COMPRESSED AIR SOLUTIONS

Confederation of Indian Industry

CII Naoroji Godrej Centre of Manufacturing Excellence

Workshop on

ENERGY EFFICIENCY ASPECTS IN COMPRESSED AIR SYSTEMS

19th April 2018: Surat

"Energy Saving Opportunities In Compressed Air System"

Godrej & Boyce Mfg. Co. Ltd.

ELECTRICALS & ELECTRONICS

The Godrej Story

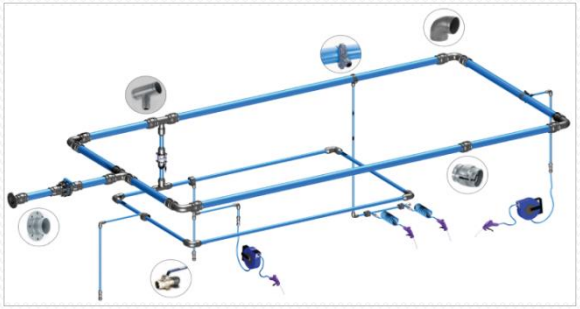
Godrej & Boyce is a **120-year-old** flagship company of the Godrej Group with a turnover of over **8000 Crore INR** and spread over **3200 acres** in Mumbai. Our family of almost **28,000 Employees** works together to realise a brighter and more sustainable future for our country and communities.

As one of 14 business areas of the Godrej & Boyce group, **Godrej Electricals & Electronics** is as old as the company. The brand strives to contribute to the vision of the group by delivering **Sustainable Technology Solutions**.

Product Portfolio

Air Compressors & Treatment Accessories

System Controls



Aluminum Piping & Turnkey Solution

Comp Air Audits

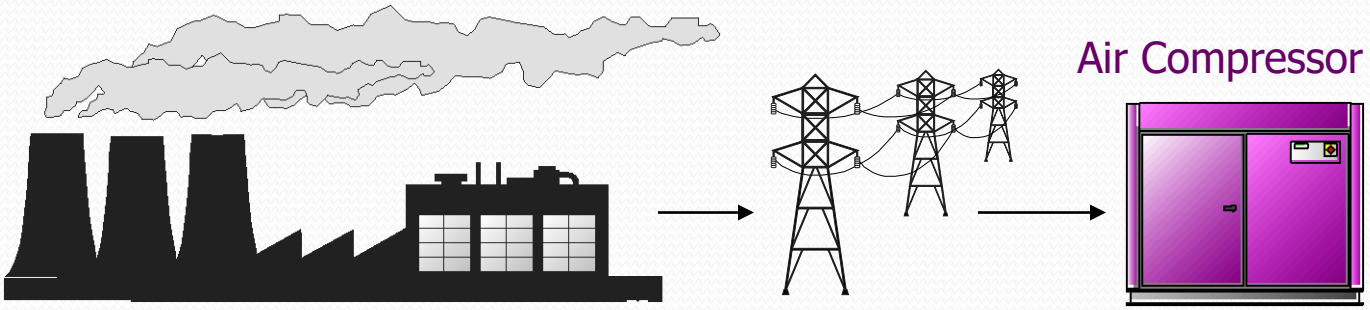
Air Blowers

Turbo Blowers

WHY TO GO FOR ENERGY SAVING ?

Compressed Air Energy

- Compressed Air: Fourth Utility, after Electricity, Natural Gas & Water



10% of industrial electricity used to power air compressors

400 TWh electricity consumption in compressed air systems worldwide equals the electricity production of 110 coal fired power stations of 600 MW each & producing CO_2 emissions of 400 Million Tonnes per year

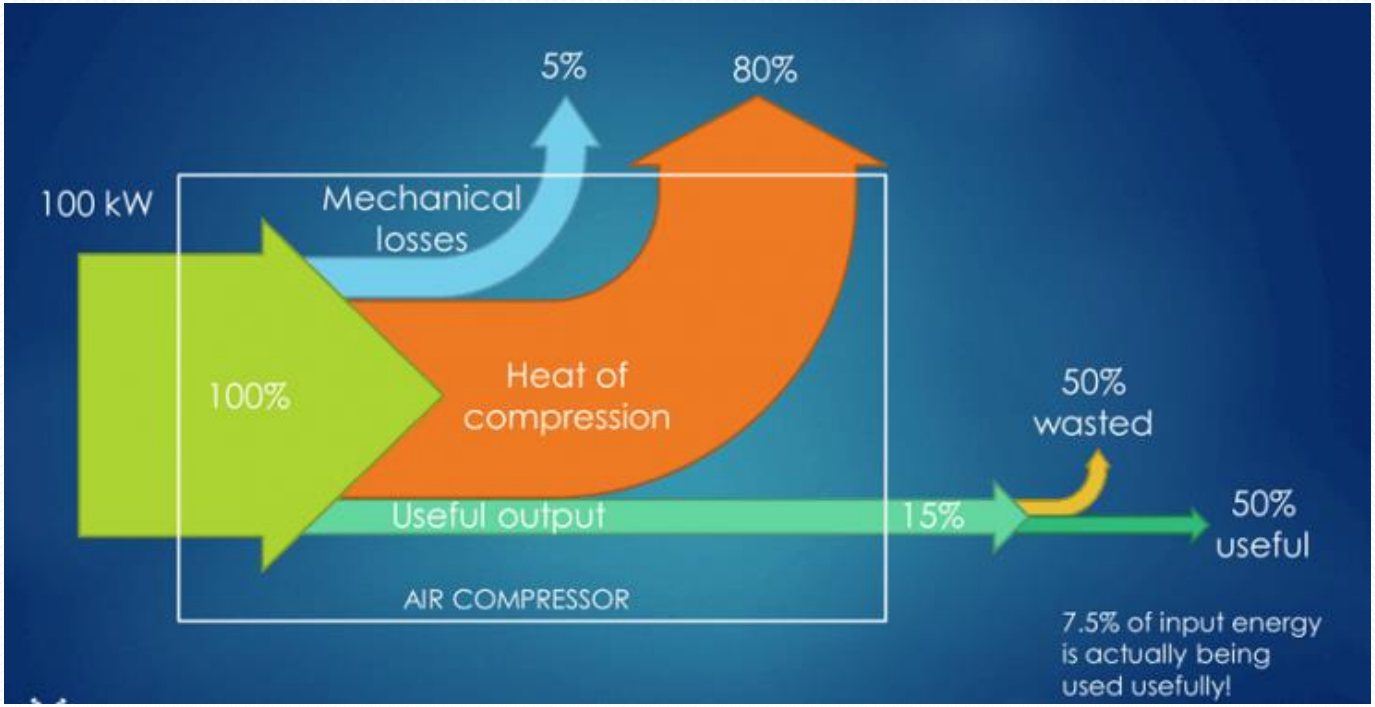
400 TWh = 400,000,000,000 kWh

Source: Energy Audit 2006 seminar Finland

What does your Compressed Air Cost???

Energy Cost
+
Carbon Mitigation Cost
+
End Use Productivity Lost Cost

Fig : Sankey Diagram For Compressed Air System



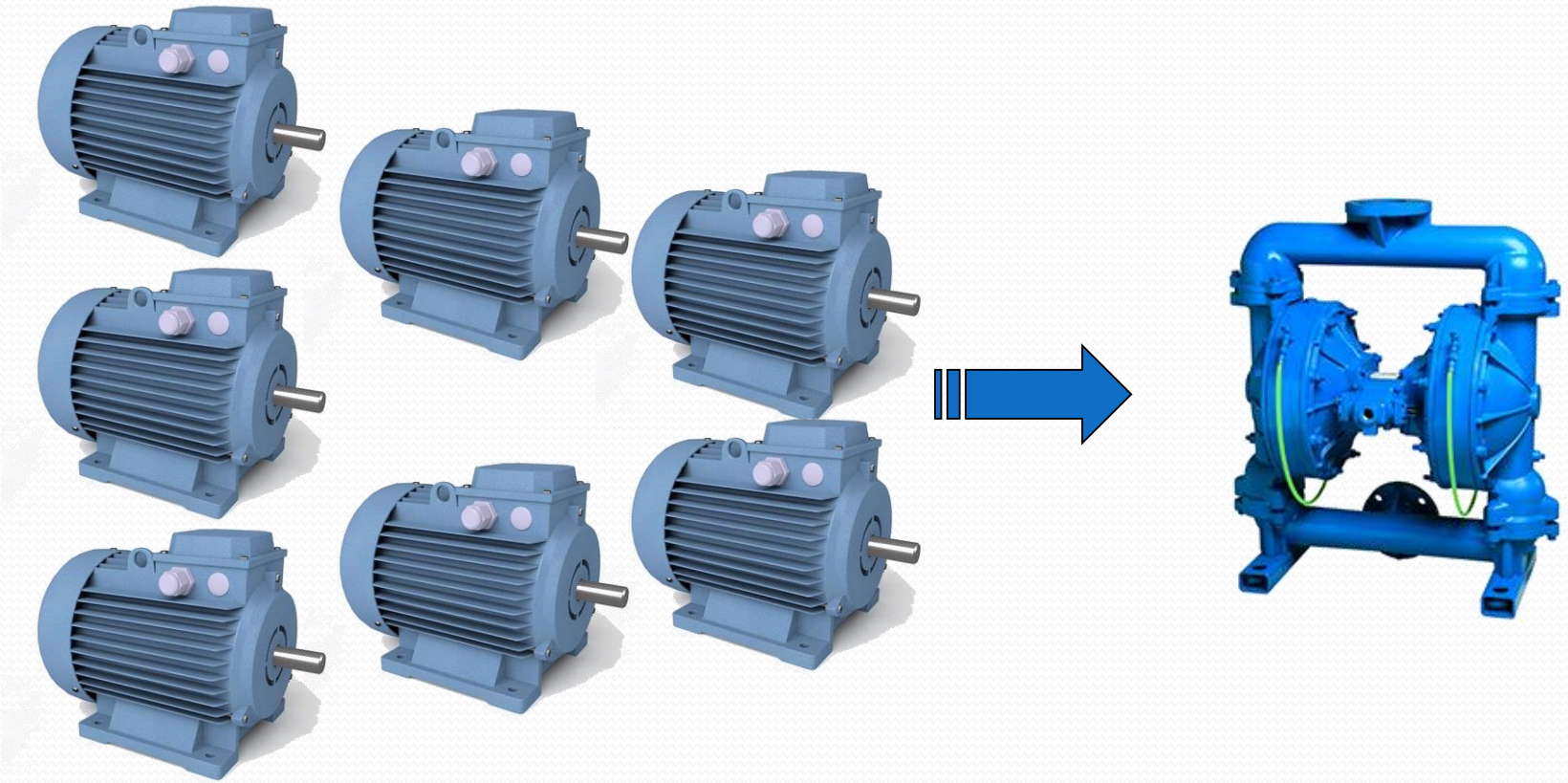
Out of 100 % Electricity Input,

- 5 % are mechanical losses
- 80 % are heat losses
- Finally, only 15 % is Actually Used

Compressed Air: Most Expensive Form of Energy!

Compressed Air Energy

Inefficient power source, even if well maintained



7 units of Electrical Energy → yields → **1** unit of Compressed Air

Energy Cost

Energy Cost of Running Air Compressor - Example:

500 cfm, 100 psi(g) Air Compressor

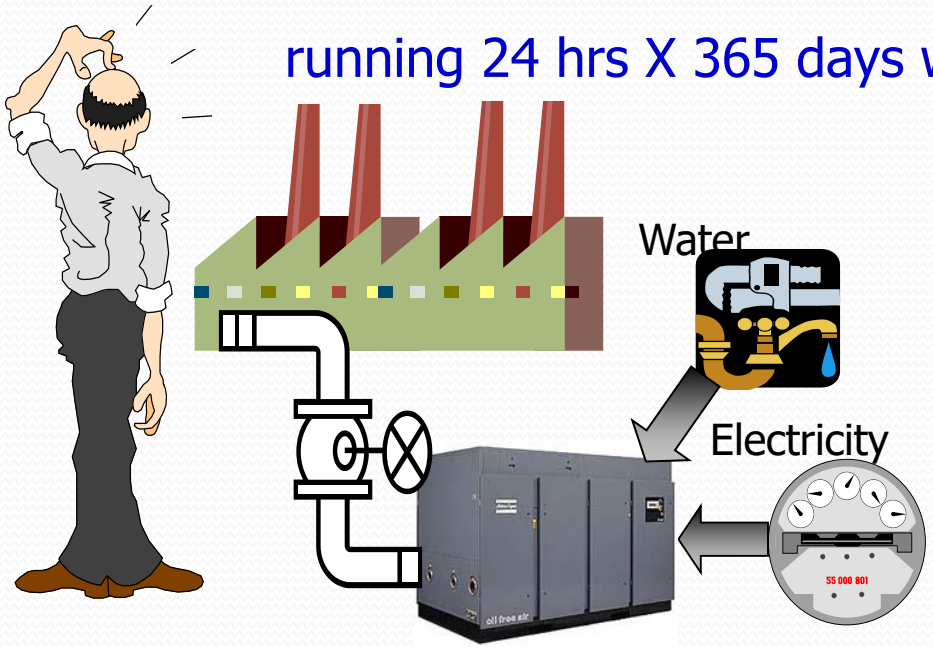
i.e. 120HP / 90kW Motor

running 24 hrs X 365 days with 70% Load Factor consumes

~ 600,000 kWh annually

at rate of Rs. 7/kWh,

Costs Rs. 42 Lacs/year



Which is 3 to 4 times the cost of Compressor itself !!

Compressed Air: Most Expensive Form of Energy!

The First Solution for Energy Saving Is

"Avoid Use Of Compressed Air"

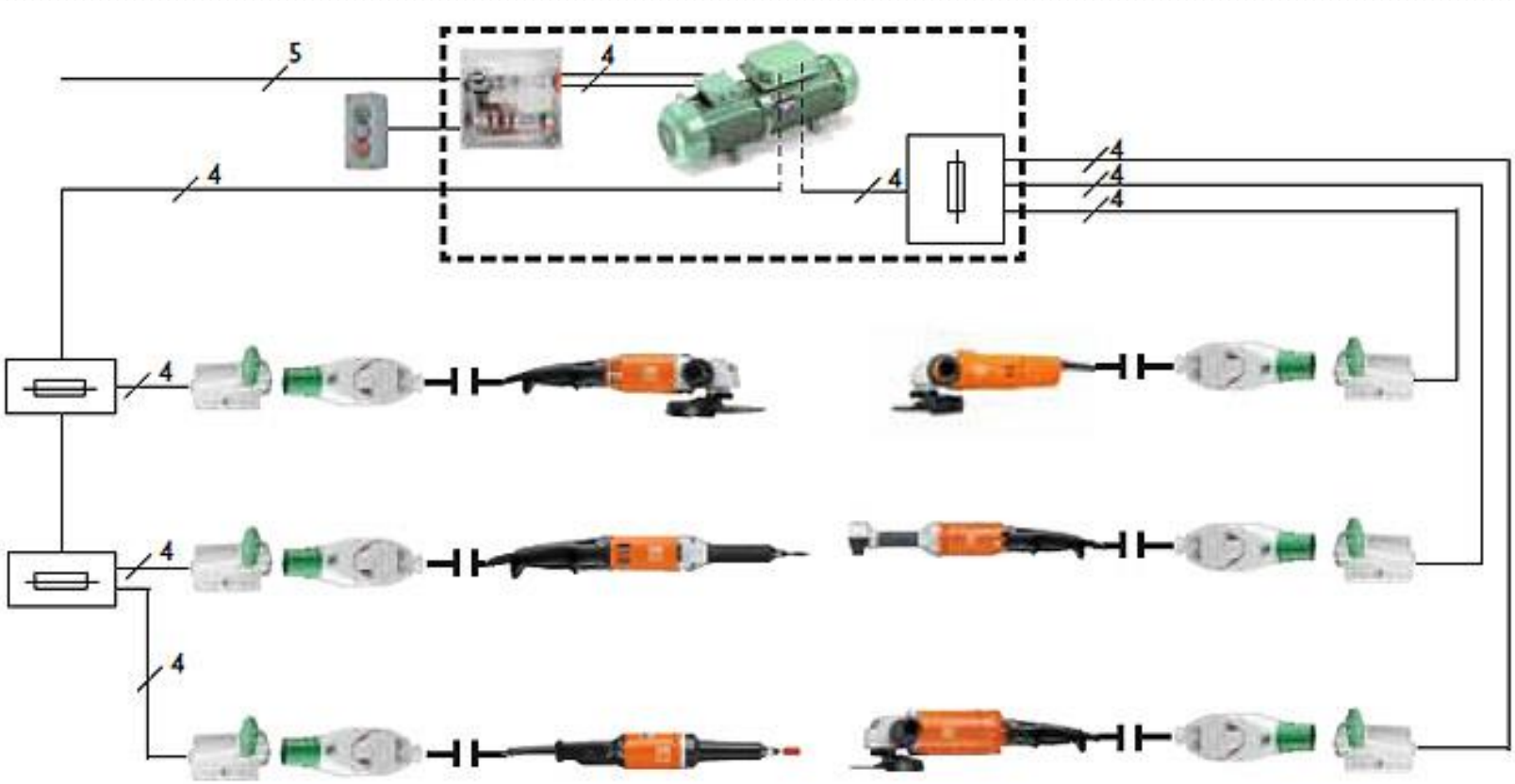
Review The Point of Use Pneumatic Application

Replace By Other Form of Energy

- Air Motors, Air Operated Pumps, Venturi Vacuum Pumps, Pneumatic Grinders, Pneumatic Screw Drivers
- Evaluate your uses - list them & determine if an electric motor or a hydraulic tool can do the job - with equal performance
- Converting to electric motors saves 80% electrical energy

Case Study Example at Godrej:

- **Replaced more than 500 numbers of Pneumatic Grinders & Polishers by High Frequency Electric Tools.**
- **Energy Saving > 80%**



The First Solution for Energy Saving Is

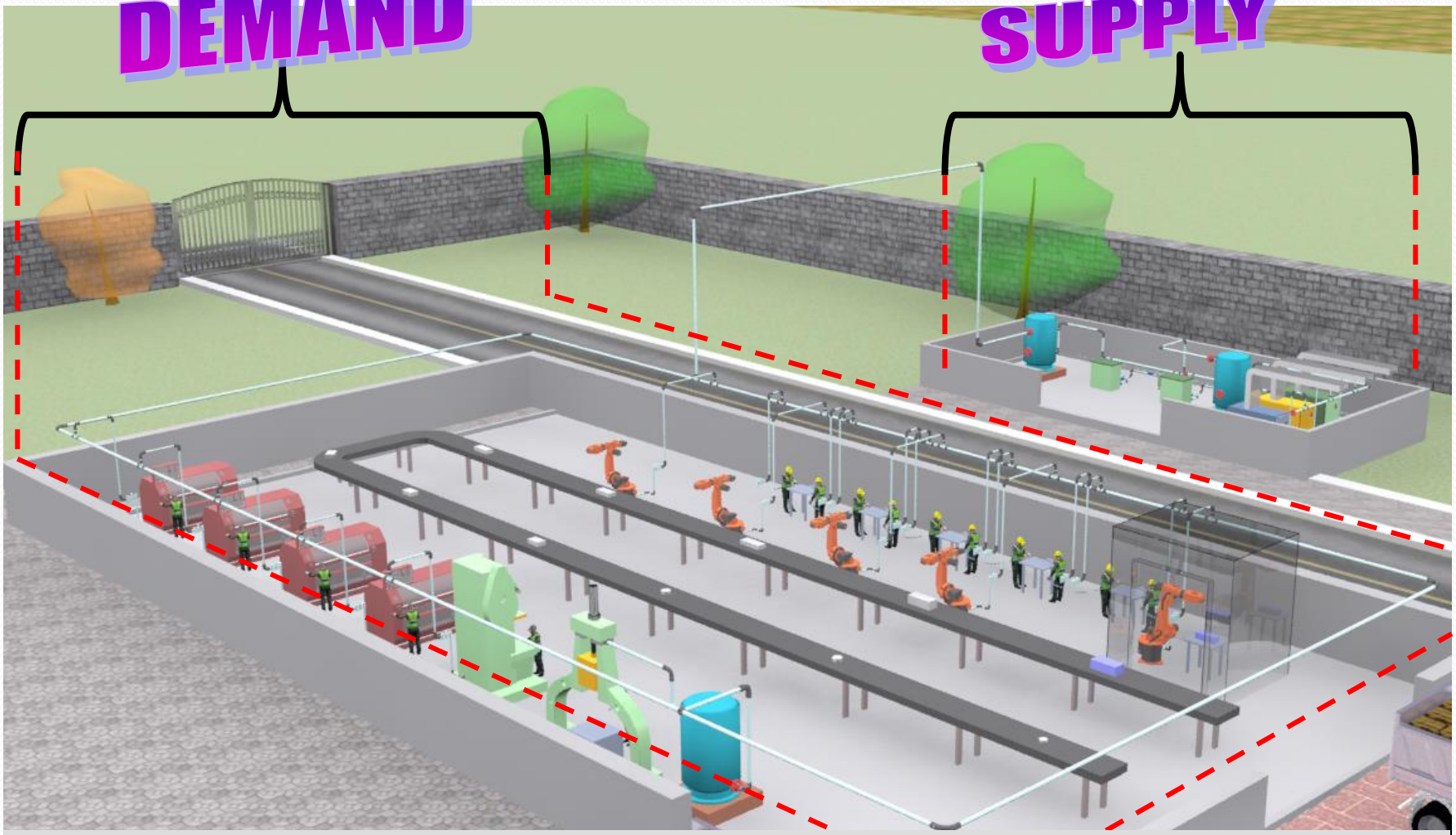
"Avoid Use Of Compressed Air"

But

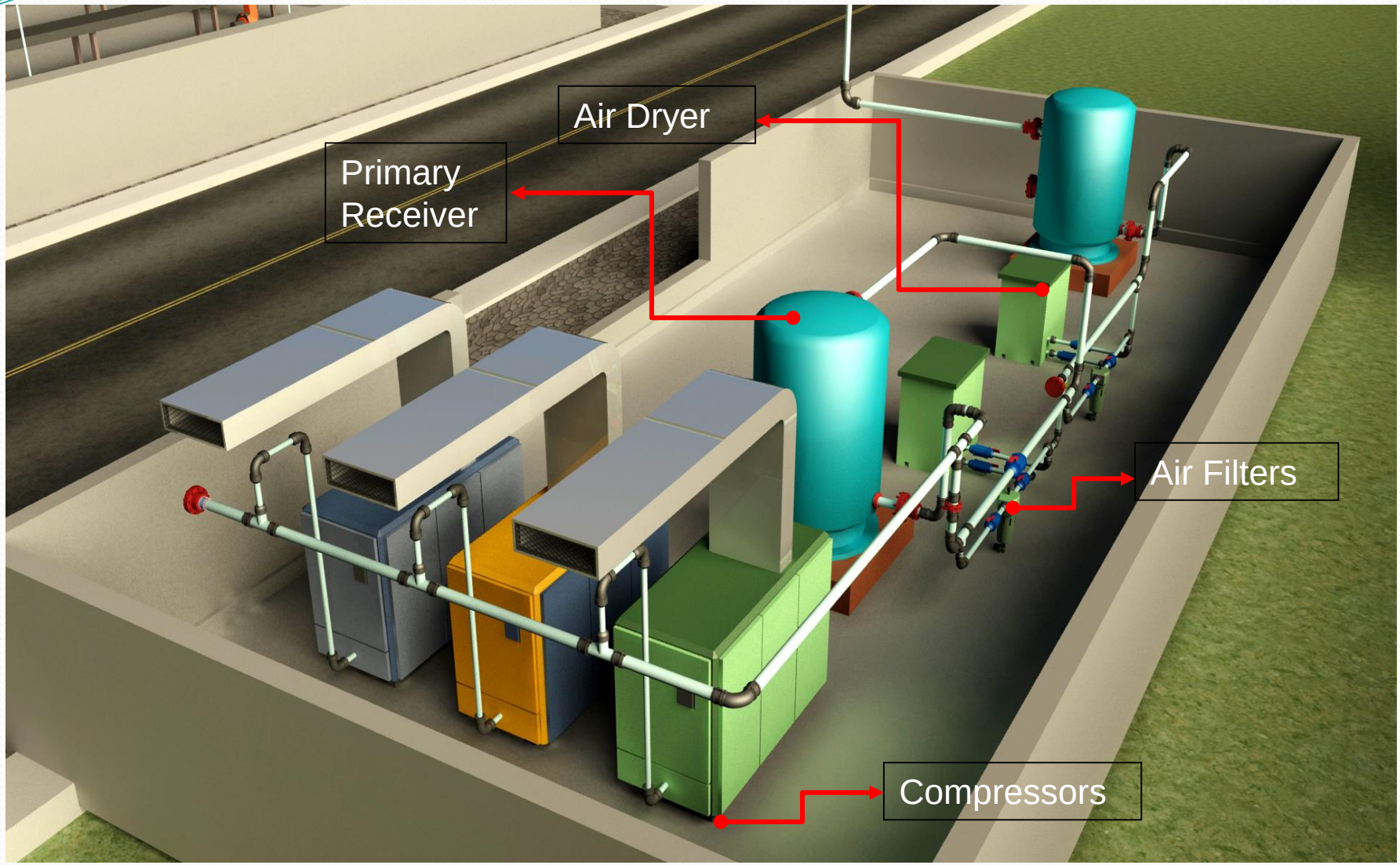
Sometimes It Is Not Possible To Avoid Use Of Compressed Air……

So, lets See…How Can We Save Energy In Compressors & Compressed Air System

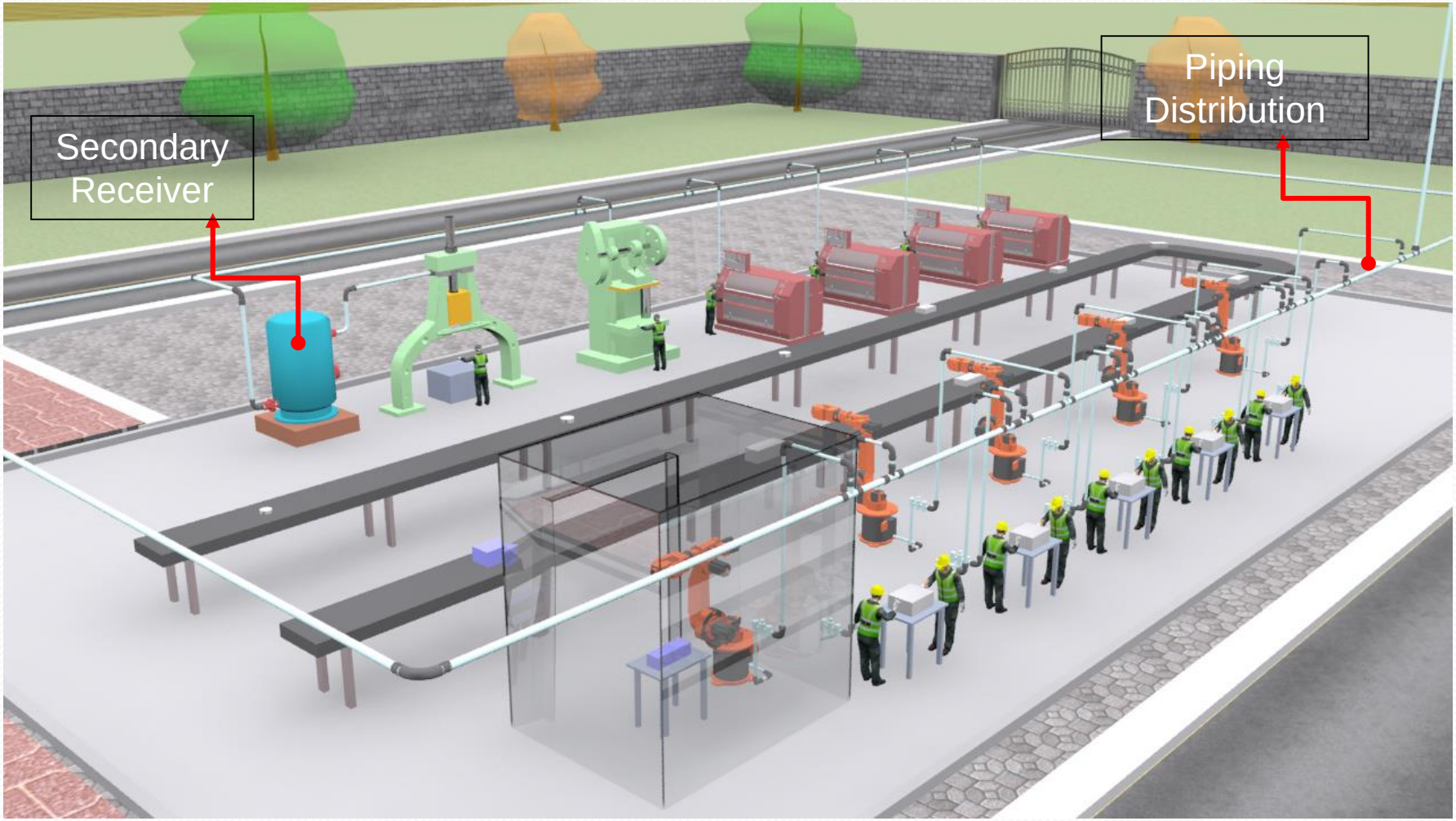
Components of Compressed Air System



Losses At Every Stage & Opportunity To Save Energy

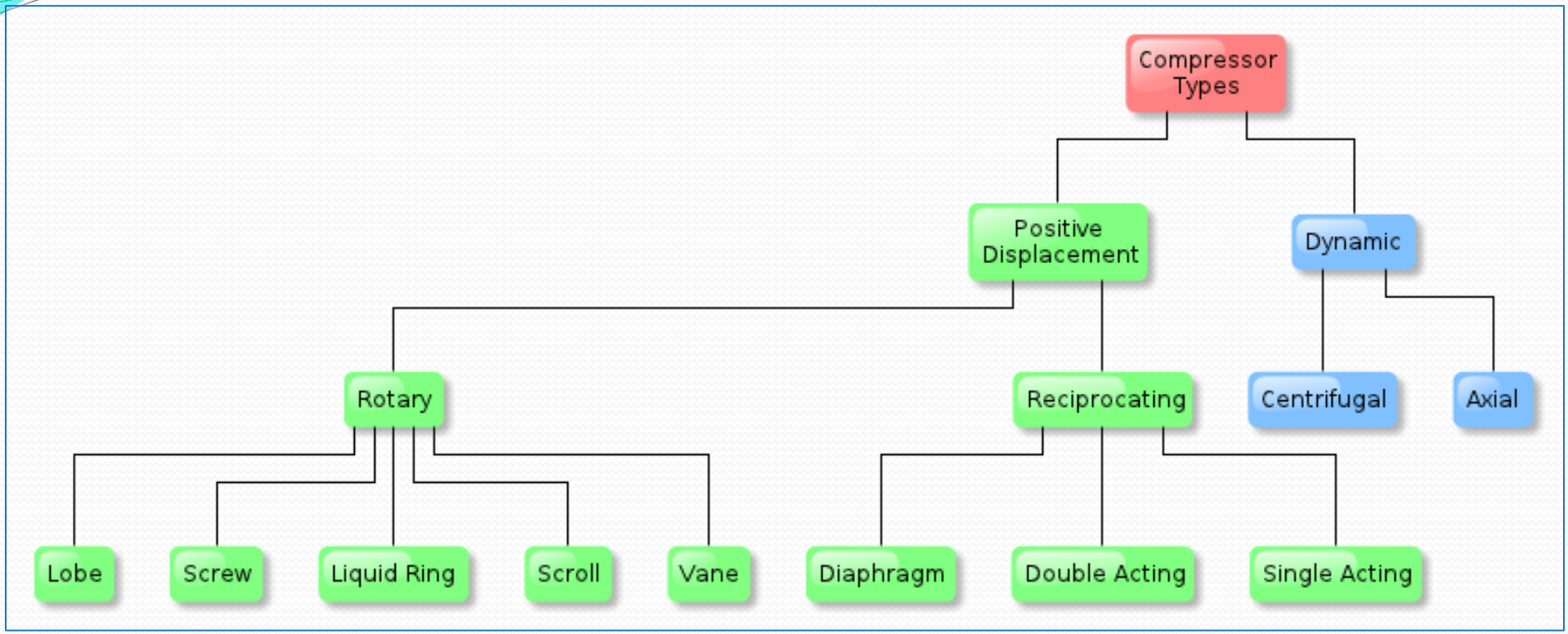


Supply Side Components of Compressed Air System



Demand Side Components of Compressed Air System

Air Compressors



Selection Criteria For Compressors

1. Depending Upon Pressure Requirement In Application :

Compressor Type	Pressure		Application
	From	To	
Blower	0.2 Barg	1.5 Barg	Aeration, Mixing
Low Pressure	1.5 Barg	4 Barg	Conveying, Cleaning, certain textile and Cement applications
Medium Pressure	4 Barg	12 Barg	Instrumentation/ Process
High Pressure	12 Barg	Upto 40 Barg	PET Application

Selection Criteria For Compressors

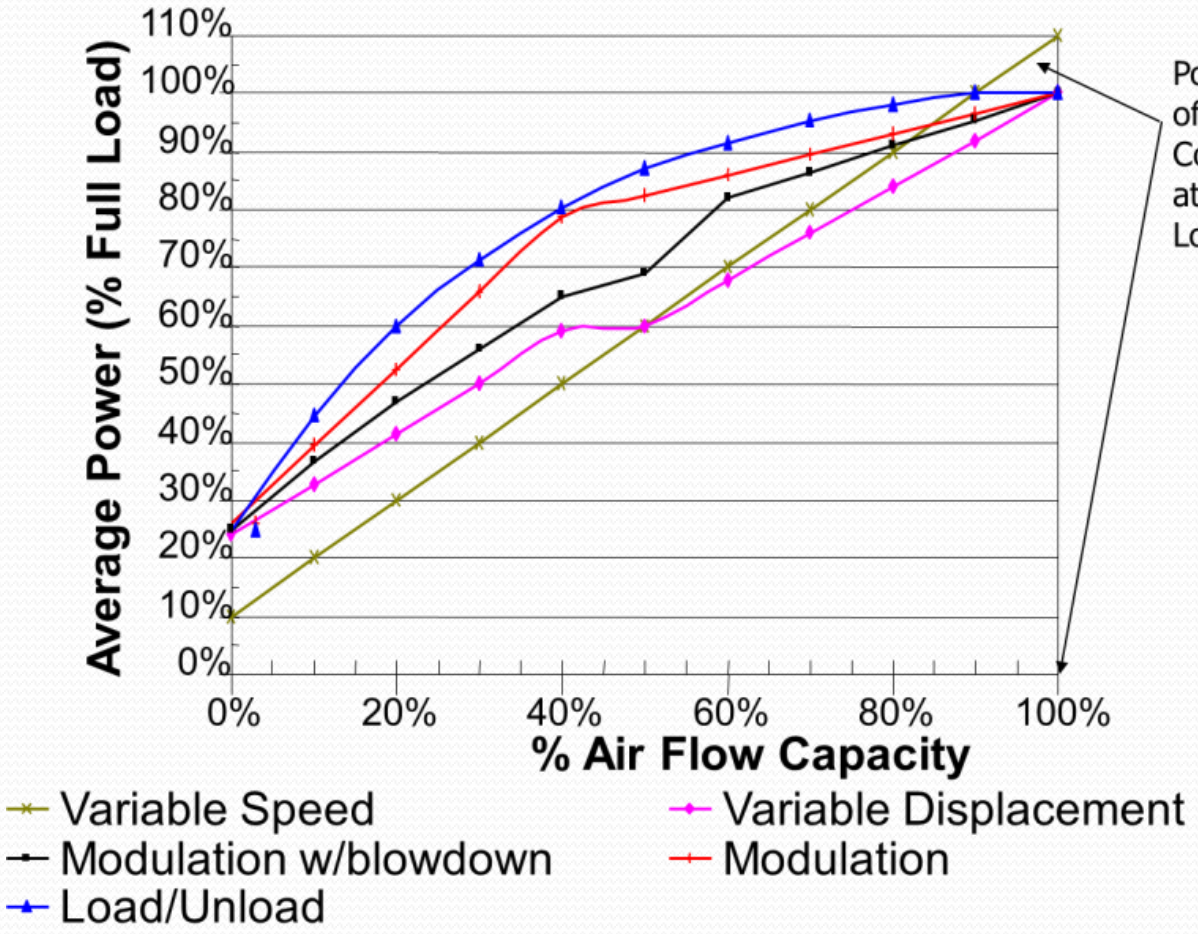
2. Depending Specific Power & Type of Air Demand:

Compressor Type	Specific Power At Full Load (kW/cfm)	Capacity Control	Energy Loss within Source
Reciprocating	Low	• Load / Unload; • VFD	• Wear & Tear – Piston Rings and Cylinders
Screw	Medium	• Inlet Modulation • Load / Unload • VFD	• Teflon coat wear off (Dry Screw) • 30% power consumption during Unload
Centrifugal	High	• Inlet Modulation • Bypass to Suction • Constant Pressure (Blow Off) • Load / Unload • Auto Dual	• Flat Performance Curve • Poor Turndown • Blow-off

Selection Criteria For Compressors

Screw Compressors: Types of Capacity Control

- **Use Correct Method For Capacity Control/Modulation :**



Selection Criteria For Compressors

Centrifugal Compressors

Advantages :

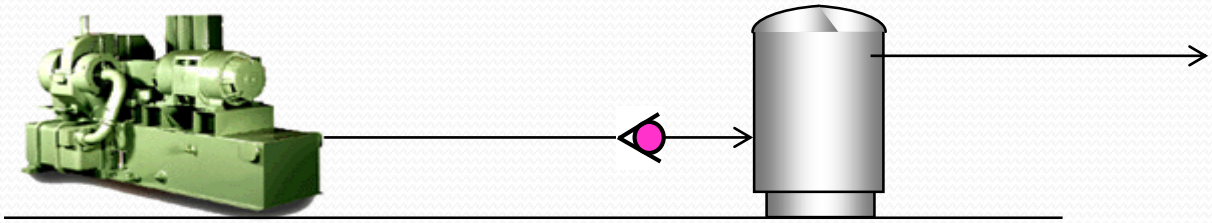
1. Oil Free
2. Designed for High Flow rates
3. Low Specific Power
4. Low Maintenance

Disadvantages :

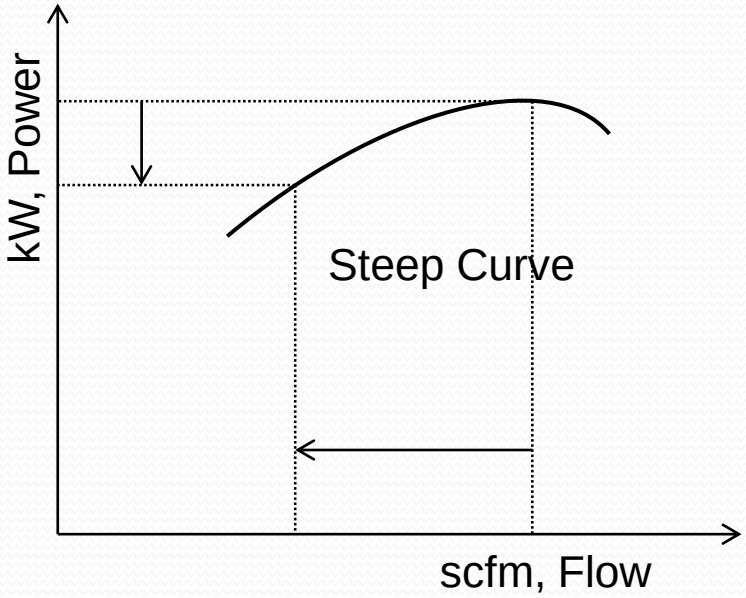
1. High Initial Cost….(But Low Running Cost)
2. Low Turndown
3. Designed for specific pressure and flow for the best efficiency; so if operated at different parameters then efficiency will be reduced.
4. If not operated on base load, performance is poor.

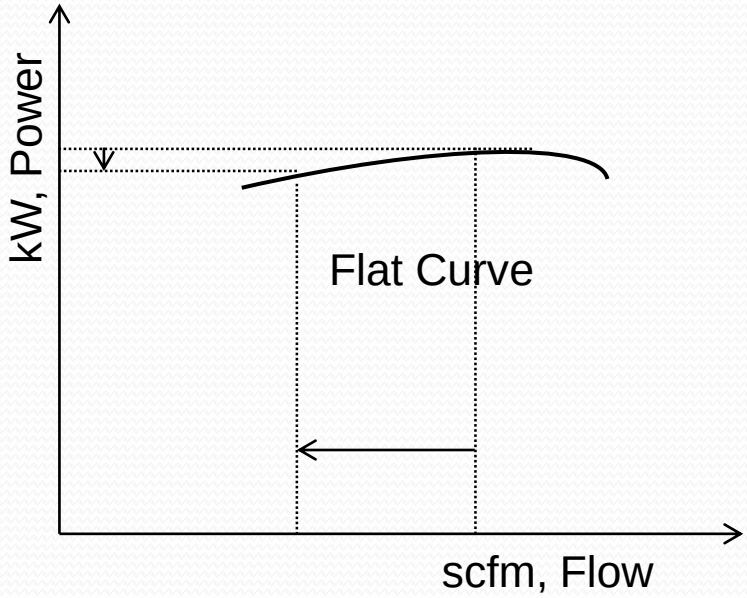
Best Scenario to Operate : 80-100% Load

Capacity Control in Air Compressors: Volumetric Displacement



POWER: Best Scenario: 80% to 100% (Min to Max)





Centrifugal Compressors: Performance Curve types

Energy Saving Opportunities In Compressors

A. Location of Compressors

Compressor performance improves with cool, clean, dry air at intake.

- **Cool air intake**

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

- **Dust Free Air Intake**

  "For every 250 mm WC pressure drop increase across at the suction path due to choked filters etc, the compressor power consumption increases by about 2 percent for the same output"

B. Utilise the Heat of Compression

Plate type heat exchanger utilizes heat from Lubricant Oil & Discharge Air to heat water and supply to process or kitchen or bathrooms.

Energy Saving Opportunities In Compressors: Heat Recovery

1 Screw Compressor

2 Heat Exchanger

3 Circulation Pump

4 Expansion tank for energy recovery system

5 Additional heating tank

6 Heating line circulation pump

7 Thermostat

8 Heater

Energy Saving Opportunities In Compressors

➢ **Use Correct Combination of Compressors:**

- Equal Capacity Compressors:
  - All on Base Load – Except One on Trim Load (Load / Unload or VFD)

- Different Capacity Compressors:
  - Smallest Compressor on Trim Load (Load / Unload or VFD)

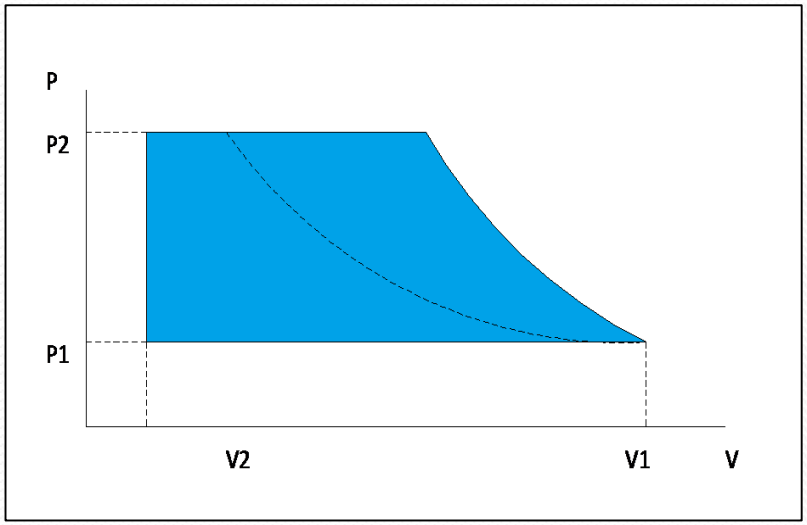
- Different Technologies of Compressors:
  - Compressor with lower part load power consumption on Trim Load.

Use Supply Side Intelligent Management System!!

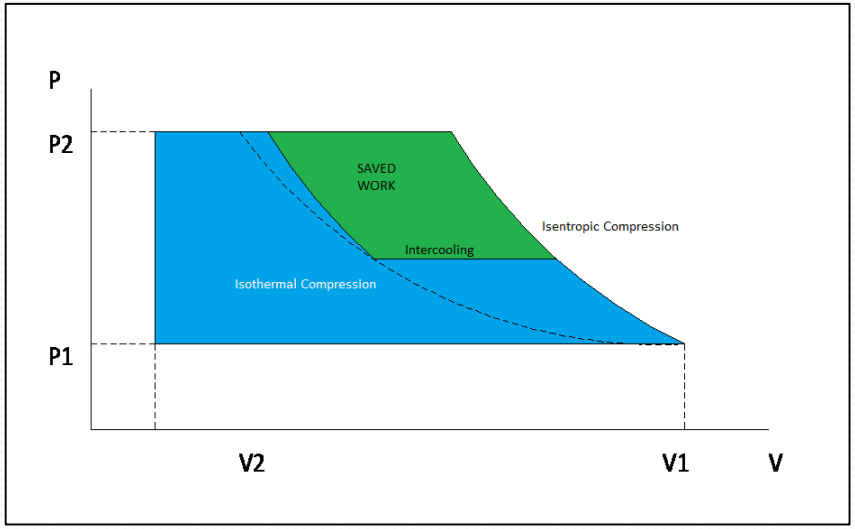
Energy Saving Opportunities In Compressors

➢ **Use Multi-stage Compressors:**

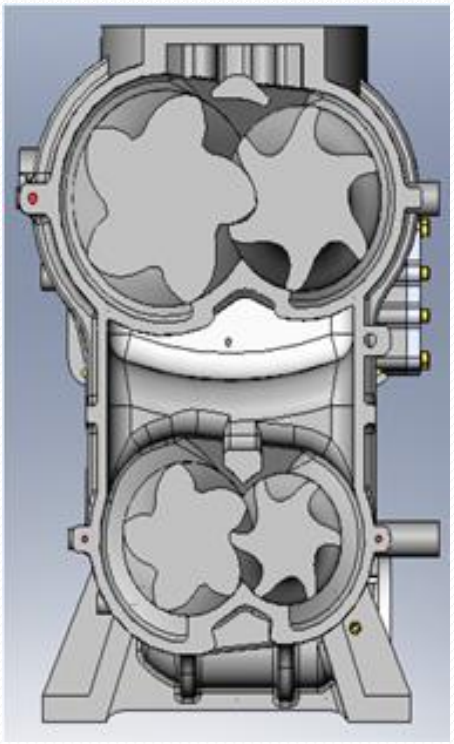
Compressing in multiple stages allows cooling to occur between the stages, which saves work in the compression process. Inter-coolers are provided between successive stages of a multi-stage compressor to remove the heat of compression hence reduces the work of compression (power requirements).

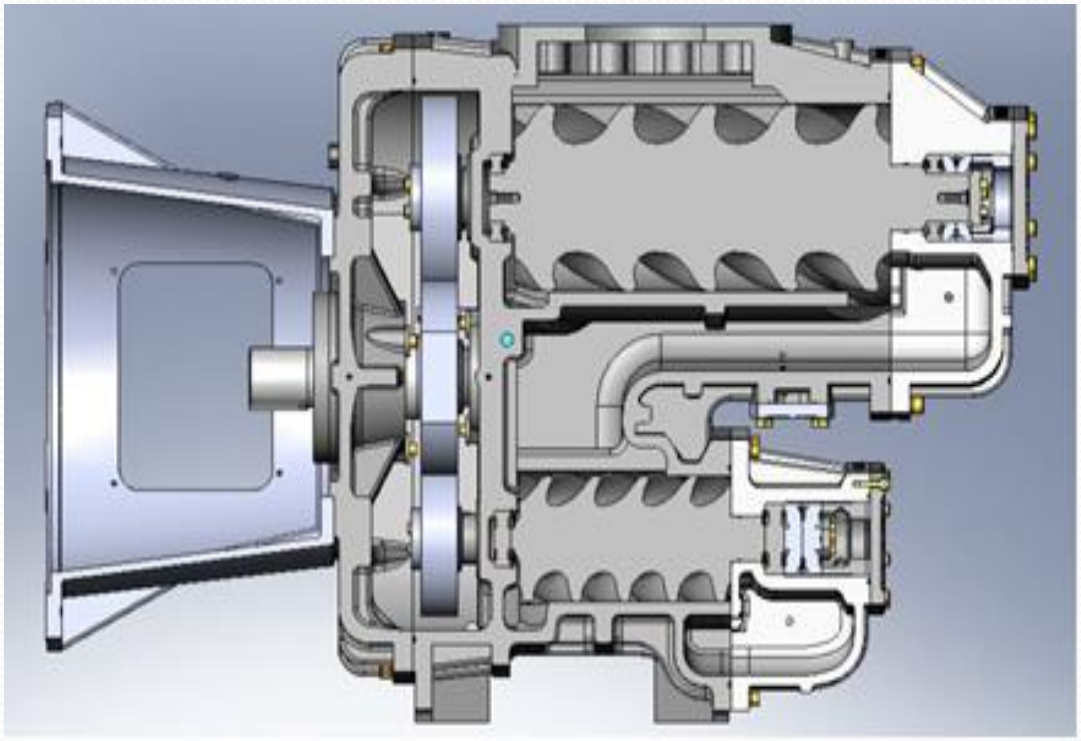


P-V Graph For Single Stage Compressor



P-V Graph For Two Stage Compressor With Intercooling





- *Inter Cooling Between two Stage*
- *Adaptability between Two Elements*
- *Optimal Oil Injection and Oil flow in Gears set*

- *Integrated design*
- *Well Balance, no vibration*
- *Minimum stress*
- *Low temperature*

COMPARISION

❖ CONVENTIONAL

Flow: 1070 cfm

Power: 160 kW

Input Power: 189 kW

Specific Power: 0.174 kw/cfm

❖ TWO STAGE

Flow: 995 cfm

Power: 132 kW

Input Power:140 kW

Specific Power: 0.140 kw/cfm

Energy Saved : (0.174 – 0.140) X 1000 CFM X 8000 HRS X 7 Rs

= Rs 18,64,603/-

Case Study

Low Pressure

Lubricated Screw Compressor replacing a standard high pressure Screw Compressor operated at lower pressure

PYRO GRINDING COMPRESSORS

OLD COMPRESSORS

132 KW – 801 CFM / 7 bar(g)

NEW COMPRESSOR (LOW PRESSURE)

GODREJ – 90 KW – 803 CFM / 5 bar(g)

Benefits of Low Pressure (5 Bar) Screw Compressor – Pyro Grinding

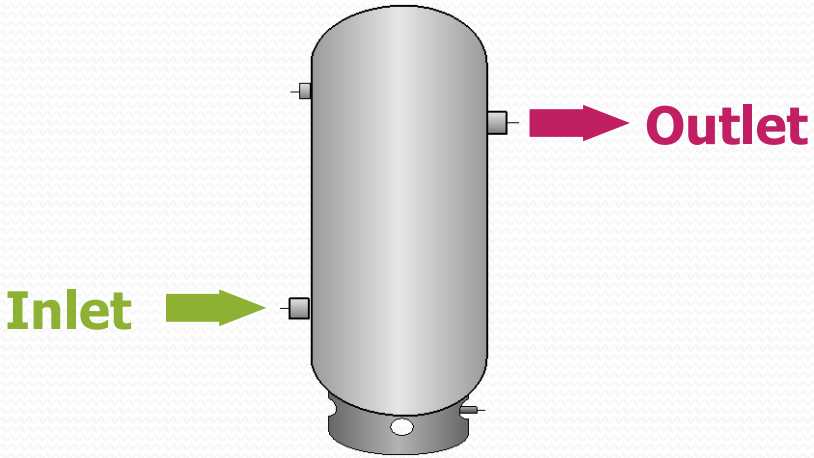
Earlier Screw Compressor:	**Godrej LP Screw Compressor:**
Energy consumption = 3600 KWH/Day	*Energy consumption* = 1800 KWH/Day
Compressors run = 1No. Screw, 7 Bar	*Compressors run* = 1No. Screw, 5 Bar
Operating Pressure = 5.1-5.6 Bar	*Operating Pressure* = 4.5-5.2 Bar

- ***Achieved Energy Savings = 1800 KWH/Day (@ 50%)***
- ***Overall Energy Savings / annum = 540000 KWH (300 Days)***
- ***Overall Cost Savings / annum = Rs.2160000 (Rs.4/KWH)***

Air Receivers/Storage

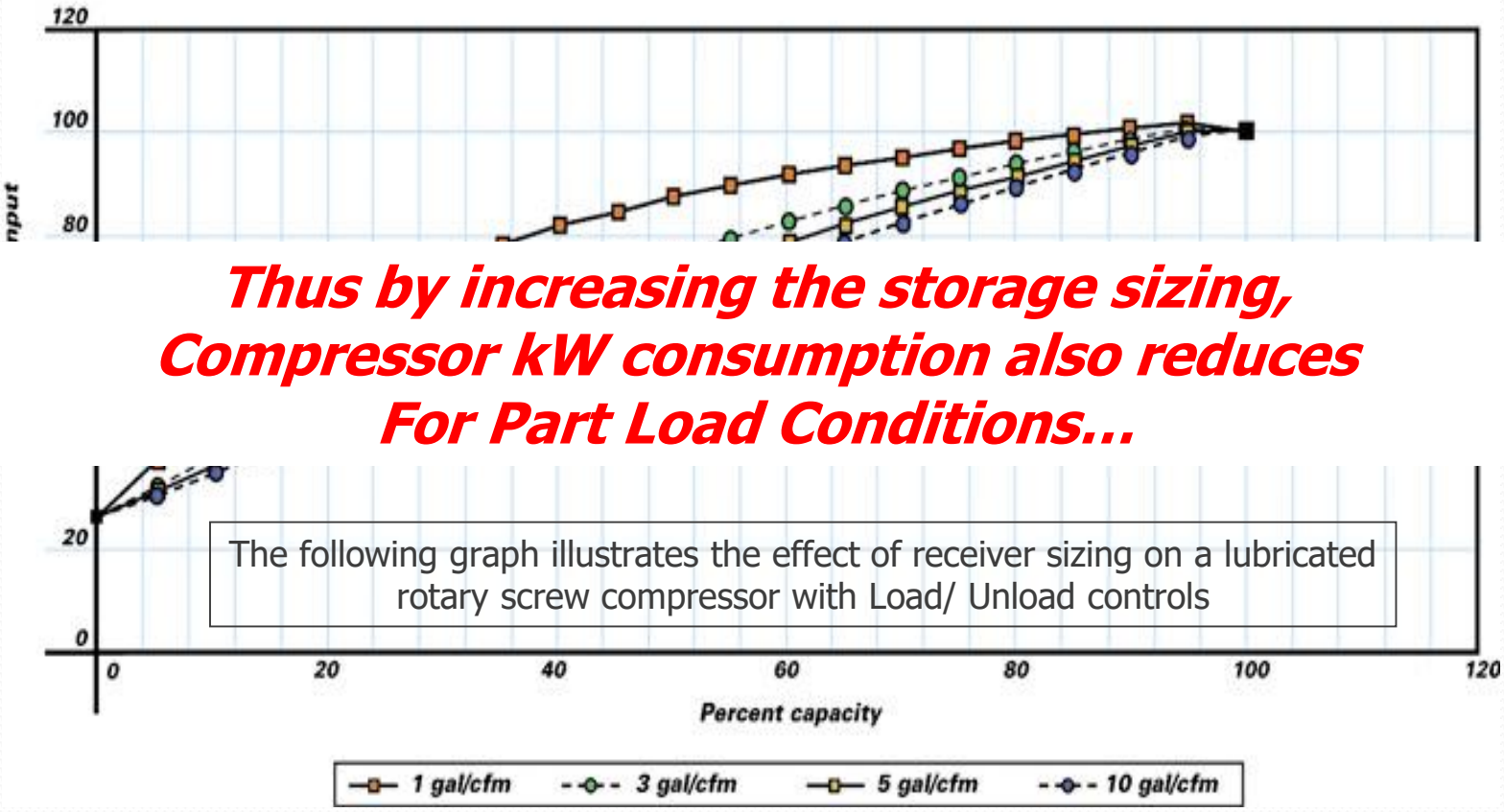
➢ **Use Of Air Receiver:**

- Dampens pulsations entering the discharge line from the compressor;
- Serves as a reservoir for sudden or unusually heavy demands in excess of compressor capacity;
- Prevents too frequent loading and unloading (short cycling) of the compressor;
- Separates moisture and oil vapour, allowing the moisture carried over from the after coolers to precipitate reducing load on Dryer



Air Receivers/Storage

Effect of Receiver capacity on Comp. kW Consumption



Thus by increasing the storage sizing, Compressor kW consumption also reduces For Part Load Conditions…

The following graph illustrates the effect of receiver sizing on a lubricated rotary screw compressor with Load/ Unload controls

Air Dryers

Type of Dryer	Pressure Dew Point °C	Energy Cons. For 1000 m3/hr
Refrigeration	+ 2 to + 3	2.9 kW
Desiccant regenerative (by compressed air purging)	-20	20.7 kW
Desiccant regenerative (external or internal heating with electrical or steam heater, reduced or no compressed air purging)	-40	18 kW
Desiccant regenerative (using heated low pressure air, no compressed air loss)	-40	12 kW
Desiccant regenerative (by recovery of heat of compression from compressed air)	-40	0.8 kW

Selecting Correct Type Of Dryer As Per Dew Point Requirement of Application Can Contribute In Energy Saving

Piping Distribution

- **Segregating Low And High Pressure Air Requirements**

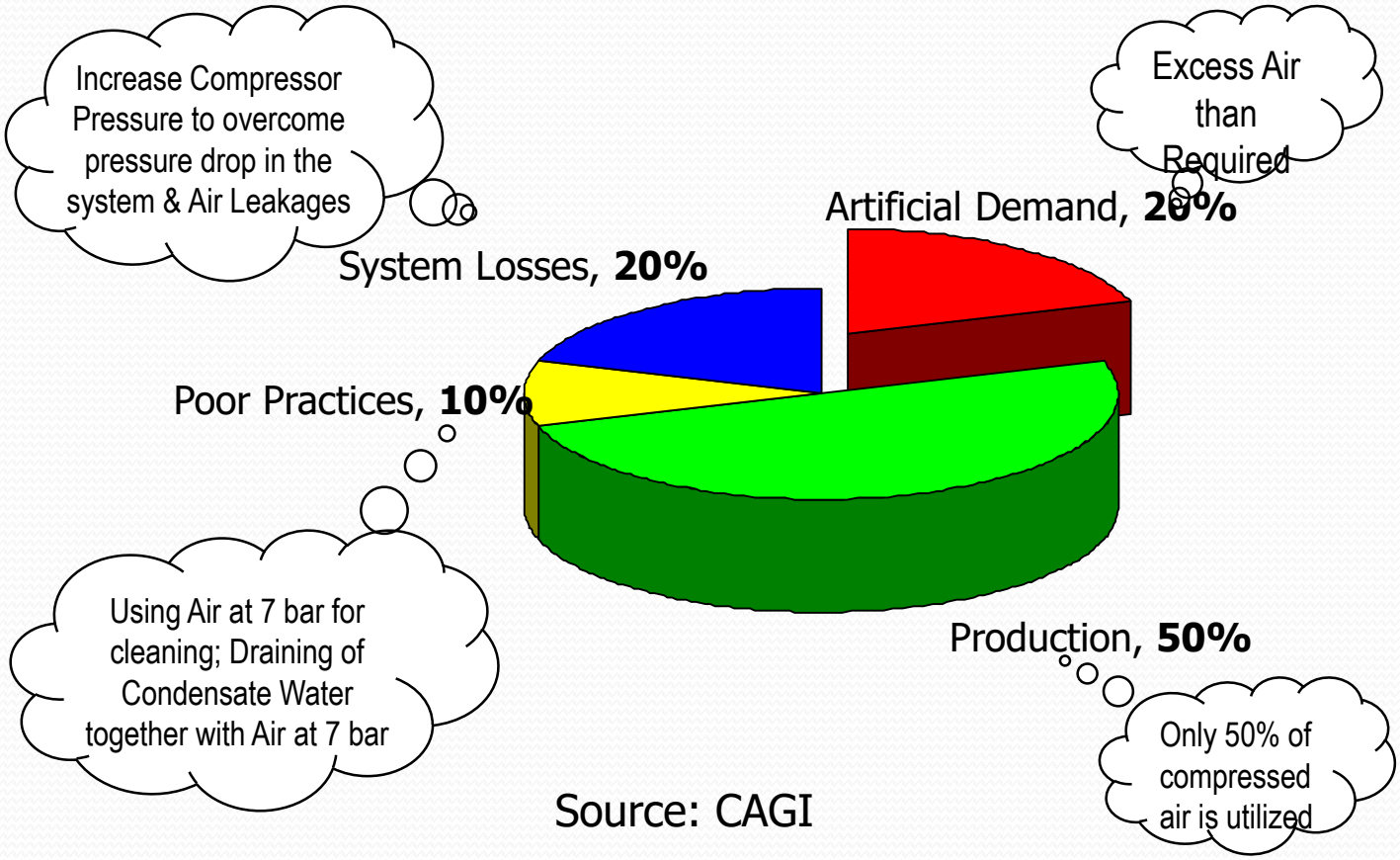
High pressure line and low pressure line should be separated as per application requirements which can give energy saving.

- **Piping Layout**

Where possible the piping system should be arranged as a closed loop or "ring" to allow for more uniform air distribution to consumption points and to equalize pressure in the piping

Compressed Air Utilisation In Conventional System

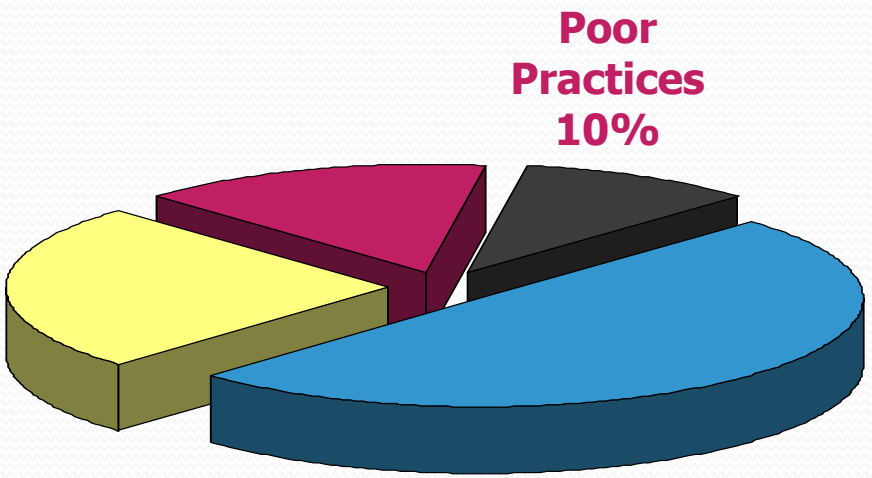
Out Of 100 % Energy Input, Only 15 % is used for Compressed Air Generation



Source: CAGI

Energy Losses – Poor Practices Waste 10%

- Using high pressure air for cleaning floors & machines
- Using high pressure air for washing of body (Safety Hazard)
- Using compressed air jets for cooling in hot weather
- Draining high pressure air along with condensate



Draining high pressure air along with condensate

Example: Loss of Energy in Condensate Drain of Air Receiver Tank:

Textile industry, Air Compressor: 1854cfm / 360 kW.

Timer Based Solenoid operated Drain Valve: 360 days/year & Energy rate @ Rs. 7/unit.

Opening Time of Auto drain	= 5 sec
Opening Interval of Auto Drain	= 240 sec
No of sec in a day (60 × 60 × 24)	= 86,400 sec
Cycle time of Auto Drain (opening time + opening interval)	= 245 sec
No of times auto drain opens in a day	= 353
Opening Time per Day	= 1763.2sec = 29 min
Air Lost through Timer based Drain	= 415cfm
Air Lost in 24 hrs	=12035 ft^3
Energy Cost Lost in each Drain valve	= Rs. 276
Annual cost of wastage from each auto drain valve	= 99,462 Rs.

No-Air-Loss Auto Drain Valve

We Recommend You To Install No Air Loss Auto Drain Valve At Receiver Drain Out Point.

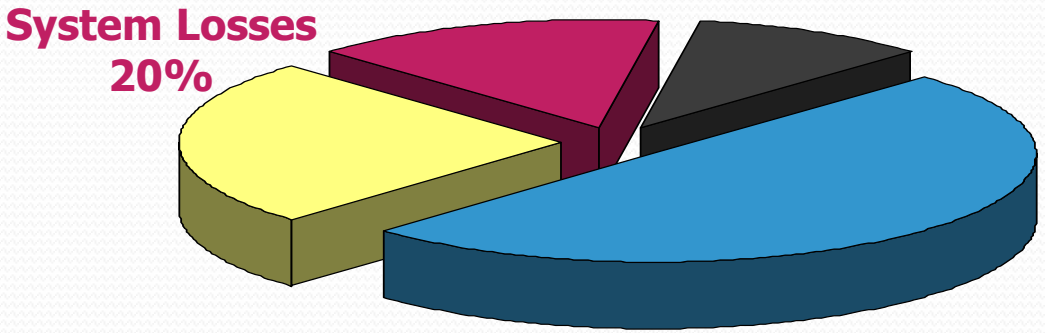
Principle :

- Twin Solenoid Operation
- When Inlet Is Open, Outlet Is Closed, And Moisture Is Collected In SS Bowl
- While Draining Condensate, Inlet Gets Closed & Drain Collected In Bowl Is Drained Only

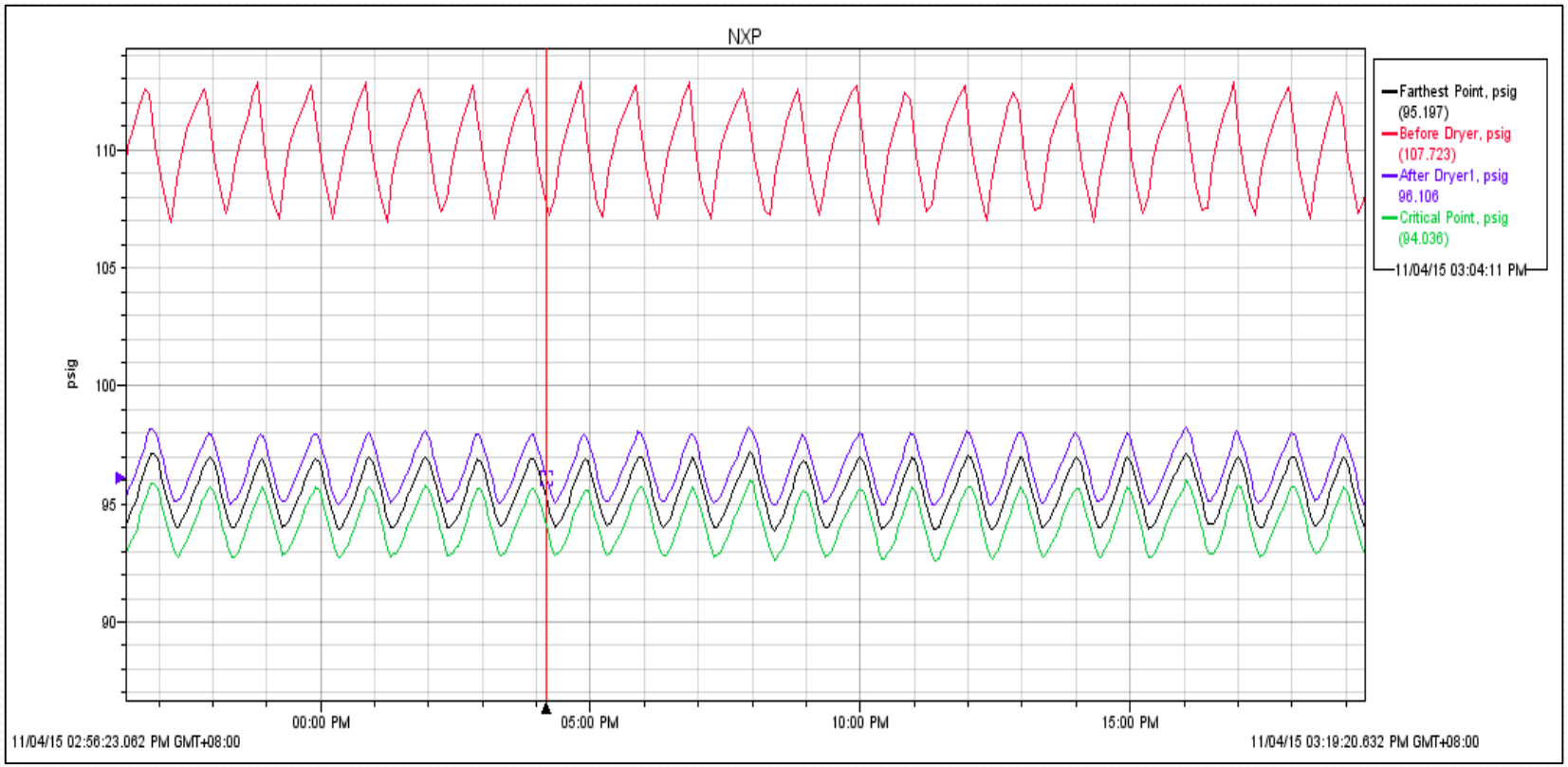
Level Sensing Type

Energy Losses – System Losses Waste 20%

- Pressure Loss in After Coolers, Moisture Separators
- Pressure Loss across Filters & Dryers
- Pressure Loss in Pipelines, Bends & Valves
- Air leakages in pipes, joints & end connections

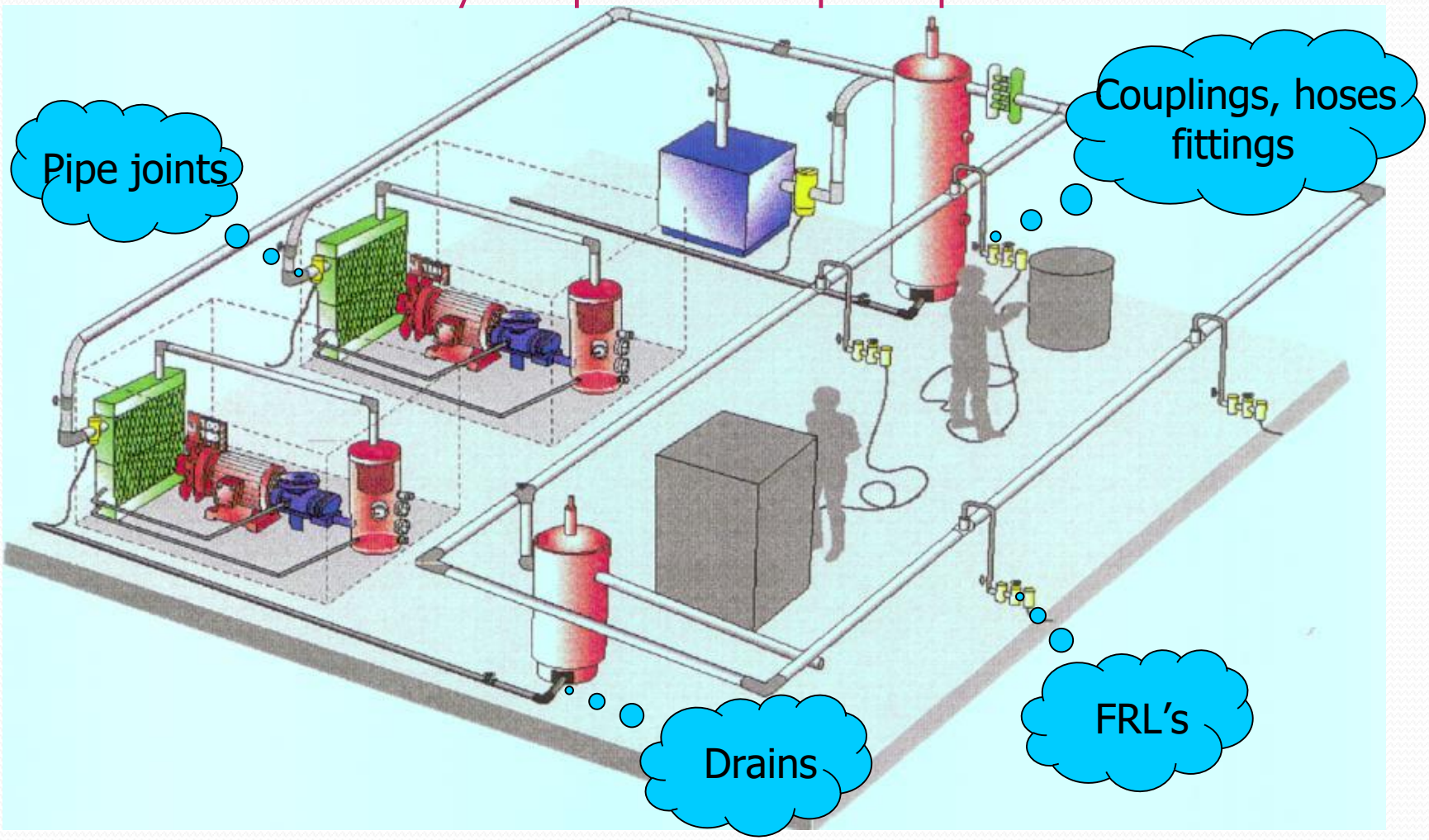


Pressure Drop Graph In Compressed Air System (Across Air Dryer)



❖How Do We Define An Air Leak ??

Air that is compressed for the purpose of performing work but inadvertently escapes to atmosphere prior to use…



Common Leak Locations

LEAKAGE CALCULATION TABLE (Air wasted in SCFM)

LEAKAGE CALCULATION TABLE
(Air wasted in SCFM)

Pressure	Leakage hole size				
(psig)	1/16	1/8	1/4	3/8	1/2
60	4.2	17	68	152	271
70	4.8	19	77	173	307
80	5.4	21	86	193	343
90	5.9	24	95	213	379
100	6.5	26	104	234	415
110	7.1	28	113	254	452
120	7.6	30	122	274	488

How Do You Find Leaks?

- **A Rs. 6000/Year Leak Cannot be felt or heard!**
- **A Rs. 24000/Year Leak Can be felt but not heard!**

Buy the time the leak becomes audible it is at least a Rs. 42000/Year Leak!

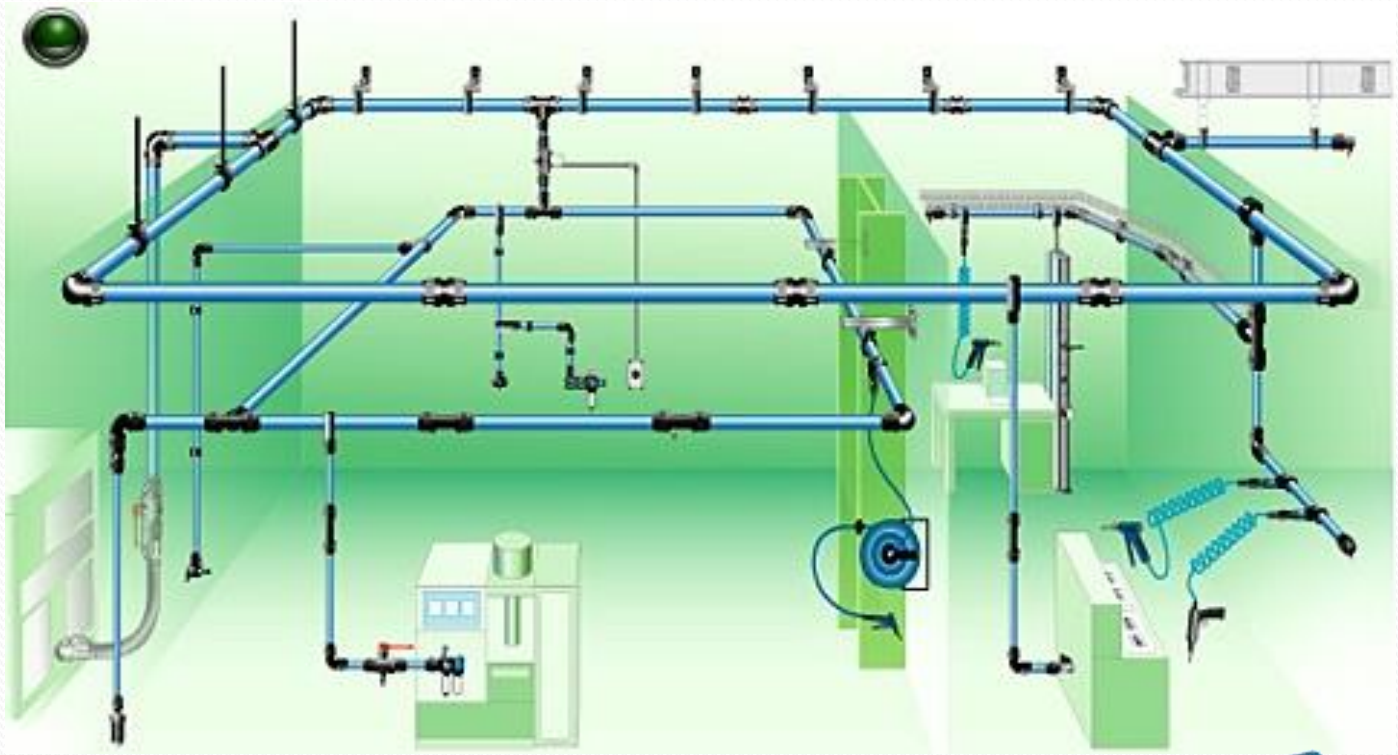
How do you find your leaks? -- by doing leakage tests regularly

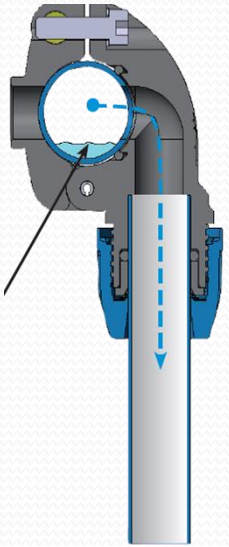
Develop a Leak Management Program to find and fix leaks!!!

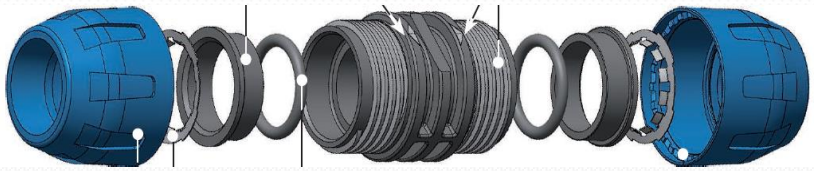
Aluminum Extruded Pipes with Aluminum Cast Fittings

Energy Efficiency in Compressed Air Distribution:

Leak-proof, Rust Free, Low Internal Surface Friction – Less pressure drop



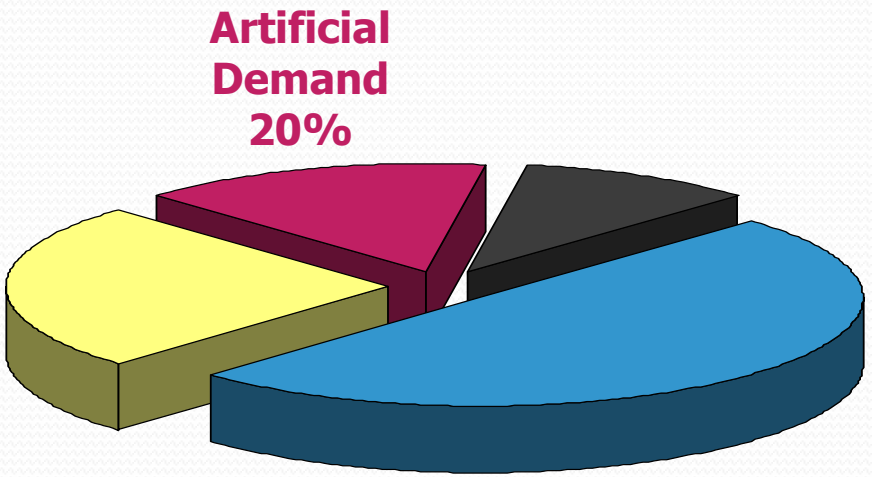




Energy Losses – Artificial Demand Waste 20%

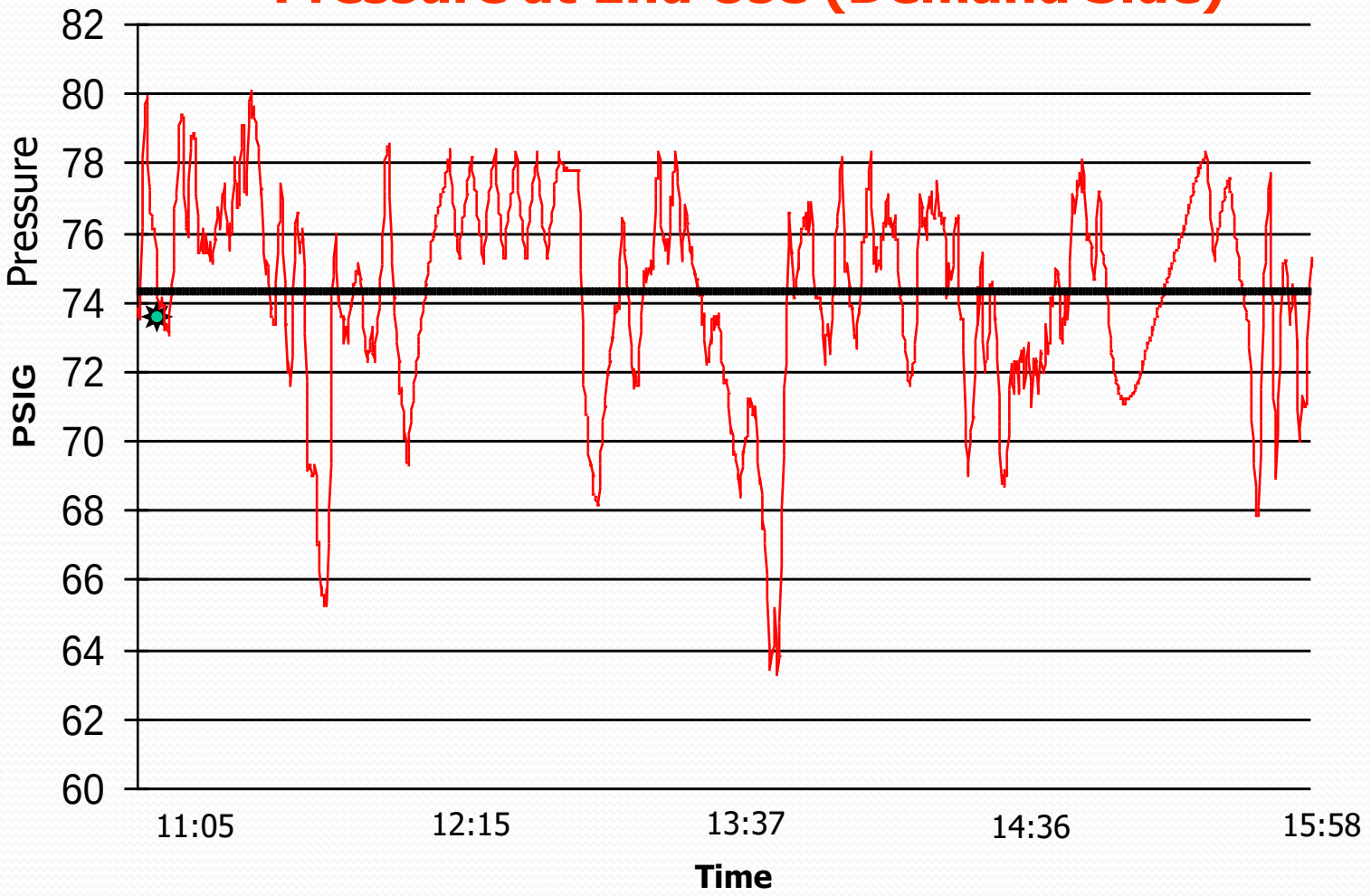
What is the definition of Artificial Demand

When an air application is supplied higher pressure than it needs, it will consume more air than it should.
The additional air consumption is artificial demand.



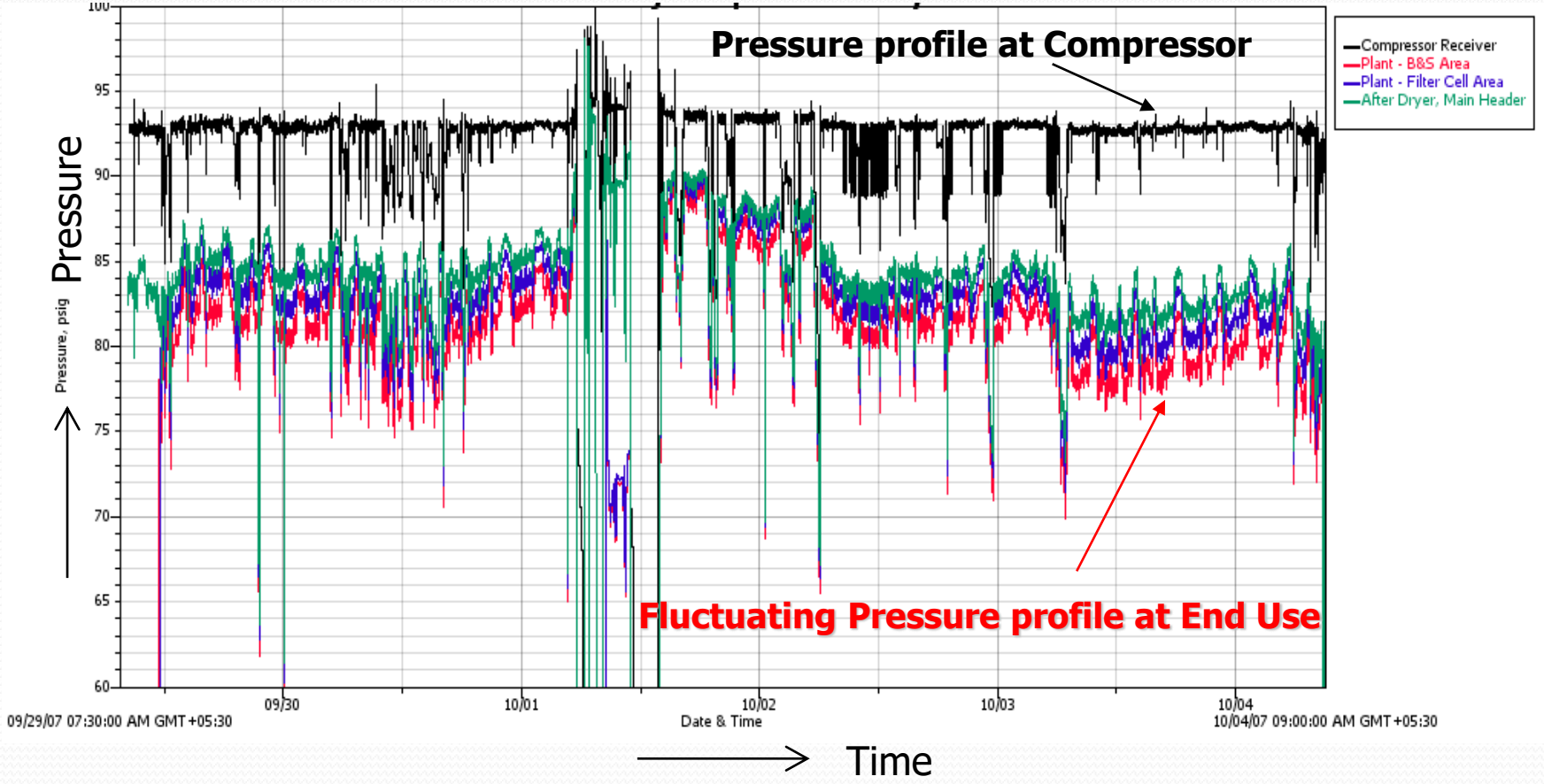
Energy Losses – Artificial Demand Waste 20%

Every industry has problem of fluctuating Air Pressure at End Use (Demand Side)



Variations in Compressed Air Pressure Real Time Data

Even with VSD Compressor, Pressure May Be Stable At Compressor, But Not At The End Use (Demand Side)



Artificial Demand

An air cylinder that is specified to use 30 psig, uses

70% more air at 60 psig,

230% more air at 90 psig,

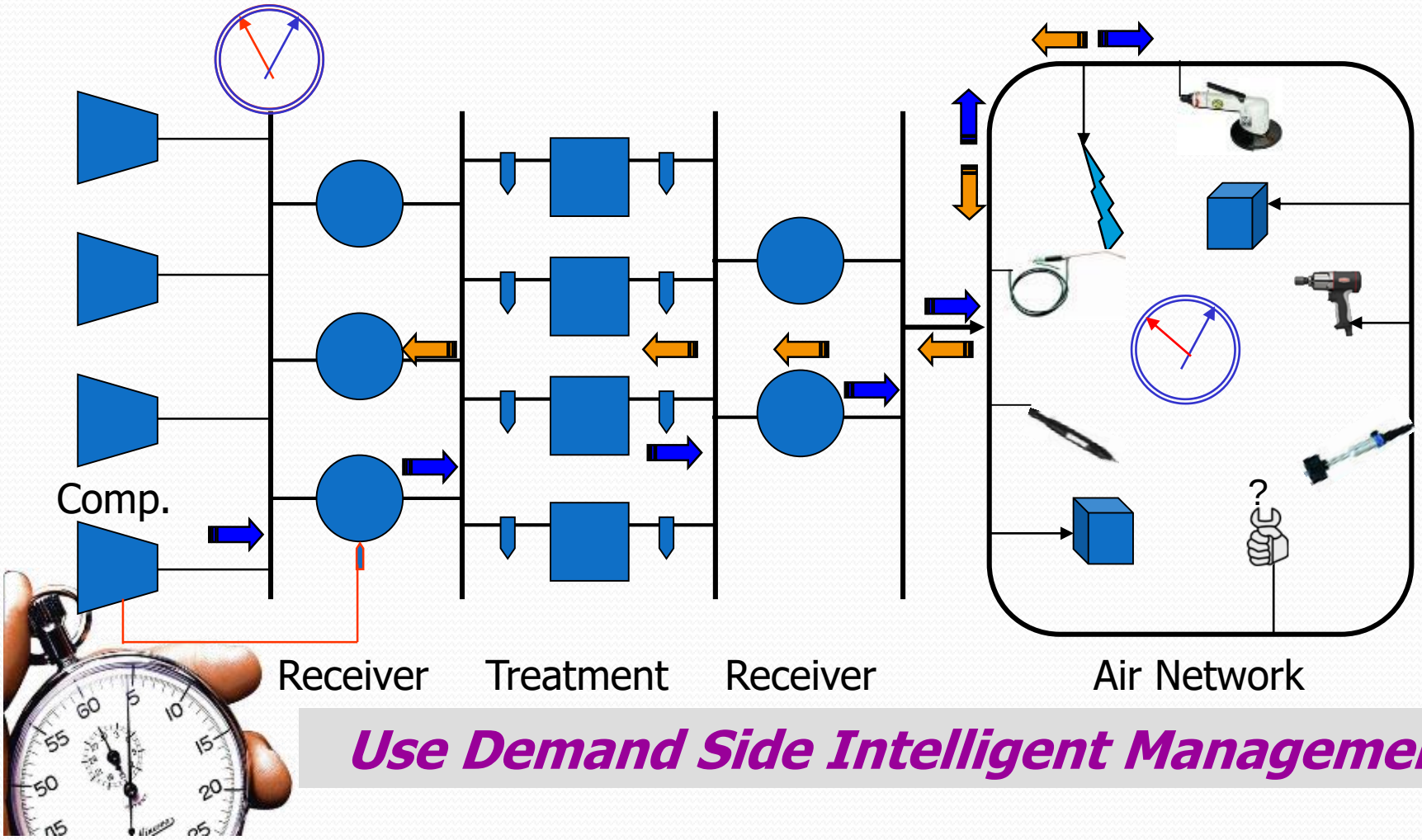
300% more air at 120 psig.

Virtually all air-powered equipment work this way – the more pressure delivered, the greater the air used. Auditors call this phenomenon as

Artificial Demand.

Conventional Compressed Air System

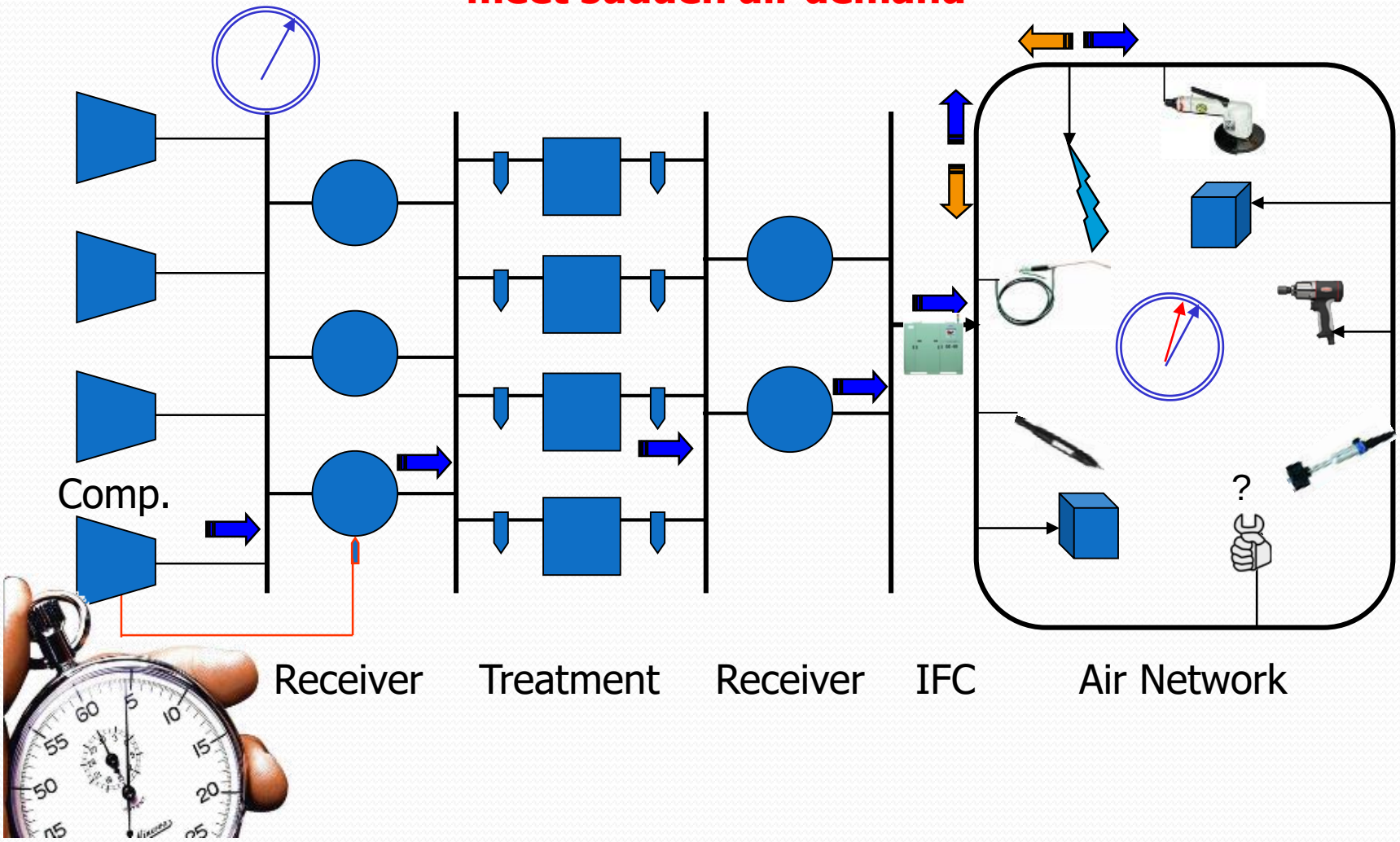
Response Time of Compressors with VFD or Load/Unload capacity control to meet sudden air demand



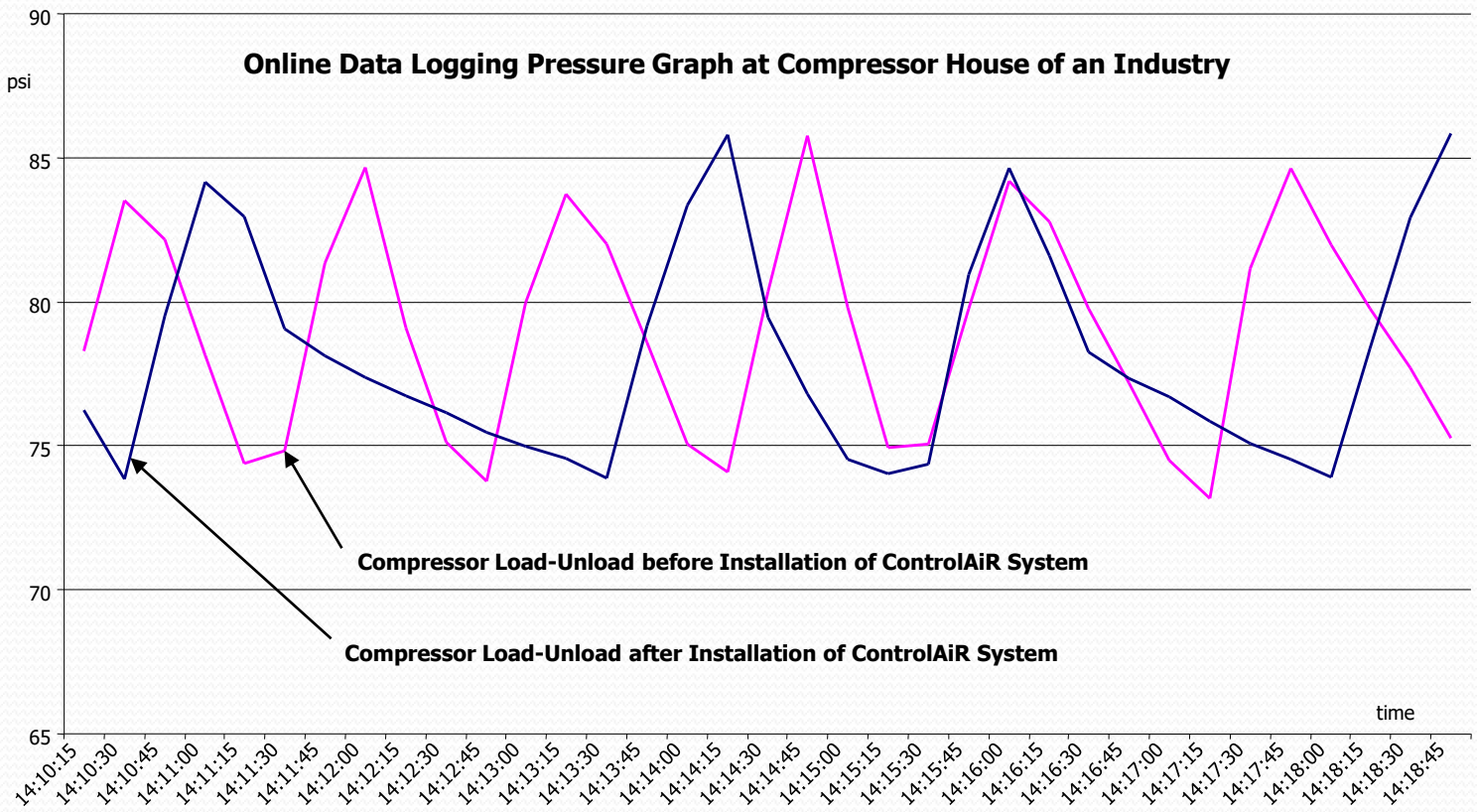
Use Demand Side Intelligent Management S

Compressed Air System with IFC

Response Time of Compressors ControlAir IFC System on-line to meet sudden air demand



IFC Reduces Load Time



IFC Reduces Load time of the Compressor .....Gives Energy Savings

Energy Savings with IFC

500 scfm Comp i.e. 120hp/ 90kW running 24 hrs/day

Without IFC

Load -70%; Unload - 30% Power Consumed:

- P_{load} = 90kW X 17hrs = 1530 kWh
- P_{unload} = 30kW X 7hrs = 210 kWh
- P_{Total} = P_{load} + P_{unload} = 1740 kWh/day

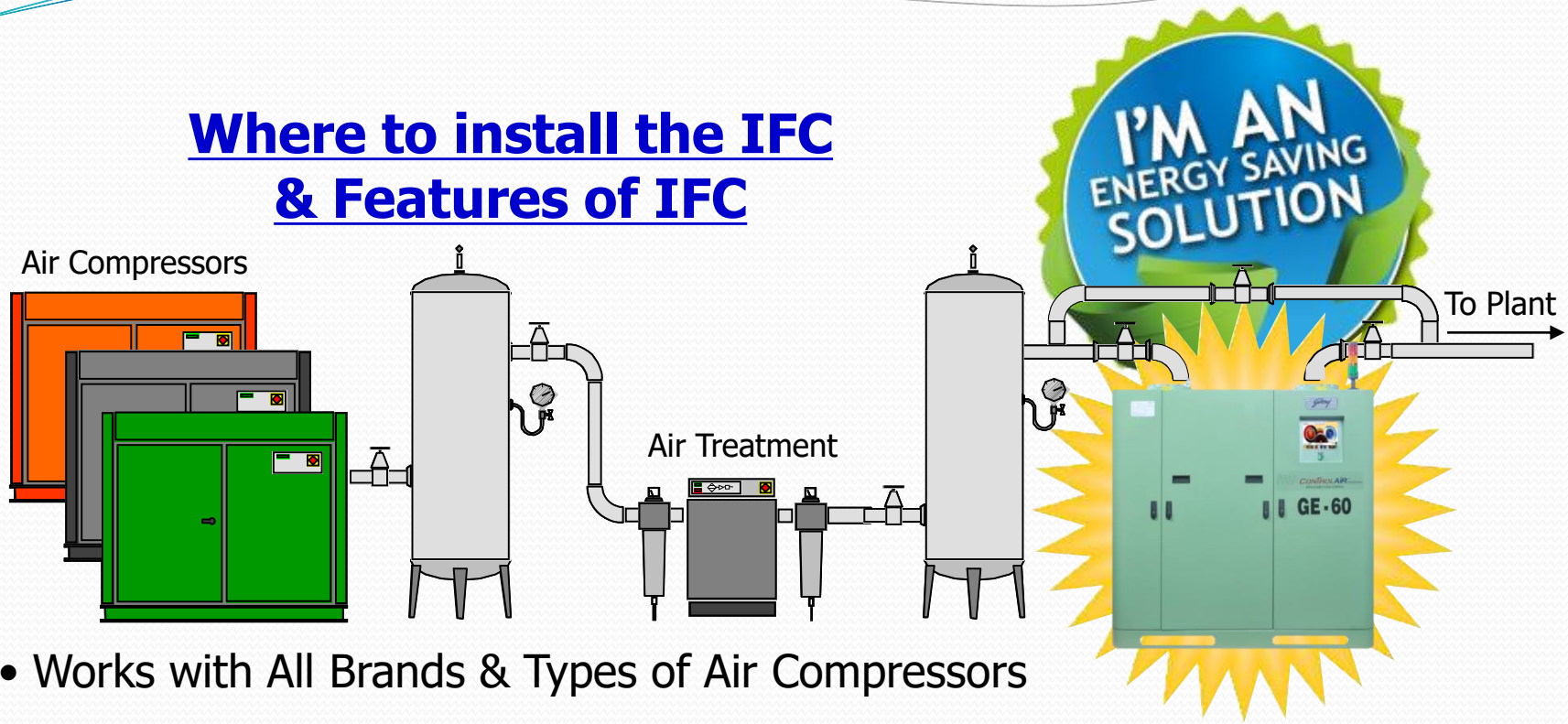
With IFC & Useful Storage

Load - 60%; Unload - 40% Power Consumed:

- P_{load} = 90kW X 14hrs = 1260 kWh
- P_{unload} = 30kW X 10hrs = 300 kWh
- P_{Total} = P_{load} + P_{unload} = 1560 kWh/day

% Energy Savings = (1740 – 1560) / 1740 X 100 = 10 %

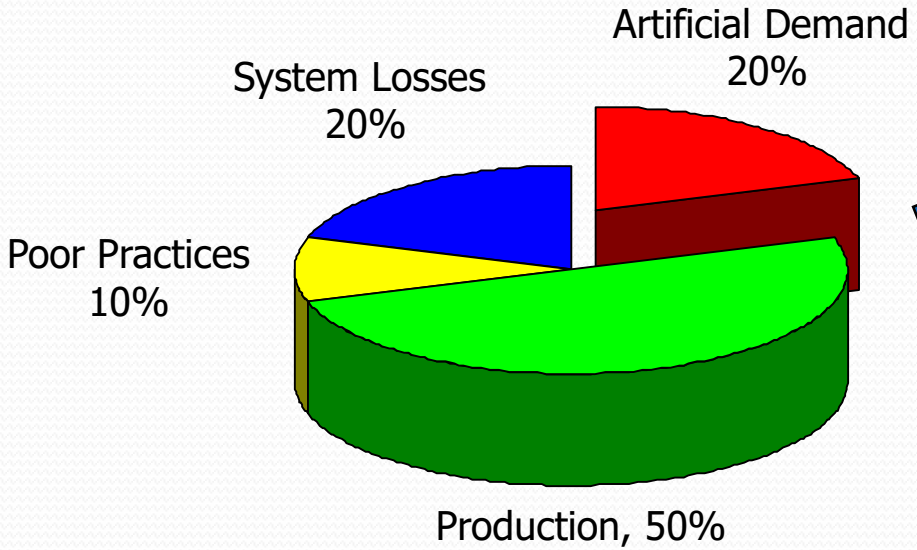
Where to install the IFC & Features of IFC



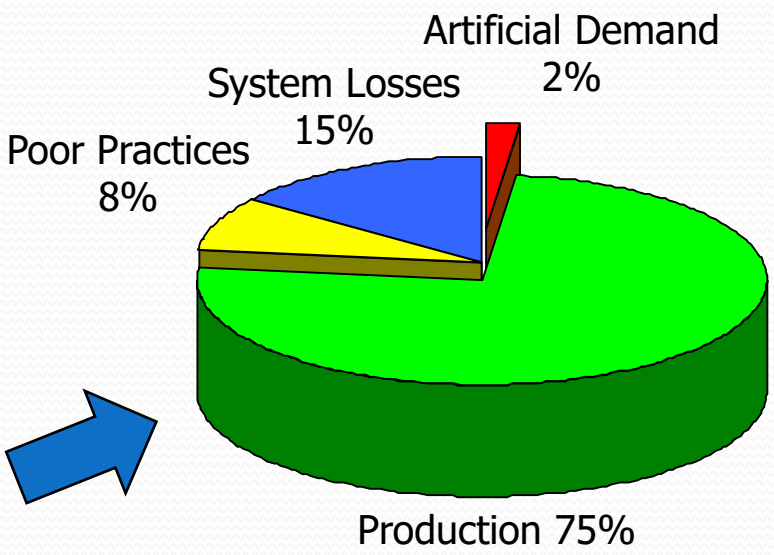
- Works with All Brands & Types of Air Compressors
- Reduces Artificial Demand & Save Energy, 4-25 %
- Provides Constant Pressure at the End Use, within +/- 1 psig
- Fail To Open System with Autobypass facility
- **Improves control performance of VSD Compressors**
- 28 Pressure scheduling & remote PC Visualization software can be done

Increased Efficiency Using Control Systems

Traditional System



Increased Efficiency with ControlAiR

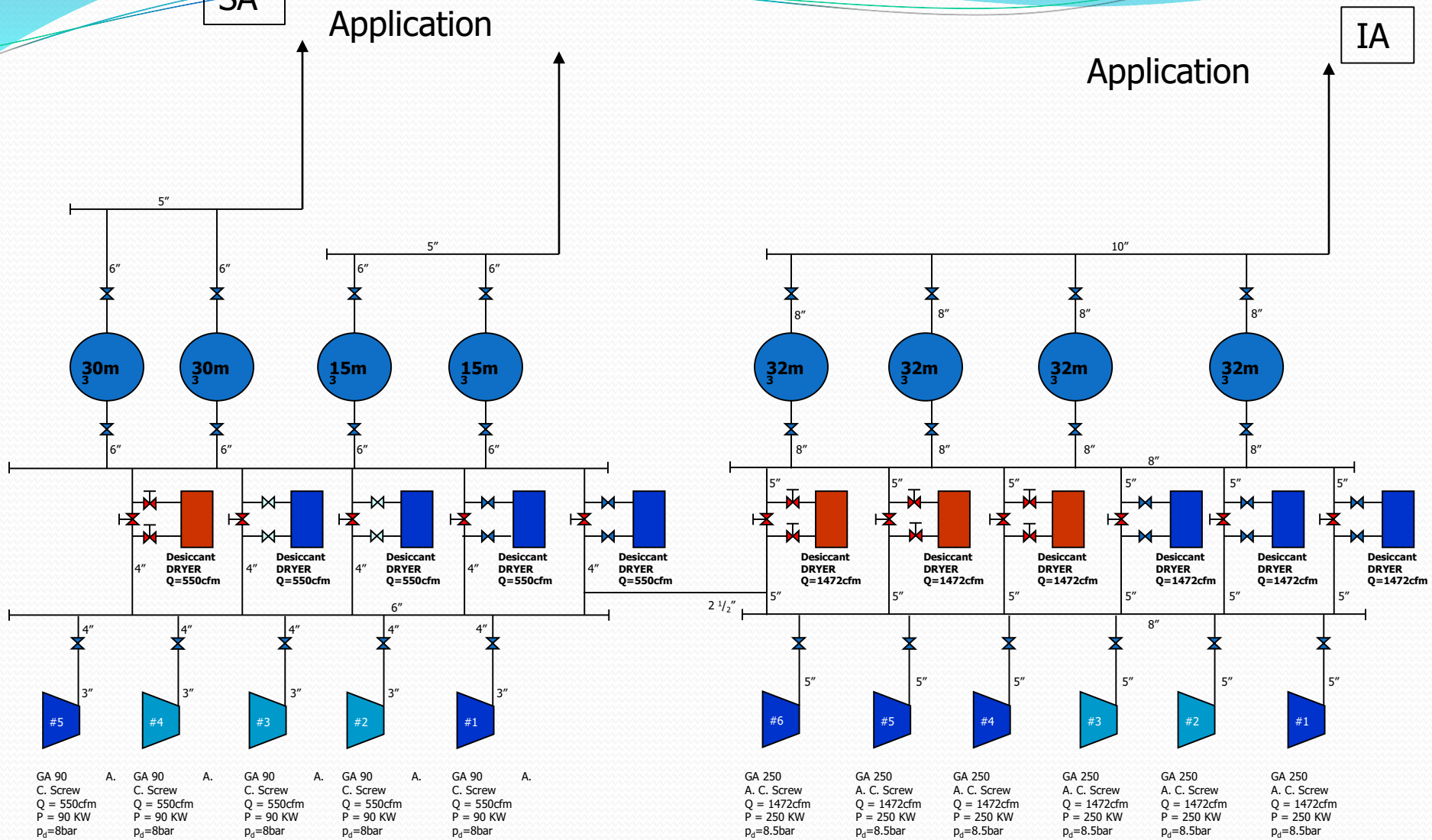


Case Study

"Energy Saving in Compressed Air System With Godrej ControlAiR IFC & ICC In Cement Industry"

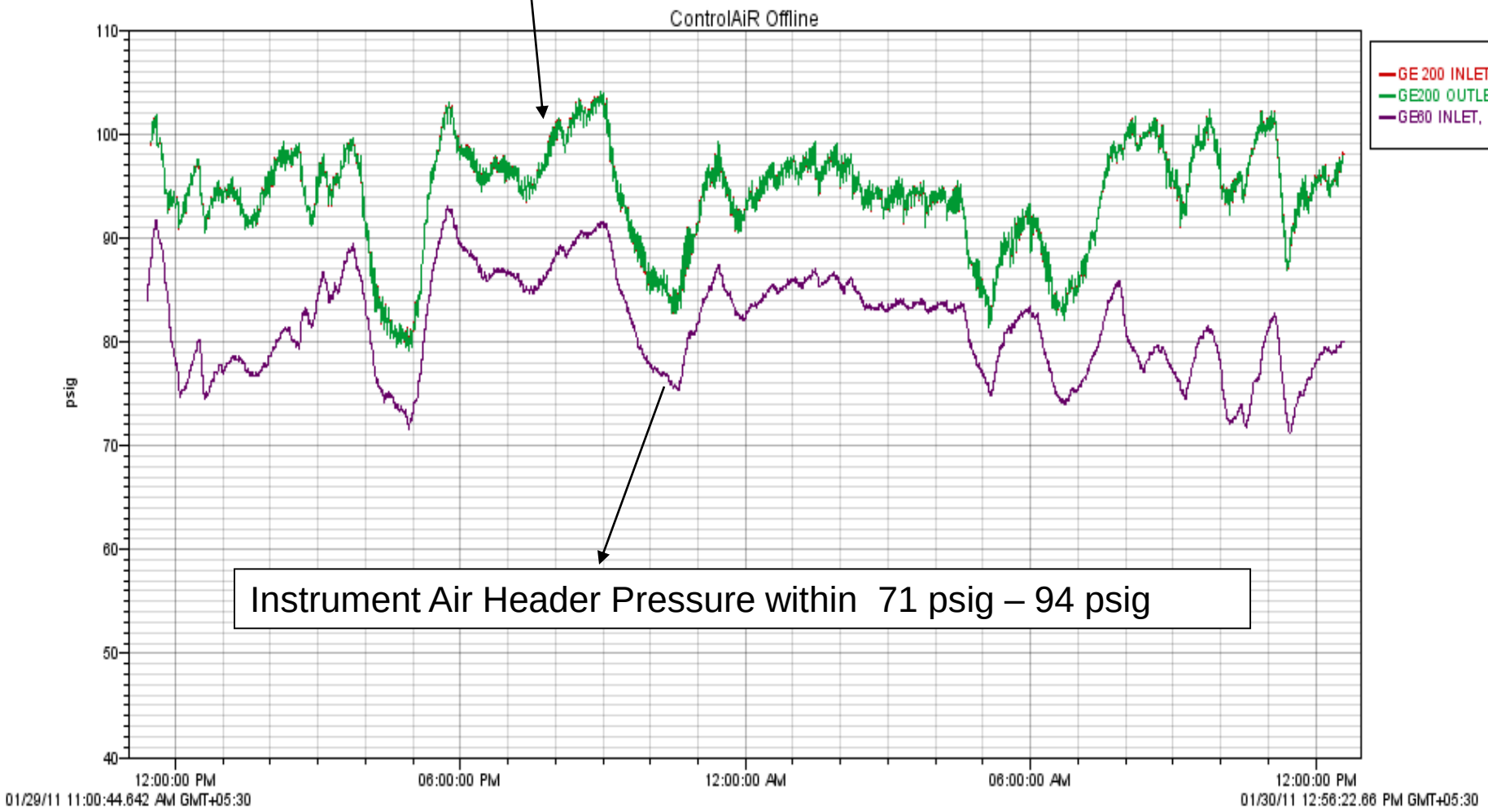
ControlAiR™
INTELLIGENT FLOW CONTROL

Earlier Compressed Air Network



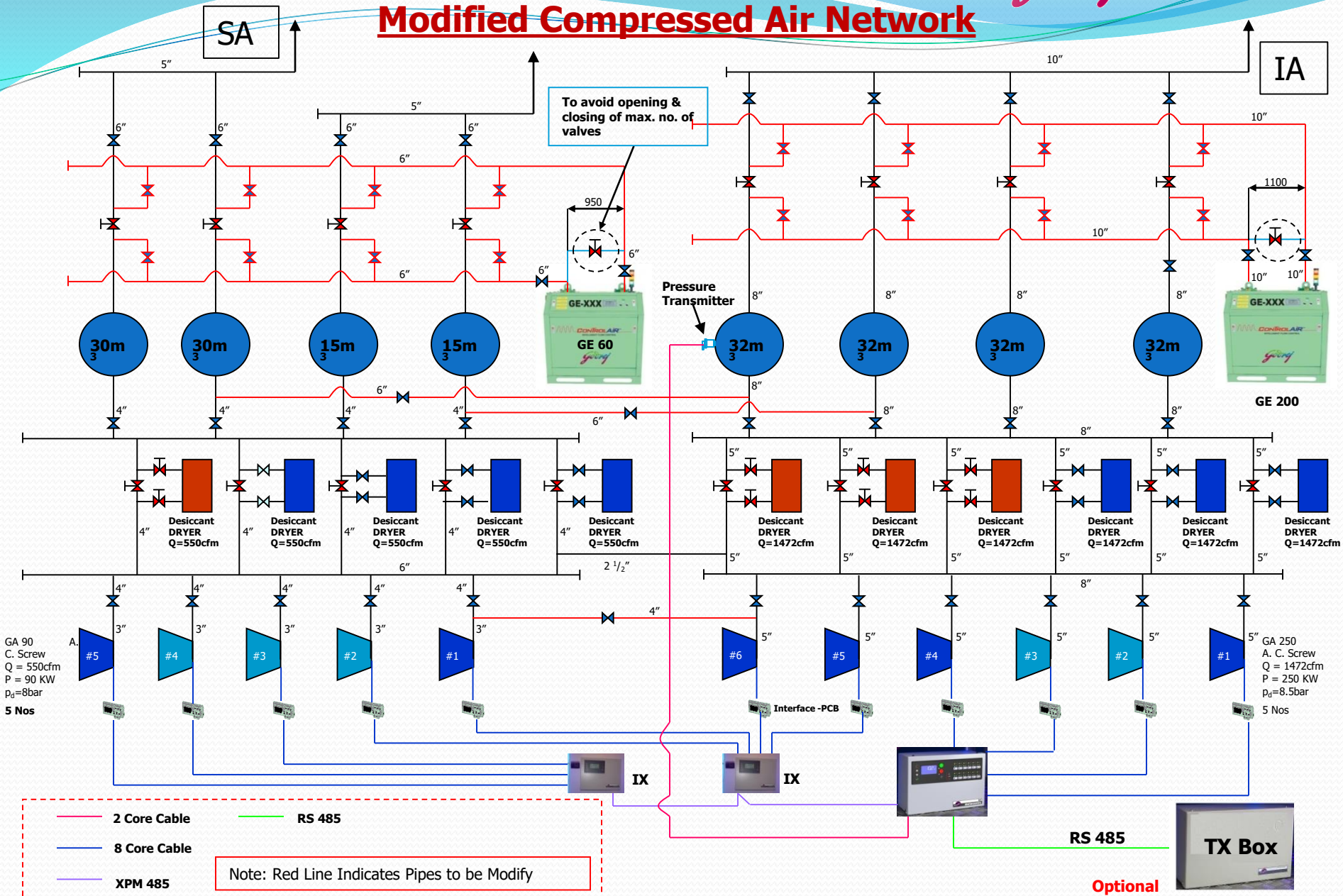
Compressed Air Pressure Trending without Godrej ControlAiR IFC:

Service Air Header Pressure within ± 80 psig – 104 psig

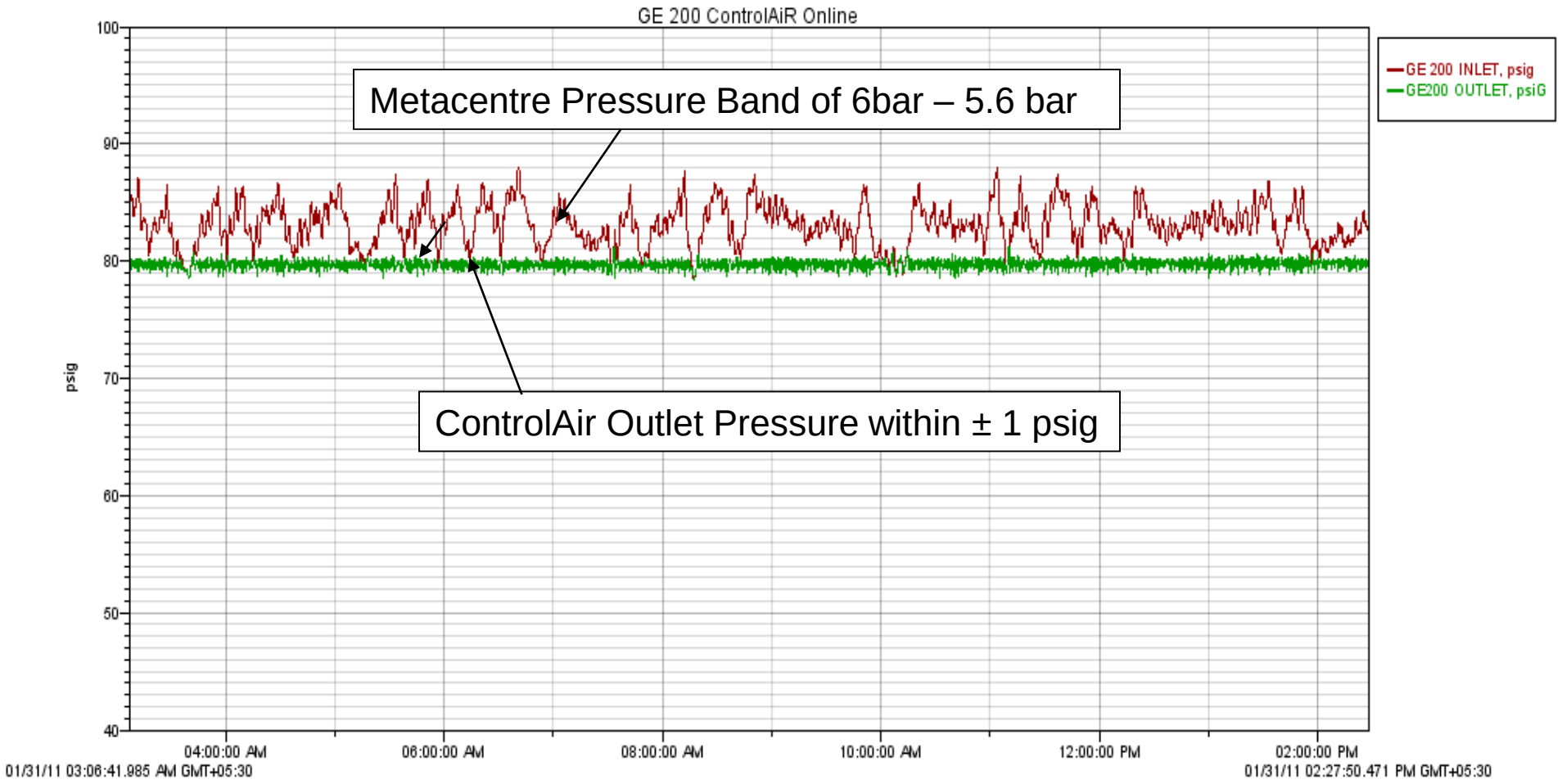


Instrument Air Header Pressure within 71 psig – 94 psig

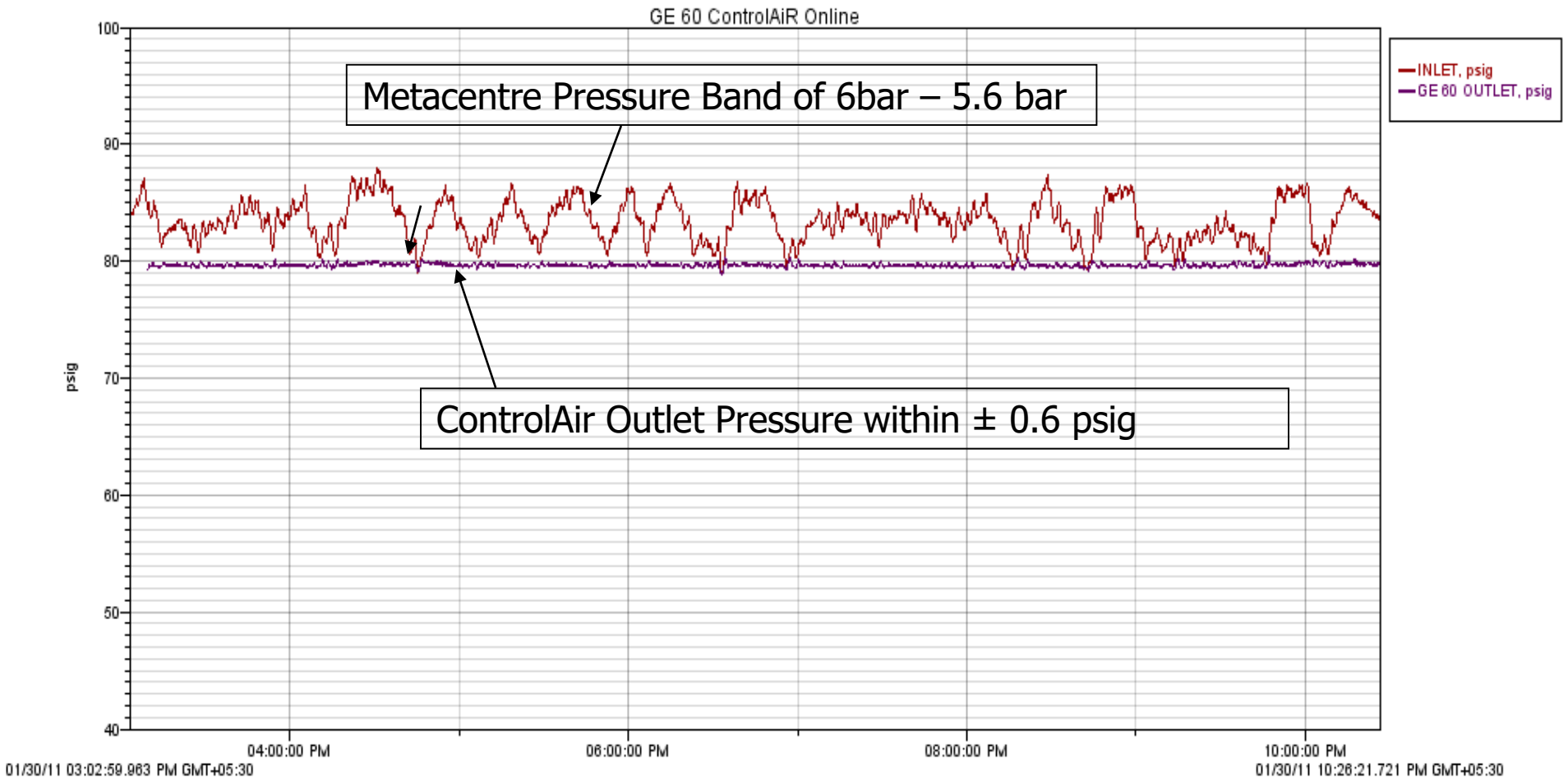
Modified Compressed Air Network



Compressed Air Pressure Trending Across ControlAiR IFC GE-200 & ControlAiR ICC In Service Air Network



Compressed Air Pressure Trending Across ControlAiR IFC GE-60 & ControlAiR ICC In Instrument Air Network



BENEFITS WITH IFC & ICC:

Without ControlAir IFC

Power consumption
= 15,447 kWh/day

Plant Pressure

- Instrument Air
  = 104 psig – 80 psig
- Service Air
  = 94 psig – 71 psig

With ControlAiR IFC

Power consumption
= 13,953 kWh/day

Plant Pressure

- Instrument Air
  = 80 psig(within ±0.3psig)
- Service Air
  = 80 psig(within ± 1psig)

Projected Energy Savings = 8 %
Achieved Energy Savings = 1494 kWh/day (@ 10 %)

Turbo vs PD Blower

Classification	PD Blower	PM Motor Direct Turbo
Aero Eff.	55%	77%
Drive Eff. (Motor+Coupling+Inverter)	82%	92%
Total Eff.	45%	70%
Total Eff. (50% Load)	22.5%	67%
Starting Current (compare to rated current)	250%	Under 5%
Maintenance	Overhaul	Air Filter
Life Time	5 years	Semi-permanent
Foot Print	Big	Smaller
Noise Level	95-110dB	Under 80dB

Turbo Blower Benefits

1) Permanent Magnet Motor:
    1) Power required only to rotate & not for magnetizing of rotor
    2) Can be started & stopped any number of times
    3) High Efficiency of 95-96% even at part load conditions
2) Direct Drive :
    1) No Gear Box → hence no lubrication required.
    2) No transmission loss due to Direct drive → Hence better efficiency
3) Variable Speed Drive:
    1) Achieves High speed without bull gear
    2) Enables Smooth starts with Starting current only 5-10% of Full Load Current
    3) Enables efficient pressure/ flow control (40-100%) by smooth speed variation
4) Air Foil Bearing
    1) Enables elimination of oil from machine
    2) Ensure 100% Oil Free Air at discharge as per
    3) High Reliability with 3rd generation airfoil bearings (used in Jet engines)
5) Quite Operation
    1) Low Noise → 80 dB against 100 dB of PD blowers
    2) Low Vibrations→1mm/sec against 15-20 mm/sec of PD blowers
6) Customer Centric:
    1) Entire range is Air-Cooled & no need of water for cooling
    2) Plug & Start --> Turbo Machines are fully assembled ,tested & ready for commissioning when shipped
    3) Compact units → footprint is 1/3rd that of PD Blowers
    4) Complete Instrumentation is built in → with flow, pressure, energy being monitored through HMI
    5) No need of any foundation. Only Plain Hard surface required

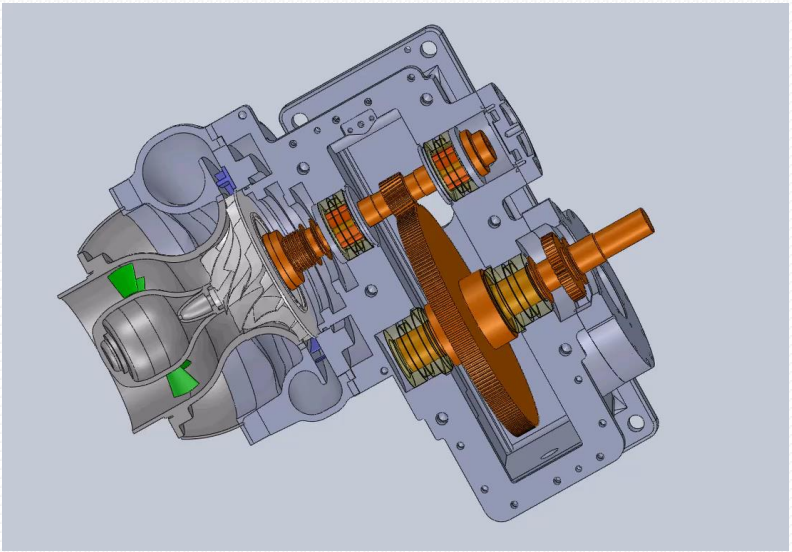
Super Energy Efficient
Direct Drive High Speed Turbo Blower

The Ultimate Rotating Machine

- **ENERGY SAVINGS (> 35 – 40 %)**
- **QUITE, COMPACT, PLUG & START**
- **OIL FREE AIR**
- **MAINTENACE FREE**

Variable Speed + Direct Drive + Oil Free

Gear Drive High Speed Centrifugal Blowers



- Inlet Guide Vanes (IGV) and Variable Vane Diffuser (VVD)
- Tilting Pad Bearings for stable Rotor Dynamics
- Milled S-Shaped impeller
- Surge Prediction and Prevention Control

Payback Calculations for Turbo Blower

Parameters	Existing PD Blowers	Turbo Blower	Savings
Power for 10200 m3/hr @ 0.3 bar (kWh)	180	117	63
Daily Power Consumption	4320	2808	1512
Electricity Rate		7	
Annual Energy Consumption Cost (355 days)	Rs 10735200	Rs 6977880	
Annual Energy Cost Savings		**Rs 3757320**	

Activities that address needs of underserved populations

Activities that address environmental issues

Good & Green

Beyond Business: Building a More Inclusive and Greener India

Ensuring Employability

Creating a Greener India

Innovating for Good & Green Products

By 2020, Godrej will…

Train 1 million rural & urban youth in skilled employment

25% Reduction in Energy Consumption, Achieve Zero Waste, Carbon Neutrality, Positive Water Balance & 10% Renewable Energy Use

Have a third of its portfolio revenues comprising Good and/or Green Products & Services

Thank You!

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