CANADIAN PURCELL MACHINERY LTD.
"A World of Compressed Air & Gas Solutions"

TECHNICAL BULLETIN

DESIGNING A FUNCTIONAL COMPRESSED AIR SYSTEM

The purpose of a compressed air system is to provide an efficient means of transmitting an adequate volume and quality of air to pneumatic equipment, with minimal loss of pressure.

Careful evaluation of existing and proposed additions to the distribution system will result in improved equipment operating costs, lower maintenance and reduced energy consumption.

Under-designed compressor installations offer false economy and normally result in the heavy penalties of condensation damage, costly maintenance, insufficient pressure or volume and high energy costs.

Completion of a scale drawing is a desirable first step in ensuring proper layout and location of each component.

COMPRESSOR LOCATION

Whenever possible the compressor should be located in a clean, temperature controlled and well lighted environment, with sufficient clearance to allow for servicing of the unit and removal of major components.

Proper design should allow for adequate cooling and ventilation of air cooled units, during the warm summer months, as well as, controlled heating if the compressor is subjected to sub-freezing temperatures.

Cleanliness of the compressor area is important to any plant. Dirt build-up on the intake filter and coolers will result in air starvation or improper cooling.

Should excessively dirty conditions exist such as in foundry or cement plant operations, fan pressurization of the compressor room is well worth consideration to prevent harmful dust from entering the room.

In many cases, a separate compressor building, which is isolated from the main plant area, will offer an even better alternative to ensure a clean operating environment.

For add-on capacity, the new machine can be located directly beside existing compressors, but consideration may also be given to the possibility of installation near the <u>center</u> of the load. Easier supervision and maintenance may be given as reasons for grouping the new machine with the old, but there are many plants where the existing location is so poor that a new location for the new machine would ease routine service, inspection and repair.

Clearance over the top and at the sides of the compressor is important for ease of maintenance and removal of components later. In very few plants is the floor space valued so highly that savings from cramming the compressor into a minimum area will exceed the added costs of maintenance of the years.

COMPRESSOR INLET PIPING

Whenever possible, the compressor intake should be located outdoors. In most cases, outside air provides the coolest, driest and cleanest source of intake air. Especially during winter months when outdoor ambient temperature and relative humidity are much lower then they are indoors. Further, as the temperature of the inlet air decreases, its density (volume) increases.

When installing a remote mounted inlet air cleaner the following guidelines should be observed.

- Install intakes at locations providing the cleanest, driest air possible.
- Install the filter in an area that is easily accessible for maintenance.
- The intake pipe should <u>never</u> be smaller than the manufactures opening on the compressor.
- Long runs (particularly in larger reciprocating units) should always be avoided.
- Intake piping should take the most direct route possible.
- Avoid the use of piping elbows.
- Size short intake pipes the same size as compressor inlet. Increase the inlet pipe diameter by one size for each 8 feet in length.
- Velocity in intake piping should not be more than 2500 ft per min.
- Be sure all piping is carefully supported to eliminate any stress on the compressor.
- When installing the inlet out-of-doors, the system should include a filter design to suit the environment, as well as a protective weather hood to guard against entry of rain or snow.
- The point of entry should be located a maximum of 6 feet above ground level to allow for ease of filter element changes.

DISTRIBUTION PIPING

Poorly designed compressed air distribution systems will result in air leakage, high pressure drops, wasted energy costs and reduced equipment efficiencies.

The pressure loss between the compressor and the point of use is due to friction in the pipe. The smaller the pipe, the greater the friction; and the longer the pipe, the greater the friction. Combining both of these in the same system will cause a substantial pressure drop between the compressor and the point of use.

Each 2 PSIG increase in pressure requires an additional 1 percent of the total horsepower to compensate. Therefore, a 100 HP air system with 20 PSIG pressure drop looses 10% or 10 HP worth of air just moving through the system.

Three steps can be taken to reduce the pressure losses:

1. Reduce the effective distance that the air has to flow.
2. Reduce the friction caused by restrictions to flow.
3. Reduce the velocity, or flow rate, of air through the system.

When laying out a new system, it costs very little more to install adequately sized piping. The increase in material costs is insignificant compared to the cost for the entire installation. Whereas a 1-1/2 inch pipe would cost only 50% more than a 1 inch pipe, three times as much air will flow through it with the same pressure drop.

Here are some basic rules to remember when selecting a piping size.

1. For a given pipe or hose size and length, the pressure loss increases as the volume of air flow increases.
2. Under the same conditions, the pressure loss increase with a lower initial pressure and decrease with a higher initial pressure.
3. A smooth inner lining of the pipe or hose will cause less pressure drop. A rough inner lining of the pipe or hose will cause more pressure drop.
4. Couplings, fittings, and valves increase the pressure drop.

Two systems are commonly used for distribution piping:

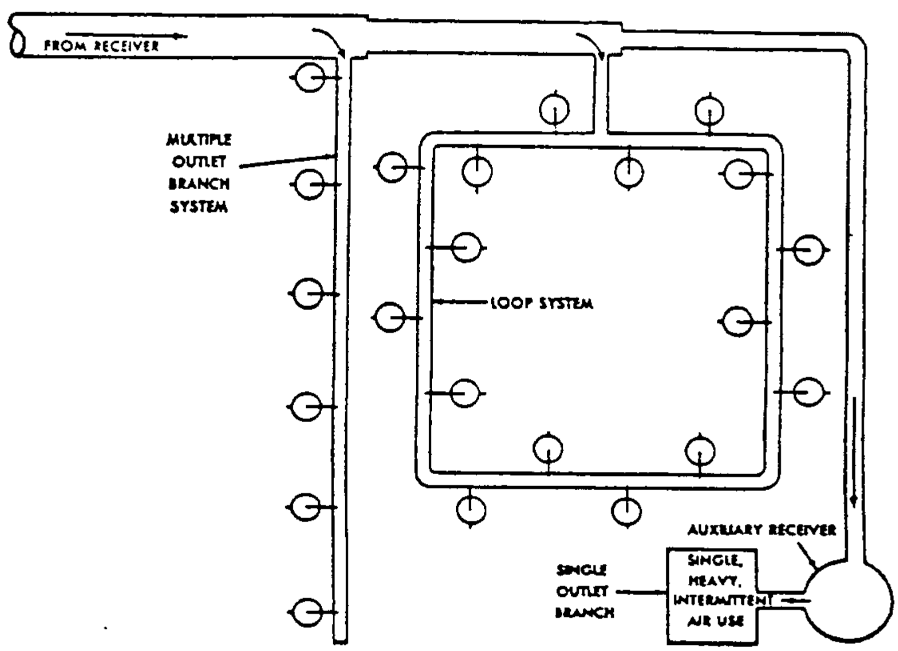
Manifold System

Most compressed air systems consist of a larger diameter manifold from which smaller branch lines will be taken off. This system offers an effective method of air distribution in light or medium demand areas, where the length of the airlines can be kept at a minimum.

Loop Systems

The most efficient layout to minimize pressure drop is a loop system with auxiliary receivers as near as possible to points of heavy intermittent demand. The loop system provides two-way airflow to any point in the system cutting the effective flow path in half, (i.e.: with a loop system containing 500 feet of pipe, the maximum effective length of flow would be 250 feet). Feeding the air 'user' from two directions also cuts the flow rate in half, thereby, reducing the pressure drop associated with increasing flow rate.

TYPICAL COMPRESSED AIR SYSTEM LAYOUTS



Regardless of the distribution system chosen the following general rules should be followed:

- Piping should be sized large enough to prevent a pressure drop in excess of 2-3%. Since the initial cost of pipe is relatively low when compared to installation or replacement costs, it is advisable to ensure that the pipe purchased is of adequate size. If any doubt exists as to the resulting pressure drop, the next larger diameter should be selected. Consideration must also be given for future expansions.
- Install pipe tees with one port plugged, in place of elbows. If an additional line must be installed in the future, simply bleed the system pressure, remove the plug and install a new branch line.
- Keep discharge piping as short as possible by locating the compressors close to the initial point of use.
- Slope piping away from the compressor at approximately 1" in 10 feet and install drip leg drain at the low points in the piping.
- To avoid excessive pressure drops during intermittent peak demand periods install auxiliary receivers at the points of occasional heavy usage.
- Install automatic condensate drains at any low points in the piping system where water may accumulate.
- In order to reduce condensation carry-over, the lines to individual equipment stations should be taken off the top of the air main. (See Drop Legs)
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- Whenever possible piping should be installed so that it can be readily inspected at regular intervals, as small leaks can result in serious volume and pressure losses.
- Pipefittings offering the least resistance to flow should be utilized.
- Terminate all branch lines with a drip leg and automatic condensate drain.
- Wherever the air piping passes through a cold are in the plant, insulate and provide a separator and condensate drain on the downstream side of the area.
- Do not install piping directly against COLD outside perimeter walls. Install piping away from the wall using stand offs.

Pipe Size

Many plants with sufficient compressor capacity and receivers still do not get adequate air pressure to their equipment – due to one of two factors, poor system layout or inadequate undersized piping. Both factors reduce the effective pressure at the equipment.

Inadequate pipe diameter and inefficient distribution layouts contribute to large pressure drops in the system, resulting in increased energy costs. A 10 PSIG pressure loss at an air tool, for example, can reduce its power by approximately 14%. A pressure drop of 3% across the entire system is usually tolerable. However, the losses are likely to be much greater than 10% if there are long runs of small diameter piping and excessive use of elbows, valves and tees.

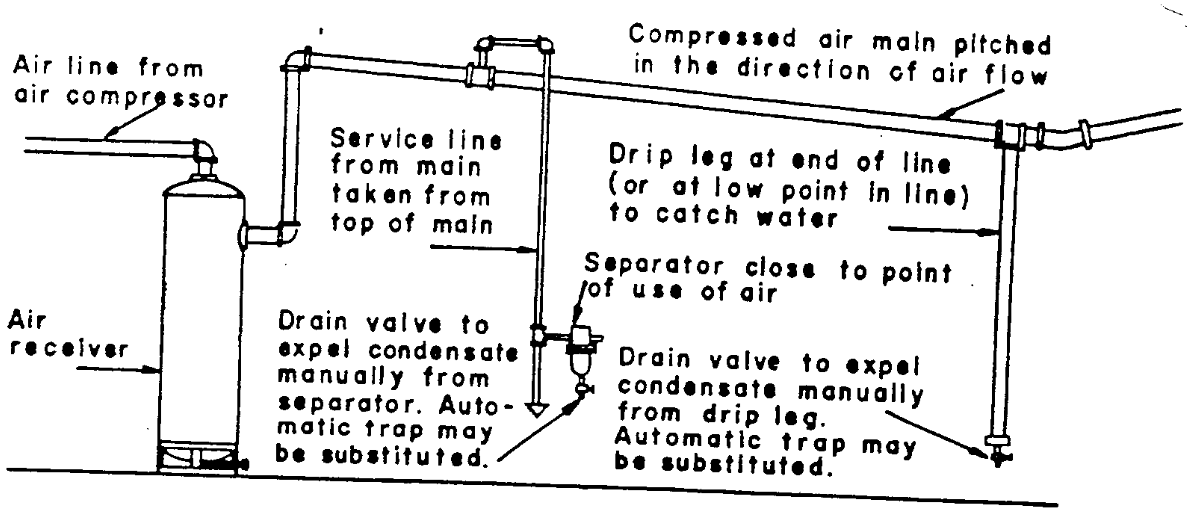
Drip And Drop Legs

Condensation will accumulate in air piping systems even though after-coolers, receivers and separators are installed (particularly if air lines are exposed to temperatures lower than the after-cooler discharge temperature). Install 'drip' legs at all of the low points in the system.

The 'drip' leg is a pipe extending downwards from the bottom of the airline to collect any condensation in the pipe. They should be at the lowest points in the airline and at any point where the airline dips to go around an obstruction. An automatic condensate drain or a manual 'blown-down' valve should be installed on the bottom of the 'drip' leg.

The 'drop leg', on the other hand, is a pipe coming from the top, rather than the bottom, of the main air distribution line to feed air to an outlet for tools or air operated devices. The 'drop leg' is taken off the top of the main line so that condensation does not easily flow into the branch. This reduces the chance of carryover of condensation from the main header to the branch lines.

The outlet of all 'drop' legs should be equipped with a filter to catch any condensed liquid or pipe scale prior to the air entering the equipment.



Air Receivers

The volume of available compressed air may be supplemented by locating auxiliary receivers at points of intermittent heavy loads. If air needs are supplied from a receiver adjacent to the using operation, there will be relatively little increase in the flow rate in the main system. This will minimize the pressure drop in the entire system, since the major load; will be absorbed by the receiver.

The air receiver serves four primary functions within the air system:

1. They serve as a reservoir to insure an adequate supply of air during periods of sudden or rapidly fluctuating air demand, thus preventing excessive loading and unloading of the compressor.
2. They act as a gathering point from which condensation can be easily expelled.
3. They dampen pulsation assuring a steady pressure.
4. They offer a suitable point from which accurate pressure control signals can be taken.

Because the air receiver is classified as an unfired pressure vessel, care must be taken to ensure that they are designed, manufactured and tested in accordance with ASME codes and that they receive provincial approval.

Flow should be in at the bottom and out at the top, whenever possible and the entrance and exits should be on opposite sides.

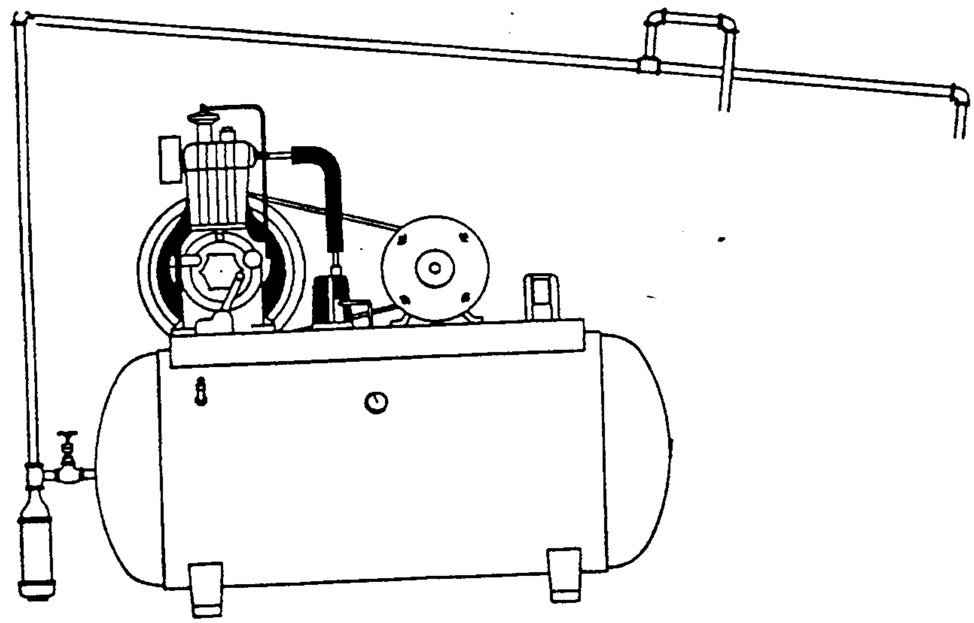
To ensure safe, functional operation, the receiver must be equipped with an inspection opening, a pressure relief valve and pressure gauge as well as a manual or automatic drain valve.

Unless frequent manual draining can be carried out, it is advisable to install an automatic float or electrically timed drain to prevent condensate accumulation.

Although interior installation is most desirable, if conditions dictate placing the receiver outside, heat tracing lines list be placed on the drain to present freezing.

Pipe Slope

All main lines in the system should slope or pitch downward at least 1”:10 ft in the direction of the air flow. This will allow condensation to collect at the low points where it can be trapped.



Compressor Discharge Pressure

The compressor discharge should generally be set at the minimum pressure required to operate the equipment. An air compressor’s energy consumption is directly proportionate to the pressure of air it produces – the higher the pressure, the higher the energy cost. Compressor discharge pressure is frequently set higher that necessary in order to overcome piping losses and maintain pressure level, or to service a small, high pressure requirement.

Typically, many systems ‘step down’ the pressure to lower levels at various end-use locations. Energy can be saved by, setting the compressor discharge pressure to the minimum acceptable level and avoiding step-downs in pressure wherever possible. A reduction in discharge pressure from 110 PSIG to 100 PSIG can reduce energy consumption by approximately 5%. (For every 2 PSIG of pressure change, the energy consumption will increase or decrease by approximately 1%).

Air Leakage

It is important to have maintenance staff trace and repair air line leakage on a regular basis.

It will surprise you to learn that a 1/8” leak at 100 PSIG will flow 26 CFM. Since a compressor will produce approximately 4 CFM per horsepower it will take 6.5 HP (4.8 kw) to produce the compressed air necessary to simply keep up with this leak.

At an average rate for electrical power of $.045/kw hour, the compressed air which is lost through this small 1/8” leak will cost $449.28 per year to produce assuming that plant operates only 8 hours per day, five days a week!

One of the easiest times to accurately trace air leaks is when the plant is not in production and when background noise is at a minimum. It is possible to actually hear air leaks.

An alternative method is to see is the air compressor is operating over long periods – when the plant is not in production, at night or over a long weekend.

The use of a detection fluid which forms bubbles around leaks can end all suspicion in doubtful cases. Maintenance crews should be particularly altered to check for leaks at the following:

- Blow buns for blowing off chips – nozzles, and shutoff valves.
- Air solenoid valves, not seating.
- Air cylinders at packing glands.
- Air-operated chucks, leaky fittings and hoses.
- Air leaks at unions and quick disconnects used on hoses.

Waste-Heat Utilization

Heat recovery is an opportunity that is often overlooked in compressed air systems, and can be applied to the exhaust air of an air-cooled compressor or to the discharge water from a water-cooled compressor. The heat recovered can be significant – a small 25 horsepower, 100psi compressor, for example, expels approximately 65,000 BTUs per hour. Heat recovered from the air could be used for space heating, product drying etc., while heat recovered from the water could be used to preheat boiler feed water or other process needs.

An air-cooled compressor rejects about 42.4 BTU per minute per brake horsepower to the air around the compressor. A water-cooled compressor rejects between 15% and 25% of that amount (the rest is rejected tot eh cooling water).

Heat recovery is even simpler with water-cooled compressors. Simple piping changes can put the warm cooling water to use in plant systems.

Reduce Compressed Air Energy Costs

Compressed are is expensive, and the management of the air system influences the cost. Areas in which energy management can be practiced in the operation of compressed air systems include the following items:

1. It is important to <u>avoid leaks</u> in compressed air systems. Major loss of air can occur at joints, valves, fittings and hose connections. During regular operation, leaks can be difficult to locate because of background noise. It is worth the effort to find and repair leaks because they are a major source of waste.

2. It is desirable to <u>operate the system at the lowest suitable pressure</u>. Air is often compressed to higher than required pressure. In some cases, tools or devices that needed the higher pressure have been removed from the facility and the higher pressure is no longer required. In other cases, poor tool or device maintenance, such as poor lubrication, or undersized airlines, may require higher pressures to satisfy the tool operation.

3. Design should <u>minimize the pressure drop throughout the distribution systems</u>. Often, plant explosions, equipment additions, or equipment relocations take place

without corresponding modifications to air distribution systems. Piping has been added, new connections made, and, in some cases, the volume of airflow through systems may have increased be4cause of a greater use of compresses air. Increased air flow through pipes and fittings increases the friction losses, thus the pressure drop. These losses can be significant, depending on the airflow and pipe diameter. Since the air pressure required at the use point is fixed, the required increase in line pressure leads to greater power requirements at the compressor.

4. Care must be taken to avoid water in the distribution systems. Water, or the mixture of compressor lubrication oil and water, causes corrosion on the inside of air distribution lines. Corrosion increases the internal resistance and the pressure drop through the system. Reduced air pressure decreases the efficiency of the air consuming tool device. Corrosion also causes pits and pockets in the piping system, which weakens it and causes leakage at joints, traps and valves. The solution is to install an air dryer on the compressor to eliminate moisture in the system. This is extremely important for instrument air systems where the operation of the instruments can be adversely affected.

5. Match compressor capacity to actual demand. Don't run the large main plant air compressor on off-shifts and weekends. Consider installing a small unit sized to handle these light demands.

6. Install pressure switches to start auxiliary compressors only when plant air pressure demands, rather than running the unloaded.

7. Substitute low-pressure blowers for drying and cleaning operations, rather than compressed air.

8. Ban use of compressed air to cool people. This is both wasteful and extremely unsafe.

9. Don't use high-pressure air for agitating liquids. This application is better suited to blowers.

10. Check all shutoff valves regularly to minimize leakage, and train employees to ensure that compressed air is shut off on all equipment when it is not operating.

11. If you need extra capacity because of infrequent loads, consider installing an extra receiver near the point of heavy use. In some cases this will allow the existing unit to handle the load without system pressure drop since the volume of air in the system will be larger, reducing the heavy swings in pressure.