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Review of Optimization of Pipeline for CASs for Best Performance with Heat Recovery in Compressors

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Abstract

Compressed air is referred to as the fourth utility. We all know the generation of compressed air consumes energy but at the same time the compressor losses and downstream components are considered, which means there are significant savings to be made. It is suggested that savings of around 33 % on average in a compressed air system are possible. It follows that cost effective compressed air production is energy efficient compressed air production, as energy is by far the biggest lifetime cost factor. 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 way for compressor selection and heat losses in compressor, efficient waste heat recovery in compressor (screw compressors) and piping material selection and design of pipe line layout for reducing the pressure losses in flow.

Keywords: *Fourth utility, CASs, Heat recovery, Pipeline design. etc.*

1. Introduction

According to the Kyoto Protocol from 1997, the EU has to reduce greenhouse gas emission by 8% below the level from 1990 by the 2008-2012 periods. To achieve these reductions, substantial efforts have to be undertaken in all branches of human enterprise. One of the important industry utilities that have to be encompassed by this energy policy is compressed air systems (CASs)[2].

The application of compressed air has had a growing trend due to its easy and safe generation, manipulation, and usage. In previous years, the research efforts in this domain were concentrated on the CASs development and application aimed at boosting the productivity regardless of the energy consumption. With increased awareness of the energy costs as well as the effects of greenhouse gas emission, the attention has been recently placed on the energy efficient use of compressed air.

Energy saving measures in CASs that have been identified in the course of energy audits in the industrial small and medium enterprises may yield an average energy saving of nearly 15%, with a payback of two years, the energy saving potential in some of them amounting from 30% up to even 60% [6]. The basis for all decisions concerning energy efficiency of the existing CASs is the understanding of the way of their functioning and existence of appropriate data. In that sense, it would be necessary to make measurements of consumed electricity of compressors, airflow, and system leakage and pressure drop in the system.

A number of common technical measures can improve energy efficiency of CASs, some of the most important being:

1. Waste heat recovery in compressor
2. Reduction in waste air due to inadequate maintenance and leaks,
3. Improving control systems,
4. Reduction of pressure drops,
5. Better maintenance and operation,
6 .Design best performance pipeline layout

Besides energy savings, increasing energy efficiency of CASs may ensure other significant benefits for the enterprise. Energy saving measures implies a high monitoring level of CASs and appropriate maintenance. That leads to decreased breakdowns of production equipment, avoiding of the loss of raw materials or other inputs, longer life cycle of pneumatic devices and higher reliability of CASs. Often, these benefits are more valuable than the energy savings.

2. Status

The heat generated by compressed air systems can be a very good source of energy savings. In fact, nearly all (90%) of the electrical energy used by an industrial air compressor is converted into heat. Heat losses in compressor can understand by sankey diagram as shown below.[3]

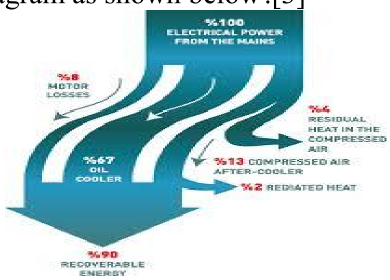

Fig. No.1 Sankey Diagram for Energy losses in Compressor

One more problem is that design of pipe line layout and material selection for pipeline improper design of pipeline for compressed air system can causes the loss of pressure in piping is caused by resistance in pipe fittings and valves, which dissipates energy by producing turbulence. Excess pressure drop due to inadequate pipe sizing, choked filter elements, improperly sized couplings and hoses represent energy wastage. Not only piping, but also fitting is a source of pressure losses. Therefore it is necessary that proper selection of compressor, pipe diameter, and fitting and best performance pipeline layout is important.

3. Selection of Compressor

There are different types of compressor are available in market. Selection of compressor for different application depending upon the requirement of pressure and capacity require. Selection of compressor for different application is show in fig below

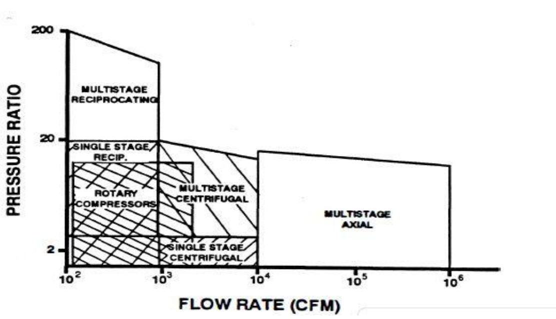

Fig.2.Compression between the different types of compressor[5]

The general selection criteria for compressor is given in the Table

Types of compressor	Capacity(m^3/h)		Pressure(bar)	
	From	To	From	To
Roots blower compressor Single stage	100	30000	0.1	1
Reciprocating				
Single/two-stage	100	12000	0.8	12
Multi-stage	100	12000	12.0	700
screw				
Single stage	100	2400	0.8	13
Two stage	100	2200	0.8	24
Centrifugal	600	300000	0.1	450

Table.1.Selection Criteria for Compressor[5]

4. Heat Recovery in the Screw Compressors

Over 90% of the energy input to compressor is lost as heat. It is usually at a relatively low grade for process work. it is however, commonly at temperature suitable for building services and other application. Recovering this heat can prove highly cost effective, reducing overall energy consumption and also benefiting the environment.

In practice, air cooled compressor can provide hot air at up to 80 ^{0}C and water cooled compressor can provide hot water at up to 95 ^{0}C . A typical air compressor of 47 l/sec (100cfm) capacity consuming 22 Kw at full load, of which almost 20 Kw can be recovered as heat at full load, of which almost 20Kw can be recovered as heat. If recovered heat-displaces electric heating, the effective cost of generating compressed air will fall by up to 90% where the displaced fuel source is a cheaper fossil fuel, such as oil or gas considerable cost saving can still possible, even though the actual value of the displace fuel will be less than that of electricity used.[1]

Different option is available for heat recovery as shown in fig. Identify the heat recovery option for your application depending up on

1. Requirement for heat
2. Types of compressor cooling

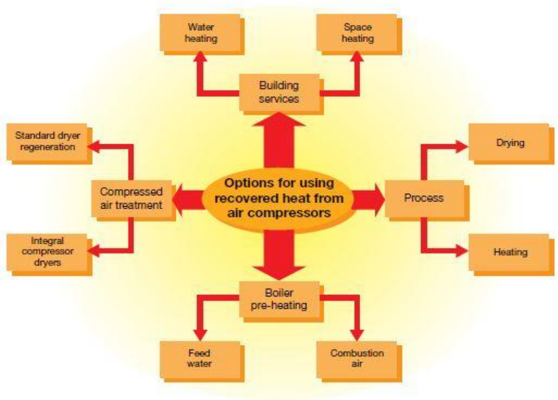

Fig.3.Heat Recovery with Rotary Screw Compressors [1]

The most common compressor equipment found in manufacturing plants is the air-cooled, lubricated rotary screw design. The amount of heat recovered using these systems will vary if the compressor has a variable load. But in general, very good results will be achieved when the primary air compressor package is an oil-injected rotary screw type design. Oil-less rotary screw compressors are also well-suited for heat recovery activities. As with other compressor systems, the input electrical energy is converted into heat. Because they operate at much higher internal temperatures than fluid injected compressors, they produce greater discharge temperatures (as high as 300°F or even greater).

4.1 Warm Air Applications

Capturing warm air is easily accomplished by ducting the air from the compressor package to an area that requires heating. The air is heated by passing it across the compressor's aftercooler and lubricant cooler. This extracts heat from the compressed air as well as the lubricant, improving both air quality and extending lubricant life.
By integrating standard HVAC ductwork and controls, warm exhaust air from compressors can be channeled to remove or provide heat in the compressor room and adjacent areas. Typical uses include:

1. Heating for warehouses or storerooms
2. Heating for production areas and workshops
3. Drying air for paint spraying
4. Air curtains
5. Pre-heating combustion air to improve efficiency

Nearly all current models have cabinets that channel airflow through the compressor, and many current designs exhaust warm out the top of the unit. This simplifies adapting compressors for space heating to the installation of ducting and (sometimes) a supplemental fan to handle duct loading and eliminate back pressure on the compressor cooling fan[3].
Space heating can be regulated easily using thermostatically controlled, motorized louver flaps for venting, thereby maintaining consistent room temperature by making continuous adjustments to the heating air flow. This also means that when heating is not required, the hot air can be ducted outside the building to reduce cooling costs.

4.2 Water/Fluid Heating

Rejected heat can also be used to heat water or other process fluids. It can be done with either air-cooled or water- cooled compressors, although the best efficiencies are usually obtained from water-cooled compressor installations where discharge cooling water is connected directly to a continuous process heating application such as a heating boiler's return circuit for year-round energy savings. The key to heat recovery effectiveness with water-cooled compressors is attaining a "thermal match" between the heat being recovered and the heat that is needed on a regular (hourly) basis.[3]
Plate heat exchangers offer a cost-effective way to capture heat from the rotary screw compressor and utilize it to heat water for diverse processes such as electroplating, chemical processing and laundry services[3].
Fail-safe heat exchangers provide additional protection against contamination of process water or fluids by the compressor cooling fluid. This makes them more suitable for heating applications in the food and pharmaceutical industry sectors – as well as for heating potable water. Some compressor manufacturers offer built-in heat recovery heat exchangers as options. In some cases, they are fully

integrated inside the compressor cabinet and require very little onsite engineering.

4.3. Energy Savings … and More

Most process applications in production facilities can benefit from heat recovery from compressed air systems throughout the year, not just during the cold-weather months. In most space heating applications heat is required during three seasons. And during the warmer months, removing the heat of compression will make the compressor room temperatures much more comfortable. Maintaining proper ambient conditions will also improve compressor efficiency and facilitate air treatment. Moreover, controlling operating temperatures will extend compressor air equipment life.
Current energy costs make an investment in heat recovery systems highly attractive. However, when attempting to calculate energy savings and payback periods for heat recovery efforts, it's important to compare heat recovery with the current source of energy for generating thermal energy, such as relatively lower-cost natural gas
Generally, the larger the system the faster the payback, but payback on heat recovery also depends on the amount of rejected heat that can be used, and the cost of the alternative energy source. After factoring in the installation cost, it's possible that smaller systems will not provide enough recoverable BTUs of energy to make the investment worthwhile.[3]
Naturally, higher energy savings will be realized when the alternative heating source is an older, less efficient technology. Investing in newer, more efficient equipment may be more cost effective. Many heaters are now operating at ~85% efficiency or better, and thus compressor heat recovery activities will result in relatively less annual energy savings.
Beyond energy savings, an important argument can also be made that heat recovery activities benefit the environment. After all, substantial energy savings also mean a reduction in the carbon footprint of a plant. As energy policies and regulations continue to evolve in the United States and other countries, these considerations are only expected to become more important.

5. Design of Pipeline For Best Performance

When a compressed air distribution system is properly designed, installed, operated and maintained, it is a major source of industrial power, possessing many inherent advantages. Compressed air is safe, economical, adaptable and easily transmitted and provides labor saving power. The cost of a complete compressed air system and pneumatic tools is relatively small in comparison with the savings effected by their use.
The main source of inefficiencies and problems affecting compressed air distribution systems is often the distribution plan of the system itself.
The majority of problems therefore usually occur somewhere between the compressor and the application points.
Most systems are usually of either of two types:
• Dead-end network
• Octopus network
neither of which provides the best results…

5.1 Dead-End Network

In a dead-end network, air flow must be sacrificed (quantity of air per minute) in order to preserve a uniform pressure at the point of use. The progressive reduction of the central pipe while it moves away from the compressor maintains pressure. However, air tools and equipment must be placed along the length of the circuit in decreasing order of consumption (SCFM). The equipment using the most air flow must be located near the compressor, and that using less, further away. This generates major handling problems, as production processes are not necessarily designed this way. This is not the optimum network design[7].

5.2 Octopus Network

A network where each additional line and extension does not necessarily match the initial configuration is often called an "octopus" network. Dead-end networks often evolve into octopus networks over time. The octopus network includes the following anomalies[7]:
• Different airline materials
• Curves, reductions and enlargements without apparent reason

• Inconsistent diameters of air lines
• Installation done with no knowledge of pneumatic standards

Predicting what flow and pressure are available at any point is virtually impossible. Air flow fluctuations from varying usage of pneumatic equipment and air tools makes it even more difficult to get the right pressure and flow at any given point.

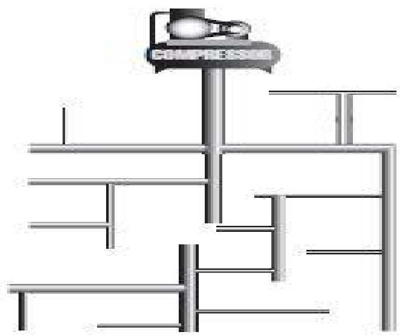

Fig.4.octopus network

This results in varying pressure and air flow conditions throughout the system, creating many problems. This type of network, while quite common, is the worst possible situation.

5.3. Closed Loop Network

A closed loop network allows the air supply to flow through several lines at a time to any given point on the network. The balance between pressure, air flow and stability of supply is ensured by using a single diameter for piping. This type of system will also easily accommodate modifications and can easily supply tools and equipment with varying supply requirements anywhere on the network. Ball valves permit the isolation of a particular portion of the air line network to allow for easy:

• Repairs
• Connections
• Enlargements
• Periodic maintenance

The size of each loop does not need to be uniform. The important thing is to have at least two different supply routes available simultaneously for each feeder pipe descending toward a tool or piece of equipment. This type of network is the ideal situation for compressed air distribution systems, providing the balance between flow and pressure required to provide the most efficient distribution of compressed air.[6]

Fig.5. closed loop network

A well-built closed loop network is therefore most often the ideal situation for the distribution of compressed air. In addition to being easy to plan and to modify when needed, this type of distribution system becomes an immense compressed air reservoir that:

•Offers a constant air flow at all times
•Guarantees a uniform pressure through out
•Contributes to the life of the compressor by limiting functioning time
•Reduces the electrical consumption of the compressor

System design should start with a layout of the shop or plant. Designate where and what tools will be used. Determine the placement of the mainline.

Try to keep the line as short as possible while providing access to where tools are used. Try to keep in mind any future needs or alterations. It is much easier to make changes if they are planned for. Drop supply lines at the point of use or at regular intervals, to minimize hose length. Size the lines appropriately for the equipment to be used [6].

5.4. Sizing a Compressed Air Pipeline

Correct sizing of the air line is essential to maximize the cost effectiveness of the compressed air distribution system. Network line size is determined by the flow capacity required for the tools and equipment to be supplied, as well as by system design and length. [6]

THINGS TO CONSIDER:

• Pressure drops are totally unrecoverable and waste energy; a drop in pressure from 87 to 73 PSI will decrease machine and tool capacity by up to 27%
• Energy cost will rise by 10% if pressure is increased by 15 PSI to compensate for pressure drop

• Pipe fittings are responsible for much of the pressure drop in compressed air systems
• Pipe size should therefore be large enough to keep pressure drop between the reservoir and the point of use to a minimum
• Main line size should never be smaller than the compressor outlet size
• Main line size is determined by total tool consumption (SCFM) and total effective line length
• Branch line size should be determined based on length and total consumption of the tools on the branch
• Main lines that are too small will cause high air velocity, thus making water separation more difficult
• A larger main line is in fact advantageous, acting as a reservoir for the air, reducing the load on the compressor and providing capacity for future demand and growth.

6. Conclusions:

Near about 90% of waste heat can be recovered from the screw compressor which can be used for different application and there reduction of pressure drop with well design pipeline.

From above discussion it is conclude that there is significant saving is possible in compressed air system with help of heat recovery in compressor and optimized design of pipeline for CASs.

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