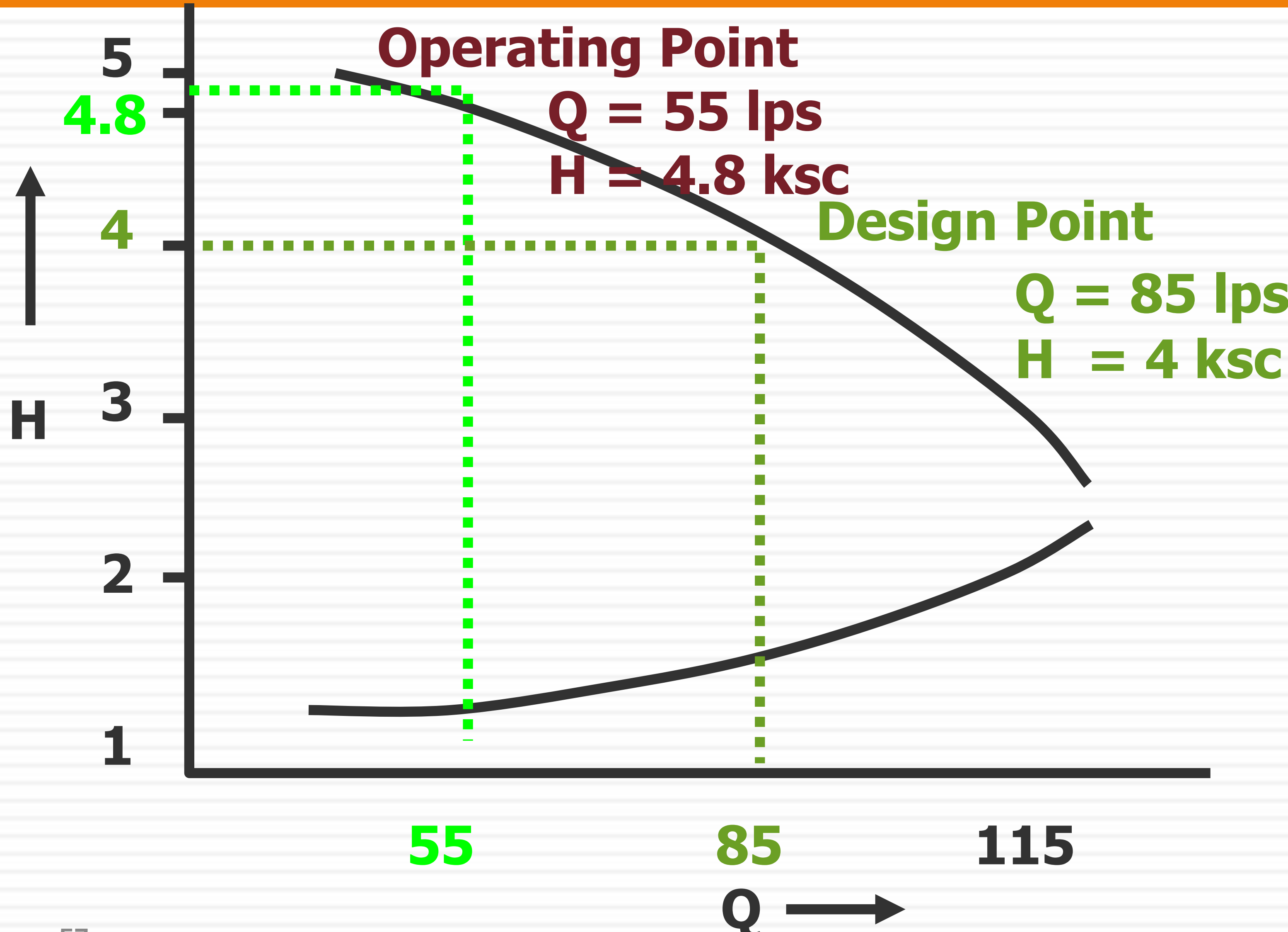




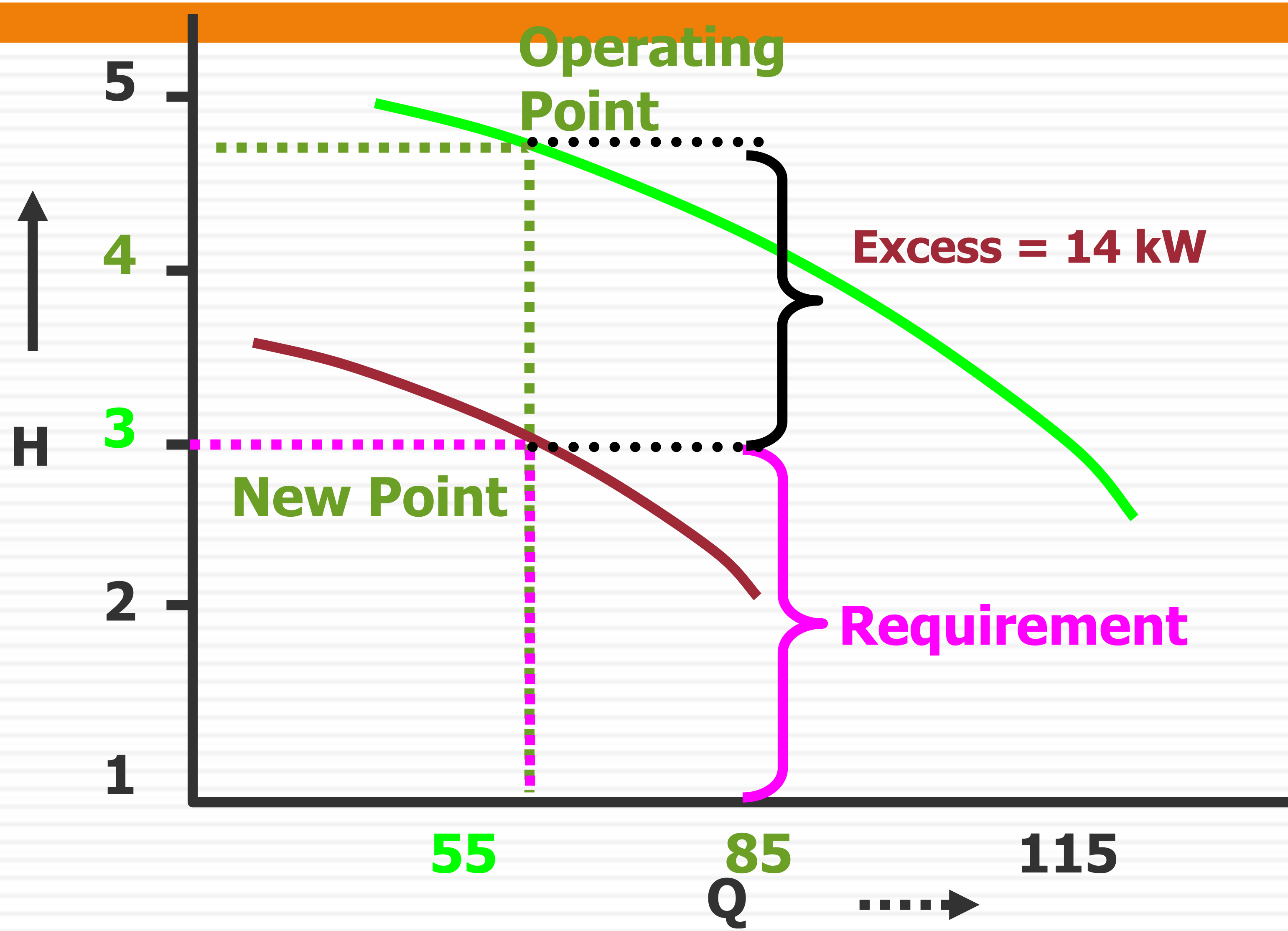
Effect of Various Capacity Controls



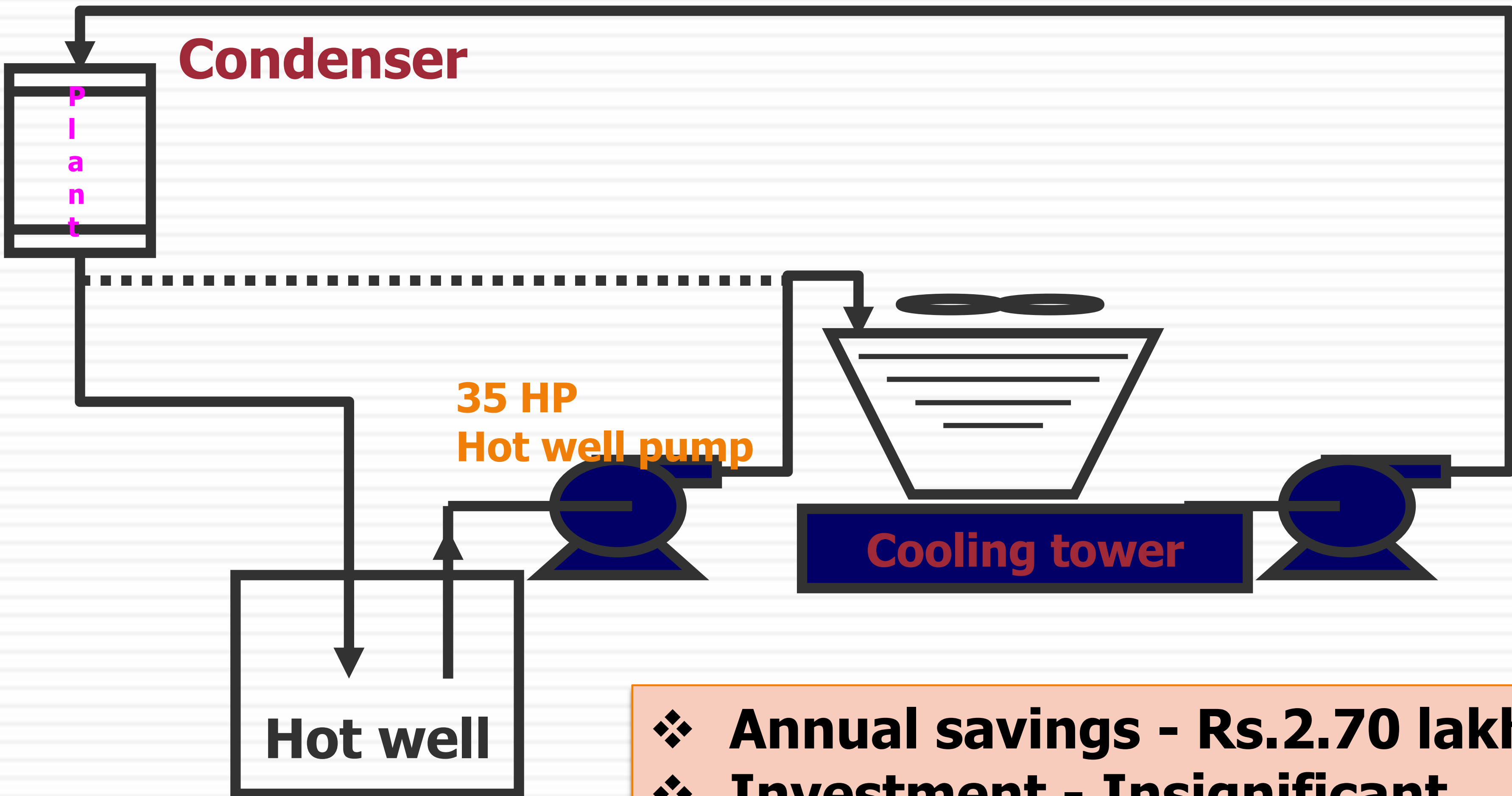
Operating Conditions of Pump



Operating Conditions of Pump



Use Gravity Flow as Much as Possible



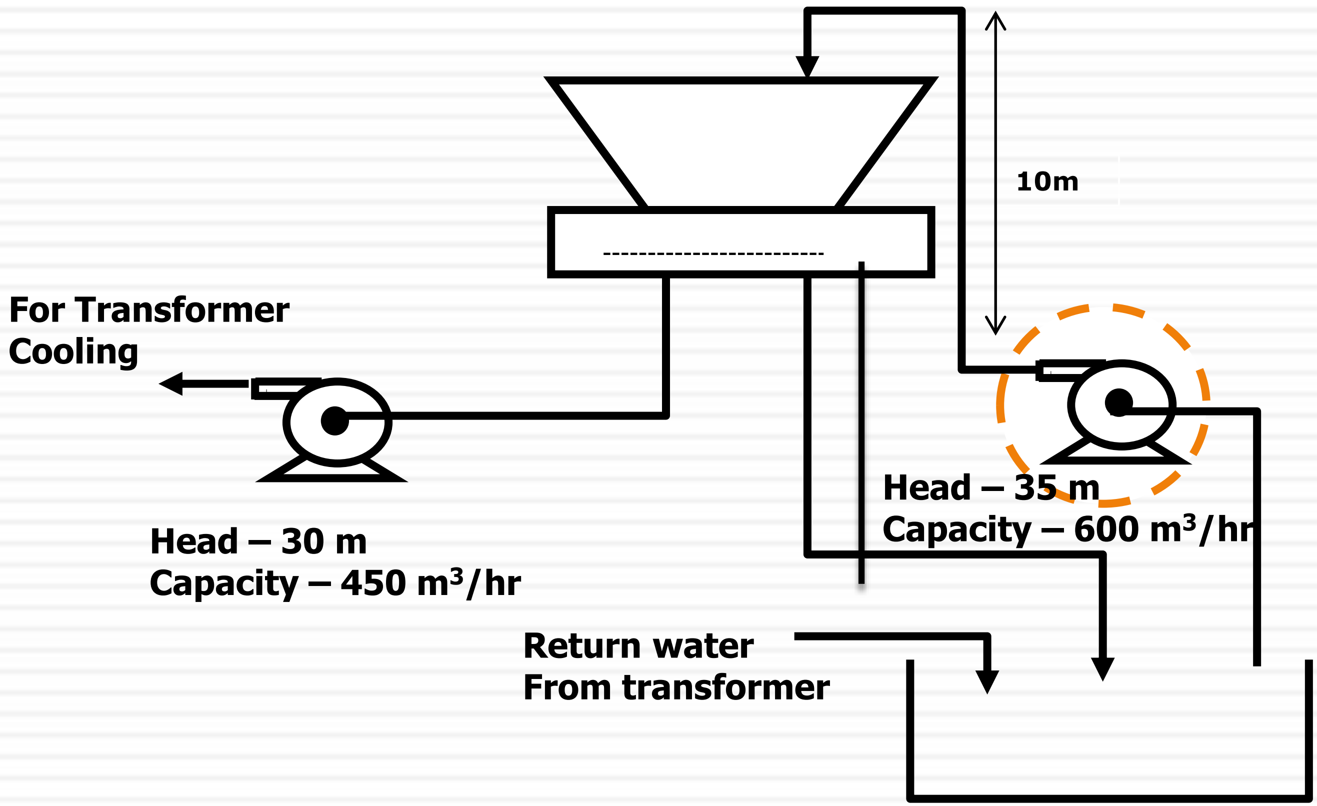
- ❖ **Annual savings - Rs.2.70 lakhs**
- ❖ **Investment - Insignificant**

Methodology of Pump Survey

- ❖ **Is the pump correctly Sized ?**
  - ➢ **Excess capacity due to uncertainty**
- ❖ **Leads to operation with valve throttling**
  - ➢ **Energy inefficient practice**

- ❖ **Impeller reduction**
- ❖ **Low capacity/head pump**
- ❖ **Installation of variable speed drive**

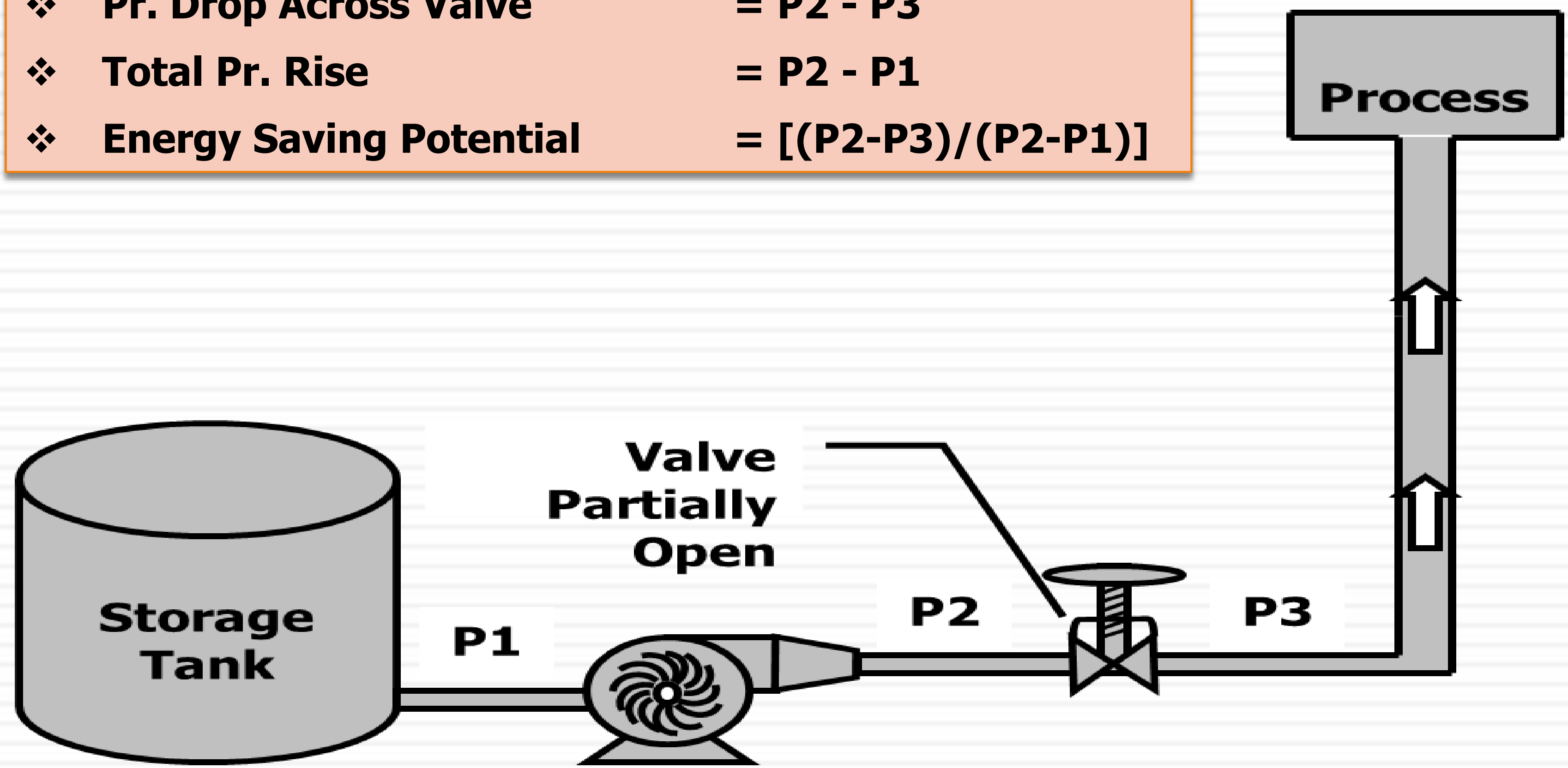
Installation of correct size pump



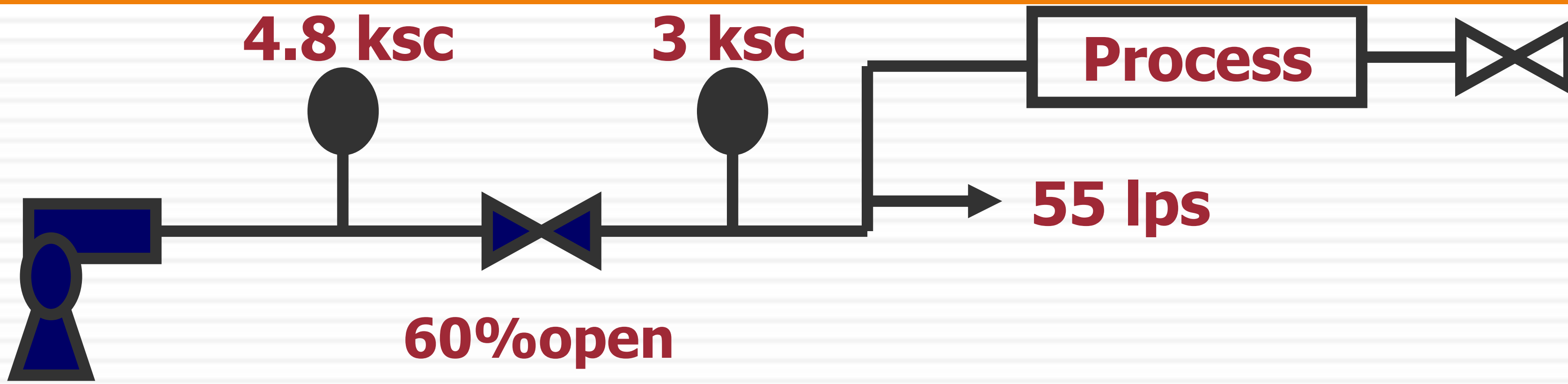
Annual savings	-	Rs 7.29 Lakhs
Investment	-	Rs 3.00 Lakhs
Payback period	-	5 months

Pressure Drop Across Valve

- ❖ Pr. Drop Across Valve = P2 - P3
- ❖ Total Pr. Rise = P2 - P1
- ❖ Energy Saving Potential = [(P2-P3)/(P2-P1)]



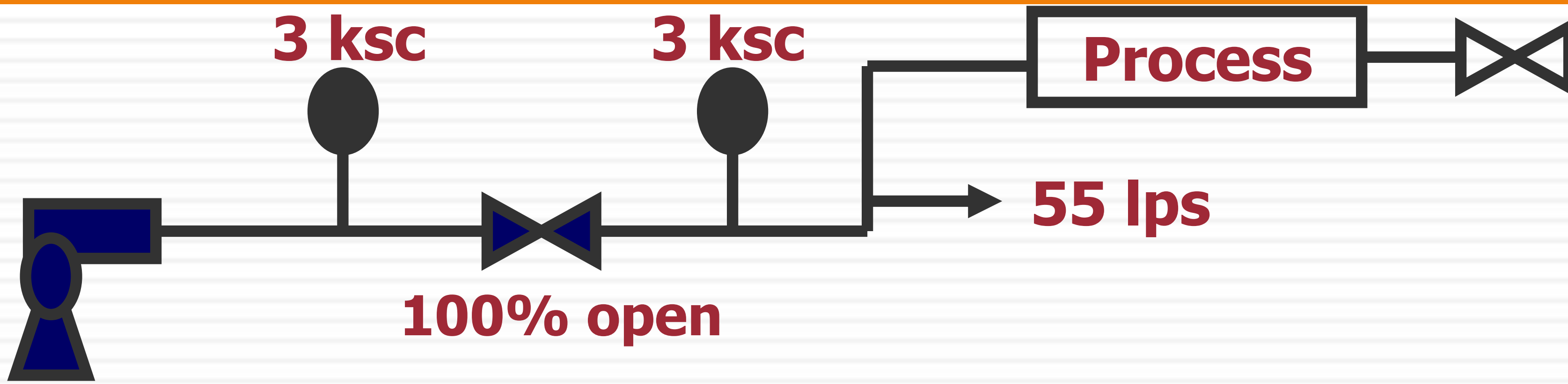
Effect of Valve Throttling



Design

Capacity	=	85 lps
Head	=	4 ksc
Existing	=	4.8 ksc
kW_{EX}	=	55 x 48/(102 x 0.7)
	=	37.0 kW

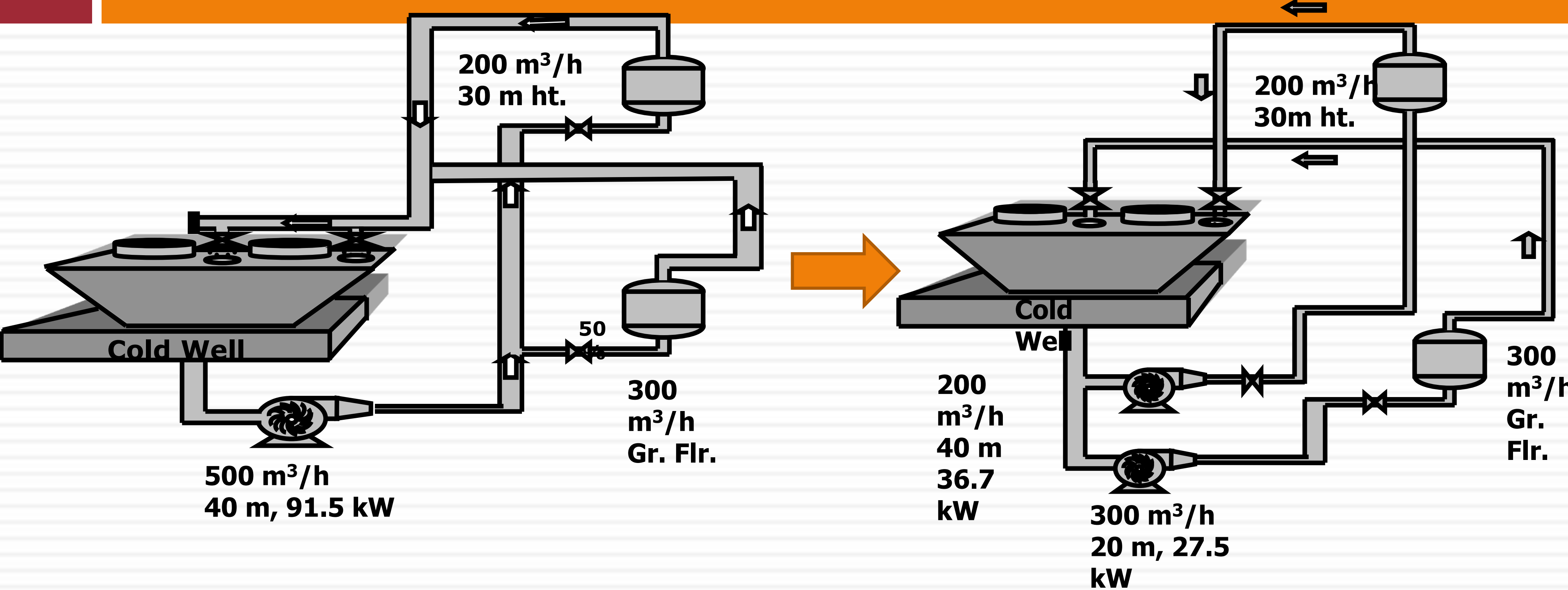
Effect of Valve Throttling



Modified

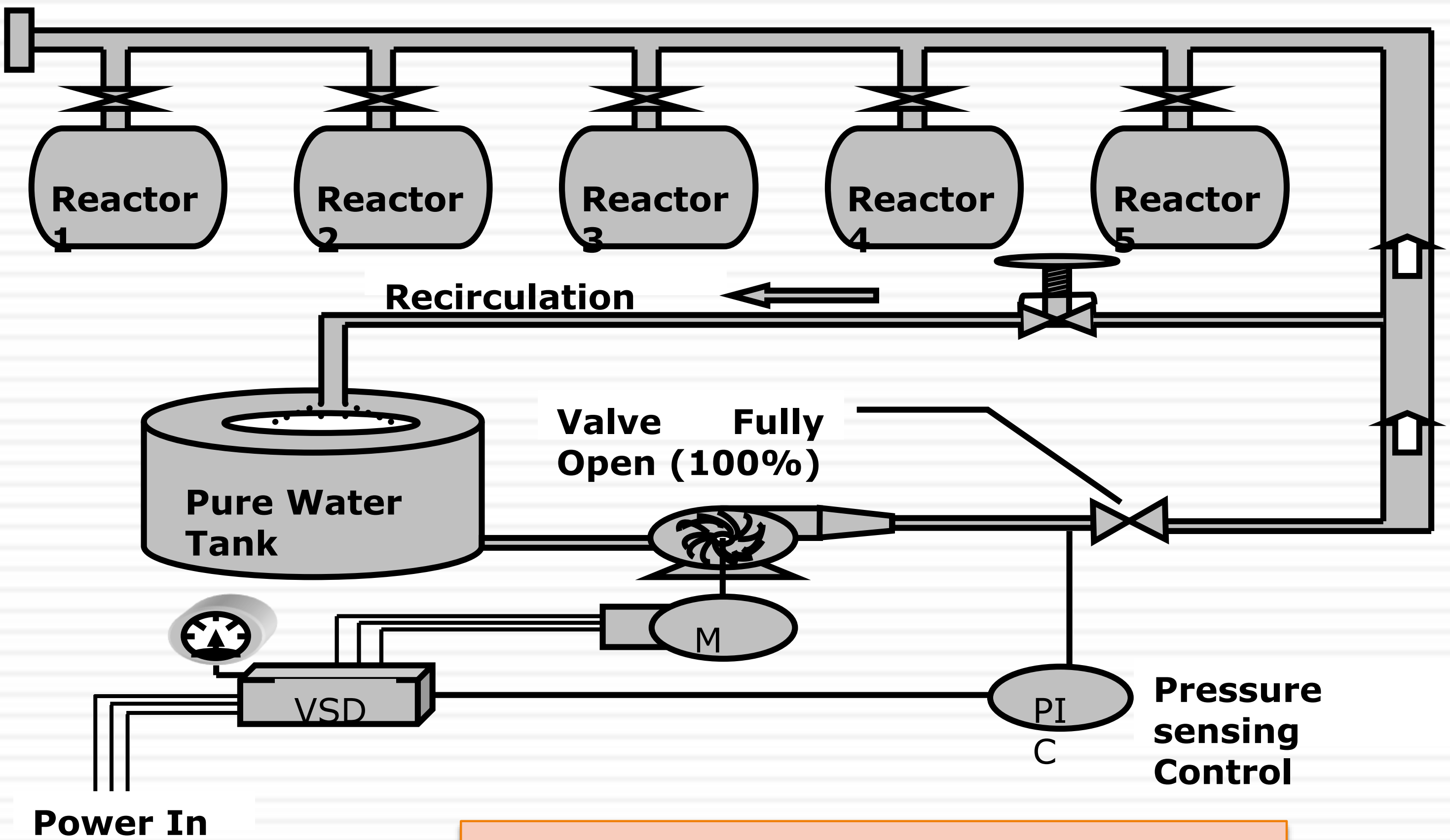
Proposed	=	3.0 ksc
kW_P	=	55 x 30/(102 x 0.7)
	=	23.0 kW
Savings	=	14 kW

Segregate high and low head users



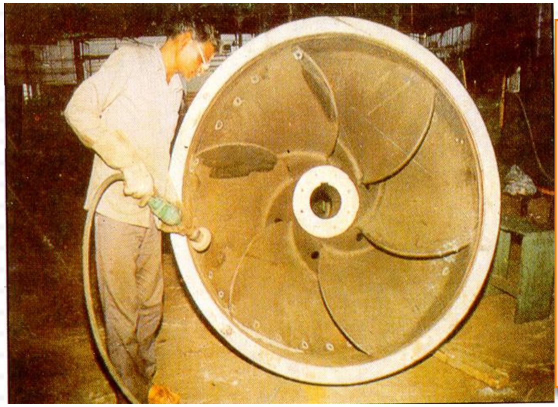
Annual Savings	= Rs. 4.80 Lakhs
Investment	= Rs. 6.00 Lakhs
Payback period	= 15 Months

VFD for Pumping system



Annual savings	- Rs.3.00 Lakhs
Investment	- Rs.2.00 Lakhs
Payback period	- 8 Months

Hydrophobic Coating

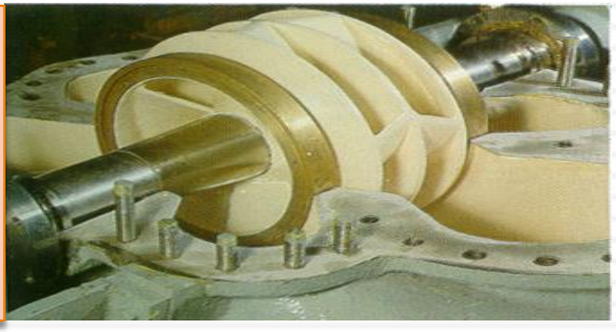


Earlier system

❖	Capacity	:	120 m3/hr
❖	Head	:	15 m
❖	Pump input power	:	50 kW
❖	Best efficiency	:	65%

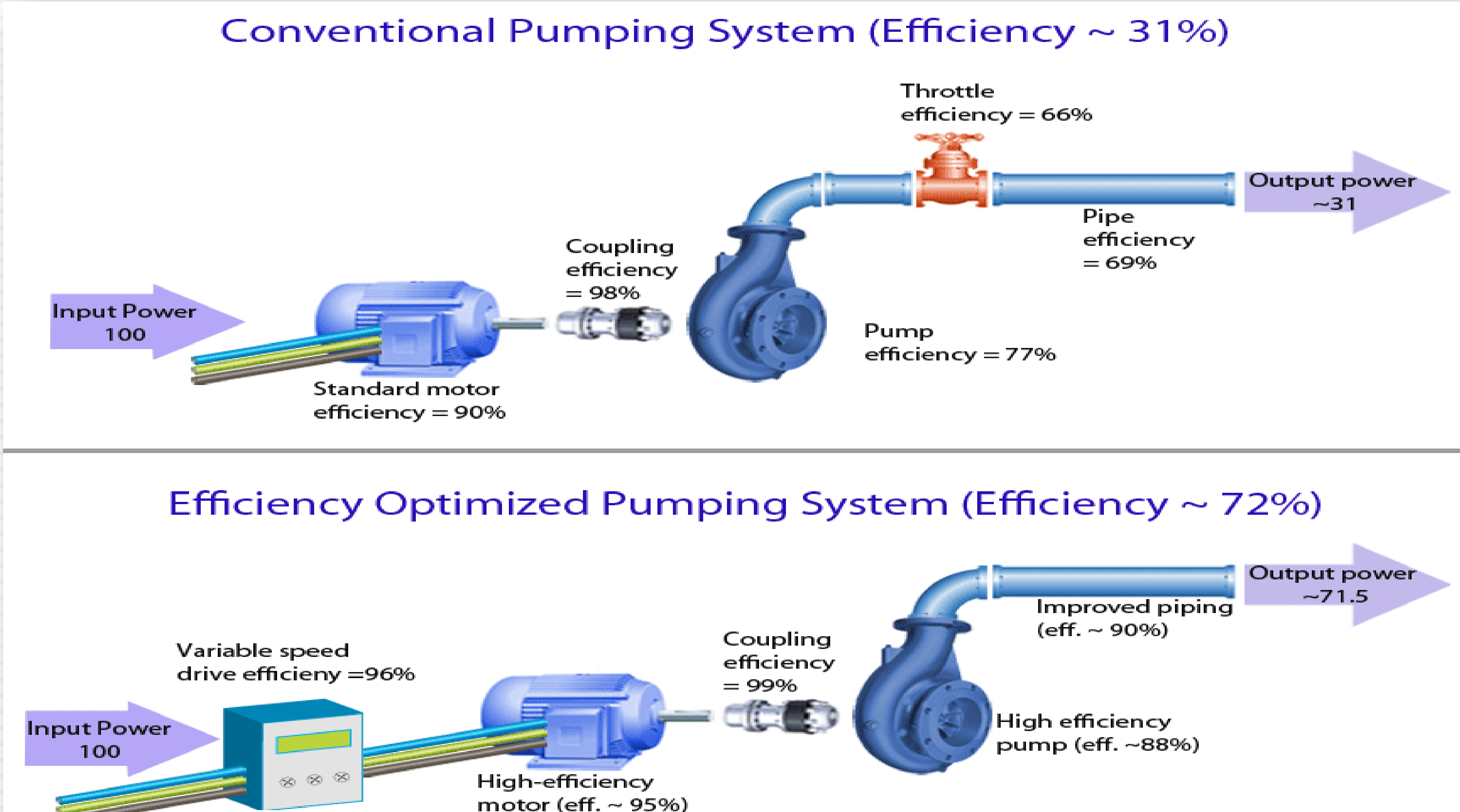
Modified system

❖	Capacity	:	120m3/hr
❖	Head	:	15 m
❖	Pump input power	:	48 kW
❖	Best efficiency	:	67 %



Annual savings : Rs. 1.12 lakhs

Energy Efficient Pumping System



Pump Maintenance Check List

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Pump use/sequencing	Turn off/sequence unnecessary pumps	X			
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place	X			
Check lubrication	Assure that all bearings are lubricated per the manufacture's recommendation			X	
Check packing	Check packing for wear and repack as necessary. Consider replacing packing with mechanical seals.			X	
Motor/pump alignment	Aligning the pump/motor coupling allows for efficient torque transfer to the pump			X	
Check mountings	Check and secure all pump mountings			X	
Check bearings	Inspect bearings and drive belts for wear. Adjust, repair, or replace as necessary.				X
Motor condition	Checking the condition of the motor through temperature or vibration analysis assures long life				X

Thank You....