THE IMPACT ON ENERGY CONSUMPTION CAUSED BY PRESSURE DROP IN A COMPRESSED AIR SYSTEM

What is pressure drop in a compressed air utility?

Pressure drop is a term used to characterize the reduction in air pressure from the discharge pipe on the compressor to the actual point-of-use. Pressure drop occurs as the compressed air travels in the air piping and air treatment system and passes on through the air distribution network. Frictional losses are firstly incurred by the piping network which is caused by the piping’s internal surface roughness, the problem is most prevalent in galvanized piping which is more suitable for water rather than compressed air, the inherent internal seam in galvanized piping inevitably causes turbulence and unwarranted flow resistance.

The velocity of the compressed air also increases if a pipe diameter selected is incorrect. High air velocity will render air treatment a waste as air treatment equipment is designed to function at a certain air velocity, exceeding this design parameter means that the specific associated ancillary will fail to perform its function. Additional congestion and pressure drop is however also created by incorrectly sized ancillary equipment such as undersized moisture Separators, Air dryers, In Line filters, Control valves or piping manifolds designed with excessive bends and poorly sized fittings or connections which can create a back pressure in the system.

A current typical compressed air system profile in the South African Industry
This reveals that currently up to 17% of compressed air energy is wasted in 90% of compressor installations in South Africa.

A properly designed system should have a pressure loss not more than 3% of the compressor’s discharge pressure i.e. an 8 bar system must ideally have no more than 0.25 bar pressure drop collectively across the air treatment equipment and zero differential across the manifold piping if the objective is to instate an energy efficient compressed air supply system. The measured differential from the receiver tank, deemed the supply system outlet, and especially in the case of a variable frequency output compressor (energy efficient compressor) which does not run on a pre-set pressure band, to the point-of-use must be accurately verified as no less than 0.45 bar, as excessive pressure drop across the Demand system will inevitably result in poor system performance and excessive energy consumption. Even when running an energy saving type air compressor, if flow restriction is above 0.5 bar the air system will require a higher operating pressure from the compressor to maintain the required demand pressure, resulting in higher energy consumption and electrical energy wastage which is the biggest expense in operating a compressor plant and not the CAPEX, piping system installation or maintenance of the utility.

Thus, minimizing pressure differentials in all parts of the system is the most important component to ensure efficient operation, but is surprisingly the most neglected aspect considered by most design, installation and maintenance engineers, usually to save on implementation costs. Pressure drop upstream of the compressor signal requires higher compression pressures to achieve the control settings on the air Compressor. A rule of thumb for systems in the 7 bar (100 psig range) is for every 0.14 Bar (2psi) increase in discharge pressure, the energy consumption will increase by approximately 1 percent at full output flow.

There is also another penalty for higher-than-needed air pressure. Raising the compressor discharge pressure increases the demand of every unregulated type of usage, including leaks, open blowing, etc. Although it varies by plant, unregulated usage is commonly as high as 30 to 50 percent of air demand. For systems in the 7 bar range with 30 to 50 percent unregulated usage, a 0.14 bar increase in header pressure will increase energy consumption by about another 0.6 to 1% because of the additional unregulated air being consumed. The combined effect results in a total increase in energy consumption of about
1.6 to 2% for every 0, 14 bar increase in discharge pressure based on a system in the 7 bar range with 30 to 50 percent unregulated usage.

*Example: 2% additional energy consumption on a 75kw air compressor running 24/7 @ average R1, 35 per kWh = R 17 688.00 wasted electrical energy per annum*

**What Causes Pressure Drop?**

Any type of obstruction, restriction, especially internal roughness in the piping (using seamed galvanized water piping for compressed air) in the system will cause an inherent resistance to air flow and cause pressure drop in the distribution system. The highest pressure drops usually are found at the points-of-use, caused by undersized or leaking hoses, tubes, quick connectors, filters, regulators and lubricators. We call the last 10 meters of piping the degradation area.

Instead of increasing the compressor discharge pressure or adding additional compressor capacity, alternative solutions should be sought, such as remedying poorly designed systems with dead ends or undersized and poor quality piping to reduce pressure drop or by adding strategic compressed air storage. Equipment should be specified and operated at the lowest efficient operating pressure. The fact that a system is working does not suggest it is working efficiently, the cost of electricity today means that a poorly designed or defunct air system can penalize your electricity bill by up to 33%

If the point-of-use operating pressure has to be increased for production purposes, it is wise to rather first try reducing the pressure drops in the system before adding capacity or increasing the system pressure. Increasing the compressor discharge pressure or adding compressor capacity results in significant increases in energy consumption. Elevating system pressure increases unregulated uses, such as leaks, open blowing, and production applications, without regulators or with wide open regulators. The added demand at elevated pressure is termed “Artificial Demand,” and substantially increases energy consumption.
On the supply side of the system, poor quality air piping, unorthodox design with excessive bends and complex air pathways and also inferior (retrograde) Compressor lubricant separators, moisture separators, dryers and In Line Filters (with blocked filter cartridges) can be the main items causing significant pressure drops. The maximum pressure drop from the supply side to the points-of-use will occur when the compressed air flow rate and temperatures are at their highest.

System components should thus be selected based upon these conditions and the Manufacturer of each component should be requested to supply pressure drop information under these conditions. When selecting filters, remember that they will get dirty. Dirt loading characteristics are also important selection criteria. Electroair works closely with their suppliers to ensure that the products they supply meet the desired specifications for differential pressure and other characteristics.

The distribution piping system often is diagnosed as having excess pressure drop because a point-of-use pressure regulator cannot sustain the required downstream pressure. If such a regulator is set at 6 barg and the regulator and/or the upstream filter has a pressure drop of 1 bar, the system upstream of the filter and regulator would have to maintain at least 7 barg. The 1 bar pressure drop may be blamed on the system piping rather than on the components at fault. The correct diagnosis requires pressure measurements at different points in the system to identify the component(s) causing the excess pressure drop. The correct sized air piping is the first aspect which can be simply analysed by verifying integrity of the actual piping installed or to be installed. In some cases, simple replacement of the Regulator filter element should be done first if the element is older than 6 months, if not culprit the filter regulator specification or size needs to be verified or increased, however the piping quality and integrity should primarily be checked as a mandatory evaluation.

**Minimizing Pressure Drop**

Minimizing pressure drop requires a systems approach in design and maintenance of the system. Air treatment components, such as heat exchangers, moisture separators, dryers, and filters, should be selected with the lowest possible pressure drop at specified maximum operating conditions.
When installed, the recommended maintenance procedures should be followed and documented. Additional ways to minimize pressure drop are as follows:

- Properly design the distribution piping system.
- Operate and maintain air filtering and drying equipment to reduce the effects of moisture, contaminants and oxidation, the causes of steel pipe corrosion, or alternatively install corrosion free piping.
- Select compressor discharge moisture separators, dryers and filters having the lowest possible pressure drop for the rated conditions.
- Reduce the distance the air travels through the distribution system and specify pressure regulators, lubricators, hoses, and connections having the best performance characteristics at the lowest pressure differential. These components must be sized based upon the actual rate of flow and not the average rate of flow.

**Best Practices and Tips for Compressed Air Piping Systems**

Pressure losses due to inadequate piping will result in increased energy costs and variations in the system pressure, with adverse effects on the production process.

**How to select pipe sizes**

The compressor room header into which the air compressor(s) discharge(s), should be sized so that the air velocity within the header does not exceed 6,5 m/sec, allowing for future expansion. Distribution header piping leaving the compressor room should be sized to allow an air velocity not to exceed 9,5 m/sec, to minimize pressure drop.

It is also recommended that the air from each compressor not enter the manifold header at 90 degrees to the header axis, but at least at a 45 degree angle in the direction of flow, always using wide radius elbows.

Iron and carbon steel piping generally is sized by the nominal bore diameter. Aluminium, Copper and steel tubing normally is sized by outside diameter.

**What about the future?**

The main header and distribution piping should be sized to take into account anticipated future expansions. If the initial piping is sized only for present flow requirements, then any additions in the demand system will cause increased pressure losses in the entire system. The next size larger pipe will add to
materials costs, but may add little to installation or labour costs but reduce the pressure drop substantially, with corresponding savings in operating costs.

**How about materials?**

Many industrial plants use schedule 40 steel piping, with or without galvanizing, for 7 to 8 bar service. Many food, pharmaceutical, textile and other plants which use non-lubricated compressors, install stainless steel piping to avoid potential corrosion problems and resulting downstream contamination but may be too expensive in some applications. For special applications, Local OHS Codes should be consulted before deciding on the type of piping to be used. The usual Standard to be applied is ANSI B31.1. For Health Care Facilities, consult Standard NFPA 99 of The National Fire Protection Association.

Contact Electroair for any advice on Compressed air reticulation design, installation, implementation and supply.

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