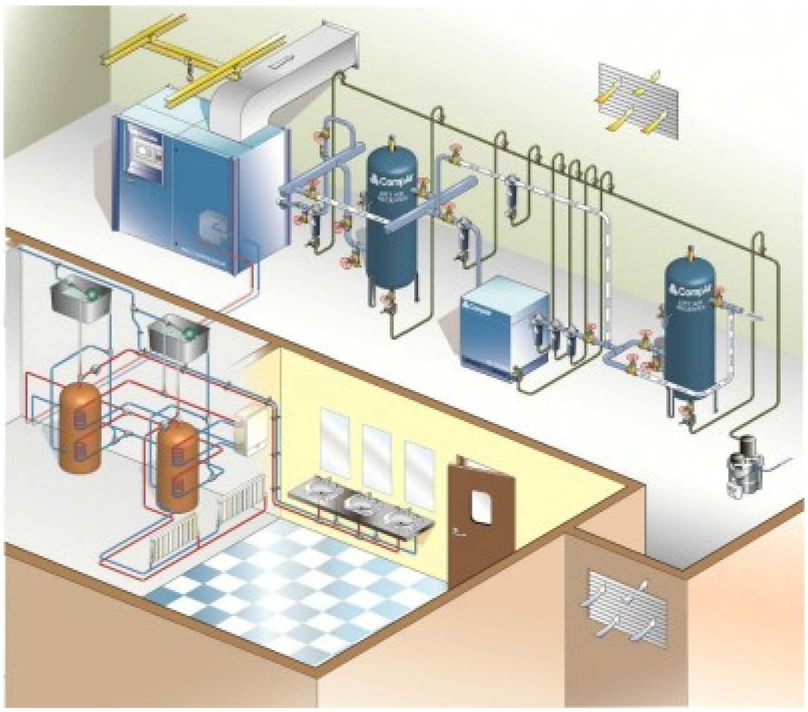

SAVING IN THE AIR

A technical paper on potential saving in compressed air system at IOCL Gujarat Refinery

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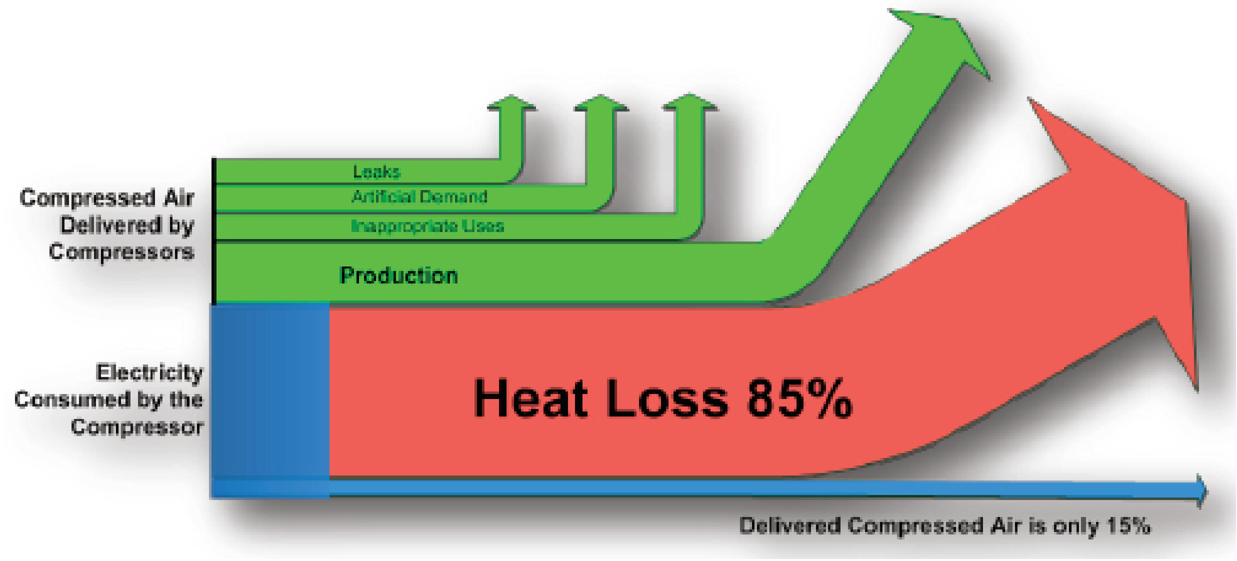
“Saving in the Air”

Abstract

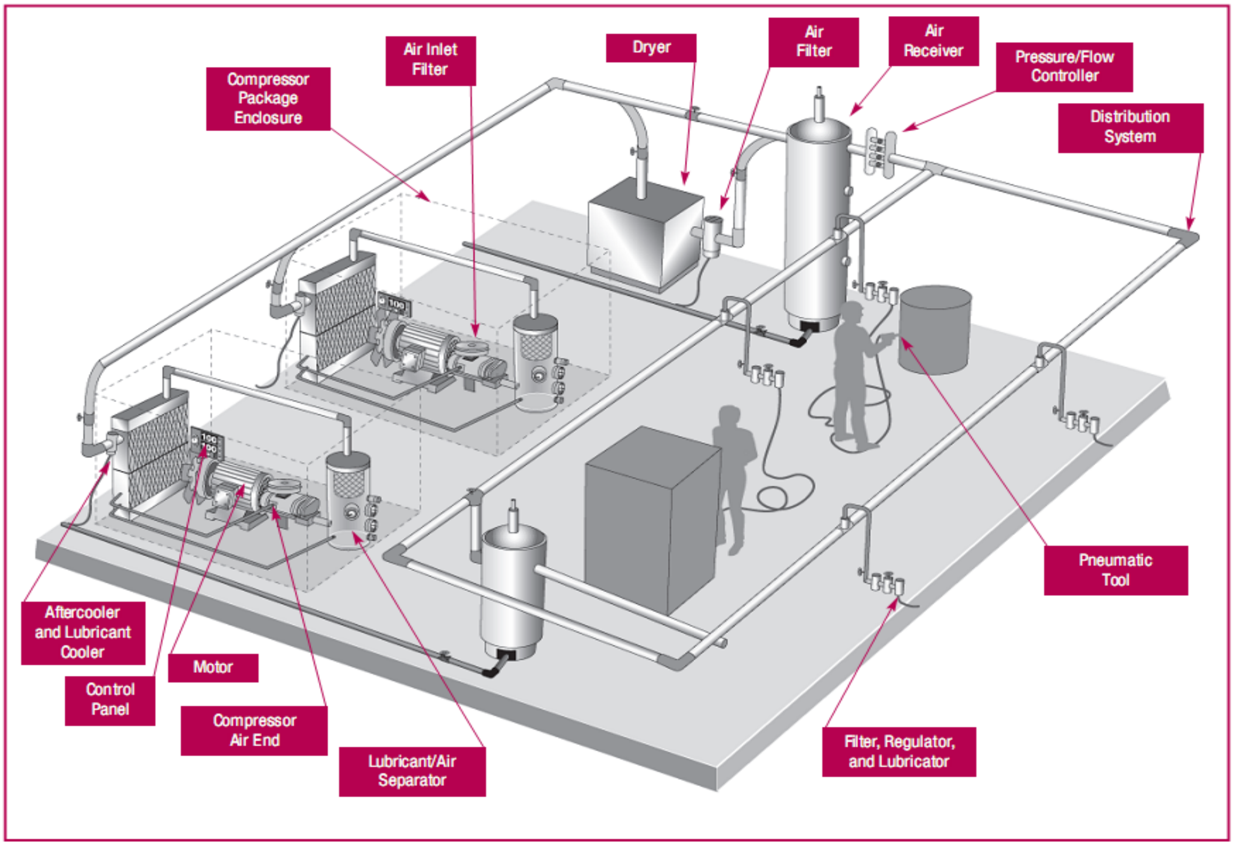
Compressed air is widely used throughout industry and is often considered the “fourth utility” in industries, other being power, water and steam. Almost every industrial plant, from a small machine shop to an immense pulp and paper mill, from small chemical plant to large oil refinery and petrochemical unit has some type of compressed air system. In many cases, the compressed air system is so vital that the facility cannot operate without it. In many industrial facilities, air compressors use more electricity than any other type of equipment. Inefficiencies in compressed air systems can therefore be significant. Energy savings from system improvements can range from 20 to 50 percent or more in terms of electricity consumption. For many facilities this is equivalent to thousands, or even hundreds of thousands of Rupees of potential annual savings, depending on use. A properly managed compressed air system can save energy, reduce maintenance, decrease downtime, increase production throughput, and improve product quality. Many of the different levers for cost reduction may be known, but just not applied due to lack of knowledge about the financial savings possible. This paper shows and explains the different ways to efficient compressed air production and distribution to the end user and provides the insight of various production & distribution issues like correct generation pressure, efficient control of multiple compressors, leakages etc. with example of their application in IOCL Gujarat Refinery.

Compressed Air

Compressed air is one of the most important utilities used in industrial applications worldwide if not the most important. Compressed air has been in use for many years. The first known application is almost as old as Christian time scale. Over the years industry became used to the presence of compressed air. It is just there, a utility, very much comparable to electricity in a private household. But just like electricity compressed air does have its costs. Compressed air is not as cheap as we think, in fact it is one of the most expensive utility in a manufacturing plant. About eight horsepower of electricity is used to generate one horsepower of compressed air in electrical motor driven compressor. But despite the tremendous energy saving potential in compressed air production and distribution system, saving in compressed air system were hitherto not taken as seriously as it should have been taken. But with the ever increasing cost of energy and awareness about the saving potential in this expensive utility the scenario has changed in last couple of years. This is much more important considering the fact that only about 20-30% of the energy given to generate compressed air is converted into usable energy at the point of end use



Components of Typical Compressed Air System



A modern industrial compressed air system is composed of several major sub-systems and many sub-components. Major sub-system include Air inlet filters, compressor, prime mover, control panel, intermediate and after air cooler, lubricant coolers, dryers, air receivers, air distribution network and end-user equipments like air tools, pressure regulators, pneumatic operated valves etc. The compressor is the mechanical device that takes in ambient air and increases its pressure. The prime mover powers the compressor. Controls serve to regulate the amount of compressed air being produced. The treatment equipment removes contaminants from the compressed air, and accessories keep the system operating properly. Distribution systems are analogous to wiring in the electrical world—they transport compressed air to where it is needed. Compressed air storage can also serve to improve system performance and efficiency. Interestingly each and every component of this system has the potential and can contribute significantly in the energy saving plan of the system.

Cost of Compressed air

Having the word "Air" in compressed air, which is available for free, we often mistaken in realizing the cost of compressed air. There are three major components of the compressed air cost namely capital cost invested for installation of facility, operating cost which is basically electrical energy as most of the compressors are electric motor driven and maintenance cost. Depending upon the size of the installation and operating hours of the system, proportion of these components varies slightly but still as shown in the fig about 70-95% is the operation cost.

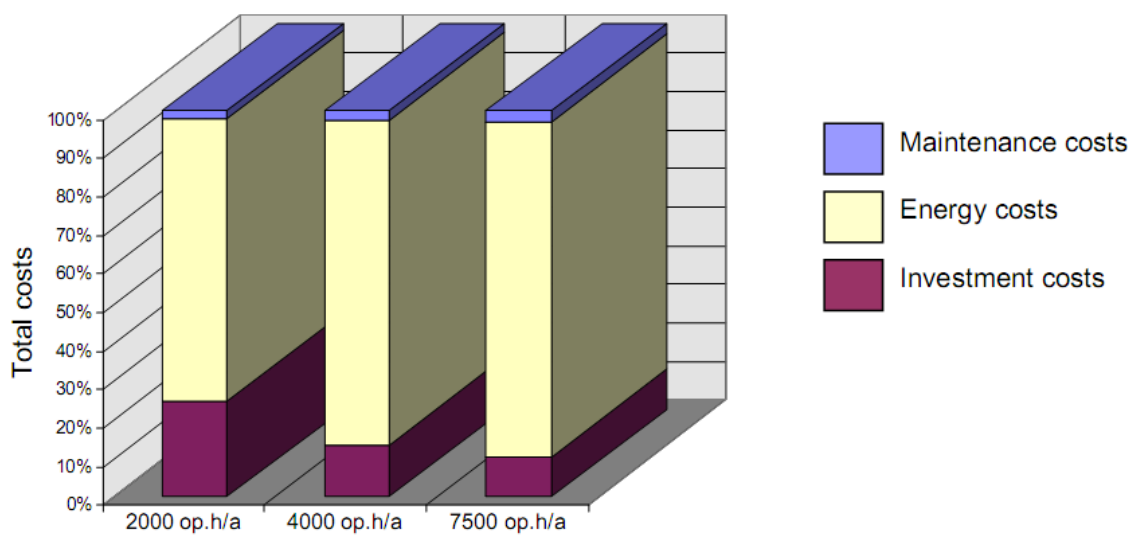


Fig-1: Cost Components of Compressed air

Annual Operating cost of operating air compressors at IOCL Gujarat Refinery can be calculated by the fact that there are total 08 nos of electric motor driven (832 KW each) compressor installed in the facility, out of which 04 compressors run continuously to meet the Refinery plant air and Instrument air requirement. As per simple calculations, annual electricity consumption for operating 04 nos of compressors considering motor efficiency as 85% and 8760 hours of operation is

Annual Energy Consumption = 4 x 832 x (1/0.85) x 8760 KWhrs

= 34297976.5 KWhrs

Annual energy cost = 34297976.5 KWhrs x 4.55 Rs/KWhr

= Rs 15.61 Cr

Major deficiencies in Compressed air system

- **Finding the correct Demand and System pressure requirement**
- **Lack of Integrated System for control of multiple units**
- **Leakages at the end point and in the distributiuon system**
- **Failure to store compressed air energy for use during peak demand periods**
- **Severe fluctuation in pressure due to Indiscriminate use of open blowing**
- **Simple lack of maintenance, including neglect of dirty filter cartridges**
- **Lack of efficient heat recovery mechanism**

Finding the correct Demand and System pressure requirement

A very important factor affecting the energy consumption of a compressed air system is the working pressure required. The pressure generated should always be such that to meet the minimum pressure requirement of the air operated equipment and also to meet the exigencies should there be any sudden requirement of the compressed air. This is easier to evaluate and implement the same in high volume networks than in small volume networks as the previous one has the higher surge observing capacity.

A rule of thumb for systems in the 100 psig range is, for every 2 psi decrease in discharge pressure, energy consumption will decrease by approximately by 1.0% at full output flow. Additional incentive being reduction in consumption through unregulated use, leakages, open blowing etc. which gives additional 0.6-1.0%

reduction in energy consumption. ***<u>So in total for every 2.0 psi reduction in discharge pressure energy consumption will reduce by 1.6-2.0%</u>***

A 2.0 *psi* reduction in discharge pressure at Gujarat Refinery will result in annual saving of **Rs 28.0 Lakh** *(considering 1.8% reduction in energy consumption).*This is very much possible at Gujarat Refinery as we are generating air at 7.9 Kg/cm2 (113 psi) and available pressure in most of the end user process units is in the range of 6.2-6.5 Kg/cm2 (88.2 psi-92.5 psi). All critical control valves and power cylinders installed in process units are designed for 4.5-5.0 Kg/cm2 instrument air pressure so surely there is scope of reduction of generation pressure by 2-4 psi without affecting the plant operation.

Minor leakage – Big Menace

A typical plant that has not been well maintained will likely have a leak rate equal to 20 percent of total compressed air production capacity.

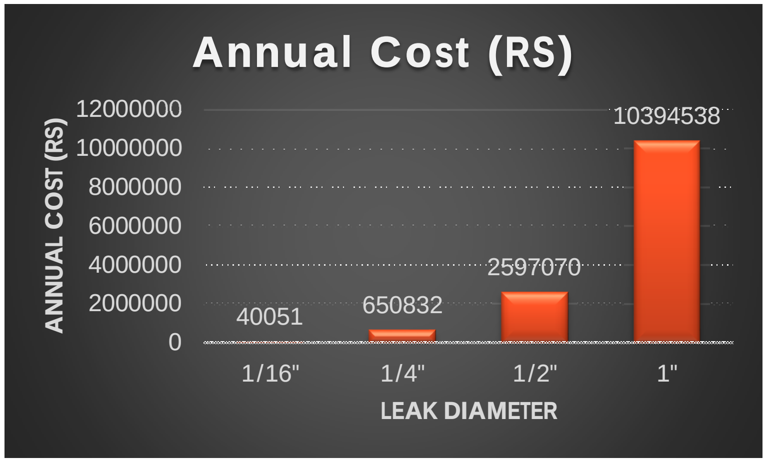
Most common sources of leakage are

- *Couplings, hoses, tubes, and fittings*
- *Pressure regulators*
- *Open condensate traps and shut-off valves*
- *Pipe joints, disconnects, and thread sealants*

In addition to being a source of wasted energy, leaks can also contribute to other operating losses. Leaks causes a drop in system pressure, which can lead to malfunctioning of all critical Instrument air operated control valves, power cylinders and other equipments.

<u>Cost Of leakages</u>

Diameter of air leak	Leakage Qty in CFM	Annual Electricity cost per CFM (0.157 KW * 8760 hrs. * Rs 4.55/KWhr)	Annual Leakage Cost In Rs
1/16”	6.40	6258	40,051.00
¼”	104	6258	6,50,832.00
½”	415	6258	25,97,070.00
1”	1661	6258	1,03,94,538.00



Air Leak Detection

Since air leaks are almost impossible to see, it is difficult to detect even the bigger leakages let alone the small leakage which are equally important. The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. These portable units consist of directional microphones, amplifiers, and audio filters, and usually have either visual indicators or ear-phones to detect leaks. To detect the air leakages and ascertain the amount of air leaking through an exhaustive air leak survey through ultrasonic detector was carried out in the year 2013 in Gujarat Refinery all over the compressed air network covering all process units, power plants, offsite and utilities section. The number of leakage and amount of air leakage detected though this survey was an eye opener for all. (See Table -1 ; all figures are in NM3/hr)

Unit	Big Leakage	Medium Leakage	Small Leakages	Total
DM Plant CGP-II	180.23	45.06	23.46	248.75
Compressor House	67.59	11.26	8.8	87.65
TPS Turbine	0	0	2.93	2.93
TPS Boiler House	67.59	33.79	18.57	119.95
CGP-II HRSG	0	5.63	11.73	17.36
DMp Plant CGP-I	45.06	45.06	45.96	136.08
CGP-I HRSG	22.53	16.9	11.73	51.16
CGP-I Compressor House	45.06	0	0.98	46.04
AU-I	157.7	22.53	28.36	208.59
AU-II	135.17	33.79	28.36	197.32
DHDS	0	0	9.78	9.78
HGU-II	0	16.9	12.71	29.61
AU-V	67.59	22.53	16.54	106.66
CRU	0	11.26	17.6	28.86
FPU-II	45.06	22.53	16.62	84.21
HGU-III	0	11.26	0.98	12.24
HGU-I	0	5.63	12.71	18.34
HCU	67.59	33.79	46.93	148.31
LAB	22.53	22.53	7.82	52.88
AU-III	22.53	16.9	10.76	50.19
UDEX	0	0	9.78	9.78

DHDT	45.06	16.9	9.78	71.74
SRU-I (OLD)	45.06	0	5.87	50.93
SRU-II (OLD)	0	11.26	1.96	13.22
ISOM PENEX	0	11.26	7.82	19.08
ISOM (NHT &NSU)	22.83	5.63	5.87	34.33
SRU-III	90.12	28.16	1.96	120.24
SRU-B	0	11.26	1.96	13.22
MTBE	0	0	0	0
FGH	0	0	0.98	0.98
VDU & BBU	225.29	56.32	10.76	292.37
CDU	135.17	11.26	6.84	153.27
FPU-I	0	5.63	8.8	14.43
VBU	90.12	39.43	24.45	154
DCU	22.53	22.53	11.73	56.79
FCC-LPG MEROX	0	0	0	0
ATF MEROX	0	0	0	0
COKER LPG MEROX	0	0	0	0
VGO HDT	22.53	5.63	4.89	33.05
MSQ	67.59	33.79	22.49	123.87
GANTRY – 5TH	202.76	61.96	46.93	311.65
GANTRY- 6TH	112.64	107.01	9.78	229.43
GANTRY-1/2	45.06	33.79	41.16	120.01
FCCU	135.17	11.26	10.76	157.19
TOTAL	**2208.16**	**850.43**	**577.9**	**3636.49**

(Table : 1, Leakages detected in various units of Gujarat Refinery)

So Total Air leakage Rate = 3636.5 Nm3/hr or 2140.08 CFM

As a thumb rule, for any large motor driven compressor, 01 HP (0.7457 KW) can produce 4.5-5.0 CFM of compressed air at 100psig pressure.

Cost of generation of 01 CFM @ 100 psig = 0.7457/4.75 KW* Rs 4.55/Kwhr

Annual Cost of generation of 01 CFM = 0.7457/4.75 KW* Rs 4.55/Kwhr * *8760 hrs

= Rs 6258.00

Annual Leakage Cost = RS 6257/CFM x 2140.08CFM

= Rs 1.34 Cr

So at IOCL Gujarat Refinery annual saving of **Rs 1.34 Cr** can be achieved by just plugging the leakages identified through ultrasonic leak detection.

Integrated System for Control of multiple compressor Units

Compressed air system controls match the compressed air supply with system demand and are one of the most important determinants of overall system energy efficiency. Proper control is essential to efficient system operation and high performance. The objective of any control strategy is also to shut off unneeded compressors or delay bringing on additional compressors until needed. All units that are operating should be run at full-load, except one unit for trimming. Compressor systems are typically comprised of multiple compressors delivering air to a common plant air header. The combined capacity of these machines is generally sized to meet the maximum plant air demand with a breakdown contingency. System controls are almost always needed to orchestrate a reduction in the output of the individual compressor(s) during times of lower demand. Compressed air systems are usually designed to operate within a fixed pressure range and to deliver a volume of air that varies with system demand. System pressure is monitored and the control system decreases compressor output when the pressure reaches a predetermined level. Compressor output is then increased again when the pressure drops to a lower predetermined level.

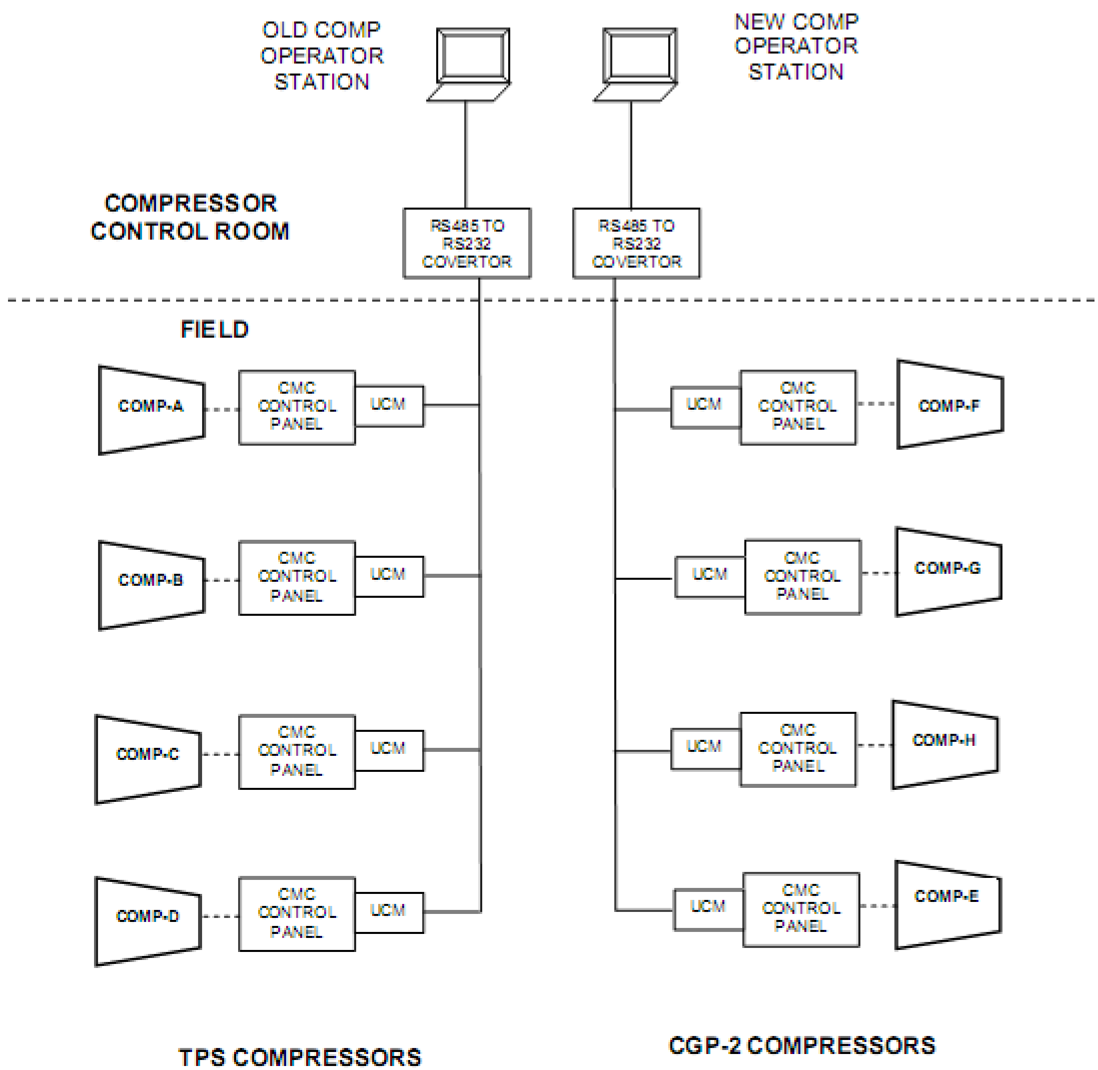
The difference between these two pressure levels is called the control range. Depending on air system demand, the control range can be anywhere from 2 to 20 psi. In the past, individual compressor controls and non-supervised multiple machine systems were slow and imprecise. This resulted in wide control ranges and large pressure swings. As a result of these large swings, individual compressor pressure control set points were established to maintain pressures higher than needed. This ensured that swings would not go below the minimum requirements for the system. Today, faster and more accurate microprocessor-based system controls and variable speed compressors with tighter control ranges allow for a drop in the system pressure set points. Precise control systems are able to maintain lower average pressure without going below minimum system requirements.

At Gujarat Refinery there are total 08 compressors available for meeting the plant air and Instrument air requirement. These compressor are divided into section namely TPS & CGP-II with 04 compressors in each section. The output from these two section are connected to common header. But the compressors were maintained at two different header pressure. The basic problems with the old architecture were

- Non-existence of system wide control & monitoring of compressed air system
- Two different set-points for two different headers
- In case of increase in demand it may so happen that two different systems can give start command to two different compressors which will lead to simultaneous start of two compressor and availability of excess air which may result in unloading of running compressors and also opening of blow-off-valves which is highly undesirable in an efficient system.

- Continuous running of compressors at part-load.

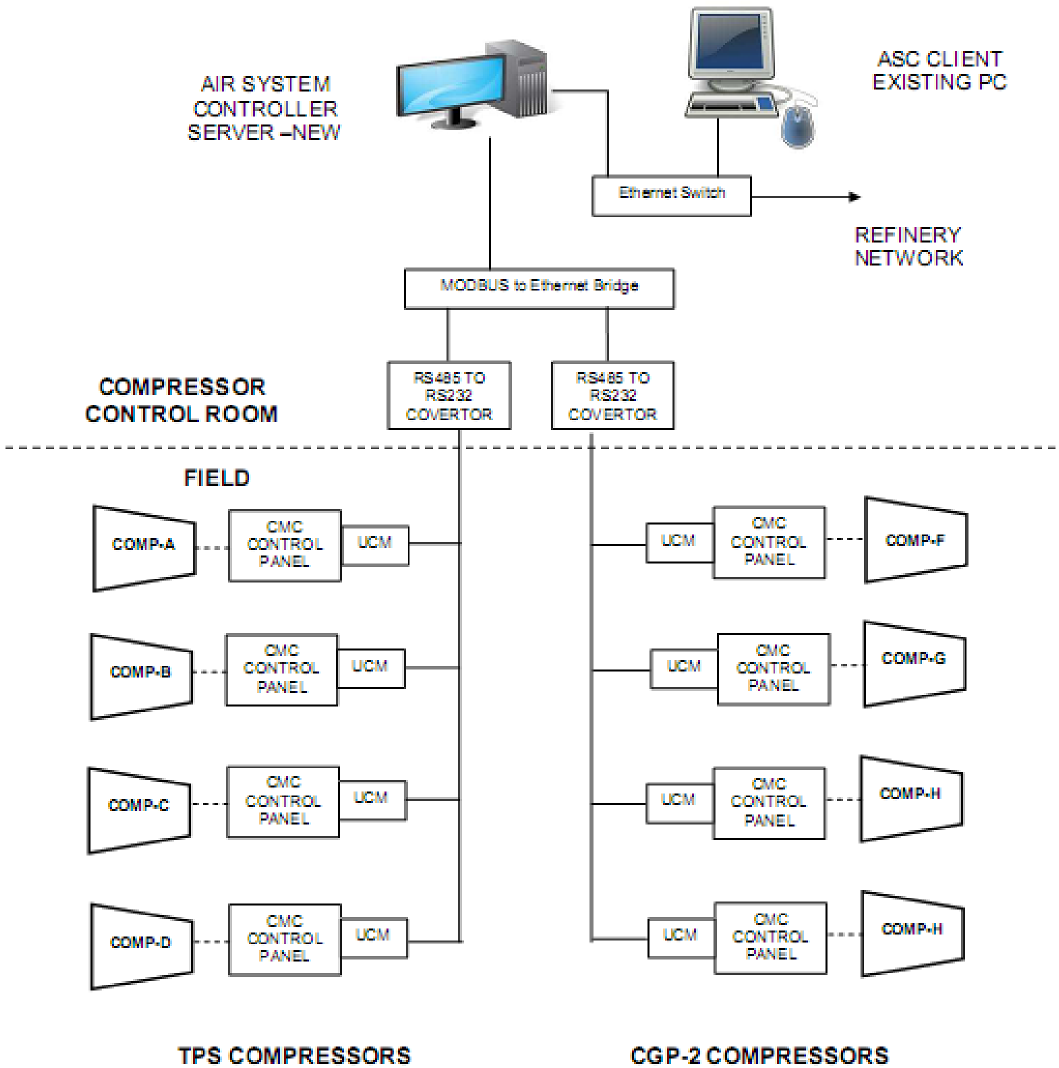
An architecture of old system is as given below



Set Point : 7.66 Kg/cm2

Set Point : 7.85 Kg/cm2

In order to achieve the maximum efficient control of all compressors it was decided to integrate both these two system with a common setpoint. All these compressors were brought the common control network utilizing the features of Ingersoll-Rand air system control package (ASC). The new architecture of this system is as given below



Features of the integrated system are

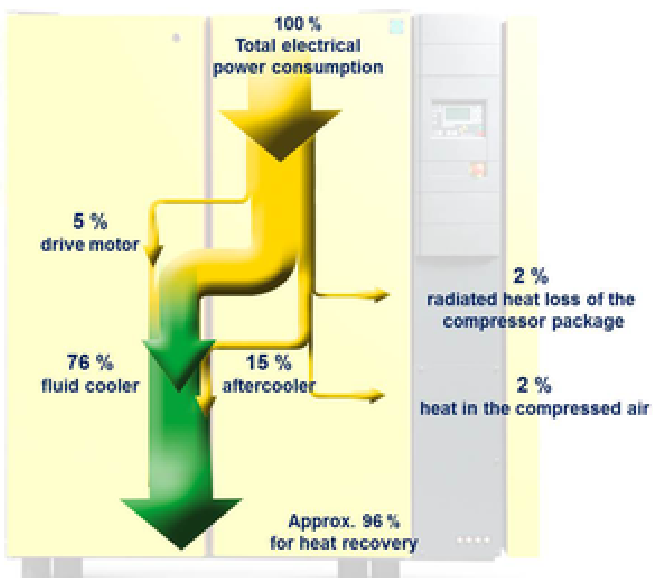
- Integration of the complete compressed air system
- Energy management through base load and trim sequencing and/or load sharing; ASC controls the number of operating compressors, matching best efficiency with dynamic system demand
- Time-based scheduling tool that enables virtually unlimited sequence change and compressor set operational combinations.
- Graphical interface – summary, setup and equipment-specific screen sets as well as object oriented graphics and dynamic icons made to represent the integrated system
- Remote monitoring and communications – monitor from anywhere at any time and get real time data

Heat Recovery from the compressed air

During the compression process a high percentage of the consumed energy is transferred into heat. As much as 80 to 93 percent of the electrical energy used by an industrial air compressor is converted into heat. In many cases, a properly designed heat recovery unit can recover anywhere from 50 to 90 percent of this available thermal energy and put it to useful work like

- Preheating boiler water
- Makeup air heating
- Supplemental space heating
- Heating process fluids
- Industrial process heating
- Heat-driven chillers

As a thumb rule, approximately 50,000 British thermal units (Btu) per hour of energy is available for each 100 cfm of capacity (at full-load). This value is based on 80% recoverable heat from the compressor and a conversion factor of 2,545 Btu/bhp-hr.



Energy Saving in Heat Recovery

Energy Saving (Btu/year)= 0.80 x compressor bhp x 2,545 Btu/bhp-hour x hours of operation

Gujarat Refinery has four compressors running at full load, each of 1116 bhp (832kw) with yearly running hours of 8760. So even if 80% of the heat generated is recovered then

Energy Saving (Btu/year)= 0.80 x (4*1116) x 2545 x 8760

= 796,170,470,40 Btu/year

The above heat generated can be used in Boiler feed water pre-heating, fuel oil pre-heating, air pre-heating, VAM air conditioning units etc.

If we consider the case of fuel oil heating with hot compressed air instead of MP steam then

Cost savings (Rs/yr) = [(Energy savings in Btu/yr)/(Btu/unit of fuel) x (Rs/unit fuel)]/ Primary heater efficiency

= [(796,170,470,40 Btu/yr)/(2644 Btu/Kg of MP steam) x (Rs1.8/Kg of MP steam)]/ 0.85

= Rs 637, 673, 24.31

= **Rs 6.37 Cr**

Conclusion

As illustrated in this paper, compressed air system in overall has tremendous energy saving potential utilizing the measures like optimization of discharge pressure control, efficient use of individual machines in multi-unit system, plugging the air leakages and efficient heat recovery mechanism. On an average each compressed air system has approximately 33% of energy saving potential. In addition to that, improving the performance of compressed-air system reduces plant wide energy costs. It can reduce downtime, increase production throughput, lower scrap rate, improve product quality, improve the plant reliability and create longer equipment life.