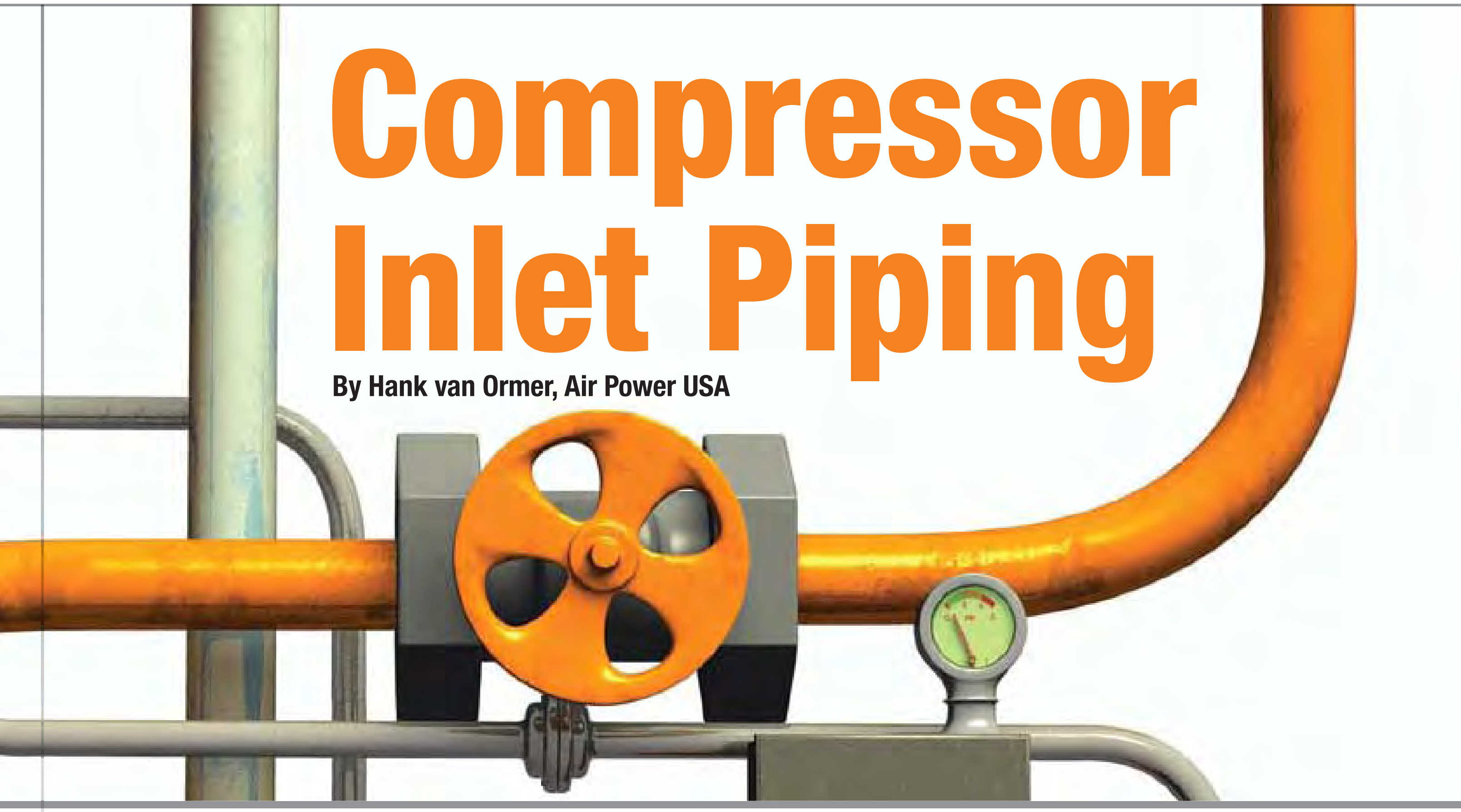
Compressor Inlet Piping

By Hank van Ormer, Air Power USA



The subject of compressed air piping has probably had more pages written about it than any other topic, even storage. Like many other topics in "practical" compressed air technology, a significant portion of this is controversial and often directly opposed.

These guidelines are not designed to replace the appropriate correct volumes of information and are not designed to answer all questions regarding a specific installation. They are designed to arm you with basic principles that always apply and, when followed, will end up with a well performing system. As with all our guidelines, they are based on performance and measured critical data in the field molded with theoretical performance. We have developed and used these guidelines over the last twenty years and find them very accurate.

Types of Piping Offered for Compressed Air

Consult federal, state and local codes before deciding on the type of piping to be used. The usual standard to be applied is the ANSI B31.1. For health care facilities, consult the current Standard NFPA 99 of the National Fire Protection Association.

The compressed air piping materials can be divided into two basic types: Metal and Non-metal.

Non-Metal Pipe — commonly called "plastic" pipe has been offered for many years as compressed air piping because:

- It is lighter than most metal and easier to handle
- It can be installed with no special tools such as welders, threaders, etc.
- It is generally non-corrosive
- Installation with the appropriate gluing material is fast
- The labor (which can also be unskilled) is much lower in cost than most metals (copper, stainless, black iron), and the total job may often be less expensive installed

What has held back this materials acceptance by many compressed air people and organizations?

Early on, PVC was used for compressed air piping, and it was not long before the fact became evident that it sometimes "shattered" when it failed sending sharp pieces throughout the area. New products were introduced that utilized material that did not shatter. However, this material and all others offered to date have significant limitations:

- Most of these are limited to an operating temperature of 140 ˚F to 200 ˚F. The failure in an aftercooler can easily reach or exceed these numbers. PVC, for instance, is limited to about 160 ˚F at 125 psig, but it actually starts to weaken at 70 ˚F

- Most of these materials are not compatible with compressor oils in general and particularly many synthetics
- Although pipeline fires are rare today, when there is one in plastic pipe, there is a good chance that it will melt through the plastic pipe and migrate into the plant

Typical Pressure Temperature Ratings for Thermoplastic Piping

As with all other thermoplastic piping components, the maximum non-shock operating pressure is a function of temperature. The heat of compression should be fully dissipated so that the maximum temperature rating (140 ˚F for 1/2", 120 ˚F for 3/4") is not exceeded in the pipe system.

The pressure ratings for typical thermoplastic piping and fittings are about a constant 185 psi for all sizes in the temperature range -20 ˚F to 100 ˚F, and are gradually reduced above 100 ˚F, as shown in the table.

Overall, the compressed air industry has not accepted any type of plastic pipe as appropriate and safe for downstream compressed air. As a consultant, we would agree with this given today's material, data and available alternatives.

Metal Pipe can be black iron, stainless steel, copper, aluminum, etc. with proper thermal and pressure characteristics.

Black Iron or Steel Pipe in compressed air systems will corrode when exposed to condensate (H_2O) and thus become a major source of contamination to the whole system. This pipe is usually

Even this HDPE plastic pipe with an aluminum centerpiece is still rated at 73 ˚F and 140 ˚F. It does not have published testing above 140˚. Resistance to common oils and solvents is not published.

COMPRESSOR INLET PIPING

Aluminum air system piping with connections that require no special tools or pipe threading. — Courtesy Transair

a threaded connected 3" diameter and smaller and welded with larger diameters. Compared to copper and aluminum, it is much heavier and harder to work with, but less expensive. The internal corrosion issue is much more significant with oil free air than with lubricated compressors.

Stainless Steel is often a good selection particularly when exposed to oil-free wet air and its extremely high acid level condensate (before the dryers). Stainless steel is often lighter for the same pressure temperature rating and installs well when welded. Threaded stainless steel often tends to leak. Ring seals such as those used in grooved connections will work well with stainless steel. As piping material, however, the potential lower installation cost and faster welding (use of grooved fittings) may well make it the most overall economical.

Copper Pipe is a common selection for sensitive air systems and when selected correctly and connected correctly is very rugged. The working pressure of copper piping is 250 psi for Type "M" hard, Type "L" hard, and Type "K" soft, and 400 psi for Type "K" hard. Further, since 50/50 solder melts at 421 ˚F, it will be more resistant to high temperatures. Even if it does fail, it will do so in a predictable manner. The pipe ends will separate. The working temperature limit of copper piping is about 400 ˚F. (Data from Piping Handbook, 6th edition).

- Never join pipes or fittings by soldering. Lead-tin solders have a low ultimate strength, a low creep limit, and, depending on the alloy, start melting at 361 ˚F. Silver soldering and hard soldering are forms of brazing and should not be confused with lead-tin soldering. Silver soldering and hard soldering is brazing with a silver alloy type of filler material which melts in the range of 1145 ˚F to 1800 ˚F.

Aluminum compressed air pipe as applied today has become very popular. This has been developed not only to provide a smooth (low pressure loss due to friction) inner surface, and eliminate self contaminating, but also offer enhanced flexibility to meet the ever changing compressed air distribution needs. This is particularly desirable in the automotive support industry with changing assembly and subassembly areas.

Most of the aluminum pipe manufacturers rate their material at +4 ˚F to 140 ˚F or 176 ˚F. The piping material usually has a melting point of over 1,100 ˚F.

Material and Optimal Coatings for Inlet Air Piping and Discharge Air Piping

The question of galvanized piping comes up often in compressed air system piping instead of schedule 40 black iron for the nominal 100 psig air systems. To help evaluate this, let's look at inlet and discharge piping separately.

Guidelines for Inlet Piping

The proper inlet pipe brings the air from the filter to the compressor with no pressure loss and should not create operational problems with any type of self-contamination on the inside. It is important to realize that the ambient inlet air condition may well dictate the selection of one type of pipe over another.

Galvanized inlet piping has the advantage of resisting corrosion better than standard iron pipe. However, over time when the corrosion does set in, the galvanizing material then peels off. The inlet pipe is now a producer of potentially very damaging, solid contaminants between the filter and the compressor. This would be particularly dangerous to the mechanical integrity of a centrifugal compressor. We do not recommend this.

During high-humidity weather it is quite conceivable that condensation will form in the inlet pipe. Therefore, the OEM installation manual usually recommends a drain valve be installed on the pipe before the inlet. Condensation in the pipe will obviously accelerate the time frame before the coating breaks down. This time frame is dependent upon where the thinnest portion of the coating is applied.

Stainless steel inlet pipe is an excellent material for such large-diameter, low-pressure inlet air, as long as it is installed properly and the inside is properly cleaned.

There are also many grades of *thermoplastic material* suitable for inlet air piping.

Air Power USA recommends either stainless steel or proper thermoplastic-type material for inlet piping and **does not** recommend galvanized piping. Extruded aluminum will work well, but, depending on circumstances, may or may not be the economical choice.

Extruded Aluminum Alloy

Aluminum tubing that can be easily assembled with normal hand tools can bring a great deal of flexibility to an operating air system or sub-system. These are particularly effective for specific work areas, which may have to change on a routine basis.

Discharge and Distribution Piping

Here we have more complex considerations:

The discharge air from the compressors can be at 250 ˚F to 350 ˚F (for centrifugal, oil-free rotary screw and reciprocating types), or from 200 ˚F to 220 ˚F (for lubricant-cooled rotary screw compressors), so the pipe must be able to withstand those temperatures.

Even if there is an aftercooler that drops the temperature to 100 ˚F, consideration must be given as to the consequences if the aftercooler were to fail.

COMPRESSOR INLET PIPING

Compressed air generated condensate tends to be acidic. In oil-free compressors (such as centrifugals and oil-free rotary screws), it is usually very aggressive.

The basic objective of the interconnecting piping is to deliver the air to the filters and dryers and then to the production air system with little or no pressure loss, and certainly with little or no self-contamination.

Galvanized piping will have the same problems once it begins to peel, as we described on the inlet application. In all probability, due to the aggressive acidic characteristics of the condensate, the galvanized coating life may be much shorter.

Regardless of the thermoplastic pipe manufacturer's claim, we never recommend any plastic type material for interconnecting piping and rarely for distribution header piping. Most of these materials carry cautions not to be exposed to temperatures over 200 °F and to avoid any types of oil or lubricants.

Here again stainless steel or coated aluminum is our number one recommendation for the interconnecting piping from the compressor to the filter and dryers when the compressed air is oil free. It will obviously resist corrosion much better than standard schedule 40 black iron. Some other considerations:

- Most areas will allow schedule 10 stainless steel in lieu of schedule 40 black iron
- For the same diameter pipe, stainless steel will be much lighter and easier to handle usually lowering the labor cost
- For welded connections, stainless steel usually requires just one bead, while black iron pipe usually requires three beads (weld, fill and cover). This should also lower the labor cost
- Stainless steel does not usually seal well when threaded. It will do much better with grooved type connections when welding is not practical

Summary

The following comparison chart summarizes some of the pros and cons of each type of piping material. This information has come from discussions with piping manufacturers, mechanical contractors, and plant personnel along with years of system analysis by field personnel.

Distribution Headers and Drops

The objective for the main header is to transport the maximum anticipated flow to the production area and provide an acceptable supply volume for drops or feeder lines. Again, modern designs consider an acceptable header pressure loss to be 0 psi.

The objective for the drops and feeder lines is to deliver the maximum anticipated flow to the work station or process with minimum or no pressure loss. The line size should be sized for near-zero loss. Of course the controls, regulators, actuators and air motors at the work station or process have requirements for minimum inlet pressure to be able to perform their functions.

Specific Guidelines on Piping — By Type of Compressor

These tips are general in nature. For a specific unit consult the manual and/or manufacturer.

Inlet Air Piping

Rotary compressors:

1. Use dry filters or pressure aspirated oil wetted if unit has modulation control
2. For remote filter installation, remove filter from package to be installed:
   - No valves or obstructions in the inlet interconnecting pipe
   - Can use supported flex/rubber hose to pipe outside enclosure to connect to inlet pipe
   - If inlet is outside, be sure to install a bird deflector
   - Support inlet piping, do not hang on the unit

> "The compressor discharge pressure was reduced to 98 psig, which represents a power savings of 6%, equivalent to about $9,585 annually."
>
> — Hank van Ormer, Air Power USA

- Be sure pipe is free of dust, rust, weld beads, scale, chips, etc. before starting the compressor

- If running over 50 feet (confirm with manufacturer), increase pipe size at least one size or greater over the filter housing connection size

Reciprocating compressors:

1. Always try to increase inlet air piping one or two sizes above compressor connection size. Never reduce inlet pipe size from connection size on the unit

2. Brace/clamp pipe at regular intervals — DO NOT have pipe weight on compressor connection

3. Be sure pipe is clean and free from rust, scale, etc., before starting the compressor

4. Be sure you are not in "critical length" and if you are, consult manufacturers data for proper corrective action

5. Use inlet pulsation bottles when possible on larger units. Be sure bottle is clean before starting the unit

6. Can use dry or oil bath filter. When in doubt, consult manual or manufacturer

7. Avoid critical lengths

Centrifugal:

1. If a remote inlet filter is to be used, it is necessary to work closely with the supplier/manufacturer to size the inlet pipe. Because the centrifugal compressor is a "mass flow" type compressor, its overall performance is very dependent on identifiable and predictable inlet air pressure

2. Install drain leg on inlet line before the air enters the compressor

Discharge Piping

Rotary:

1. Pipe size should always be larger than unit connection size. Determine correct pipe size based on system flow, length of pipe, number of bends/valves, acceptable pressure drop, etc.

2. Pipe so condensate from air line cannot run back into unit

3. Support pipe so there is no strain at or on the compressor connection

Reciprocating:

1. Pipe size should be one or two sizes larger than compressor connection size. Never reduce discharge pipe size from connection size of unit. Check the pipe size for velocity and calculate pressure loss

2. Brace/Clamp pipe at regular intervals. DO NOT have pipe strain on compressor connection

COMPRESSOR INLET PIPING

3. Be sure you are not in "critical length" and, if you are, consult manual or manufacturer for proper corrective action

4. Use discharge pulsation bottles when possible on larger units

Centrifugal:

1. Refer to the manual/manufacture for detailed location of check valves, back valves, safety valves, etc

2. Discharge piping should be larger than the compressor connection and should have a smooth run directly away from the unit. It should not be too large, which can possibly create a "stonewall" type effect at the discharge

3. All turns should be "long sweep ells" to allow a minimum of backpressure. This is always recommended in any air system but it is much more critical in a mass flow centrifugal

4. All piping should slope away from the compressor. All risers should have drain legs. Install a drain leg immediately after the compressor in the discharge line

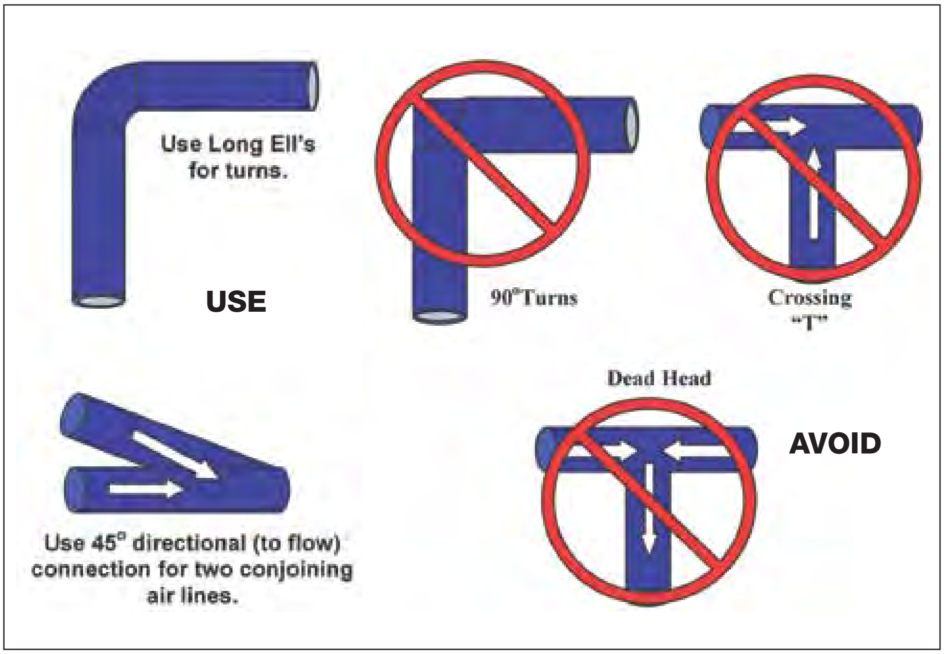
Interconnecting Piping with Multiple Units

Interconnecting Piping Configuration is between the compressor discharge through the air treatment equipment and storage before entering the production area.

Over the years we have found very few plants where the interconnecting piping does not cause control problems with multiple units, particularly rotary screw units with modulating controls. This usually leads to multiple units at part load and, consequently, poor basic efficiency. Step controlled units with extreme short cycling may experience poor efficiency and lead to premature failure of operating components.

The objective in sizing interconnecting piping is to transport the maximum expected air flow from the compressor discharge through the dryers, filters and receivers to the main distribution header with minimum pressure drop. Contemporary designs that consider the true cost of compressed air target a total pressure drop of less than 3 psi.

Avoiding such things as high turbulence and its resistance to flow with resultant pressure spikes and loss, the interconnecting piping should be sized with regard to velocity rather than friction loss only. Design configuration has significant impact on this also. All pipeline velocities are to be 20 fps or less at pipeline psig. At these velocities, even some poor piping configuration practices will have much less negative impact, if any.



General Guidelines for All Piping

All air inlet and discharge pipes to and from the inlet and discharge connection of the air compressor must take into account vibration, pulsations, temperature exposure, maximum pressure exposed to, corrosion and chemical resistance, etc. In addition, lubricated compressors will always discharge some oil into the air stream, and compatibility of the discharge piping and other accessories (such as O-rings, seals, etc.) with both petroleum and/or synthetic lubricants is critical.

General Rules for Sizing Pipe in a Compressed Air Distribution System

1. Pressure drop between the compressor and point of use is irrecoverable

2. Pipe size should be large enough that pressure drop is held to a minimum or even nonexistent. There is no reason to tolerate any pressure loss during normal operation in the header distribution

3. Arrange piping to avoid the following types of strains:

   A. Strains due to dead weight of the pipe itself

   B. Strains due to expansion or contraction of the piping with temperature change

   C. Strains due to internal pressure within the piping

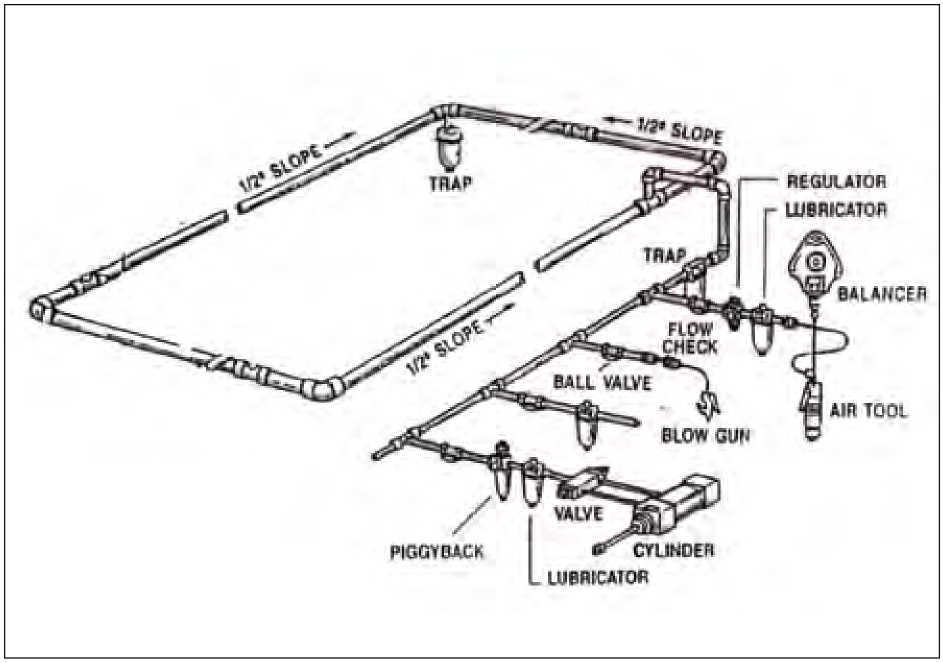
4. Design inlet and discharge piping for smooth flow with uniform translateral velocity over the entire area of the piping

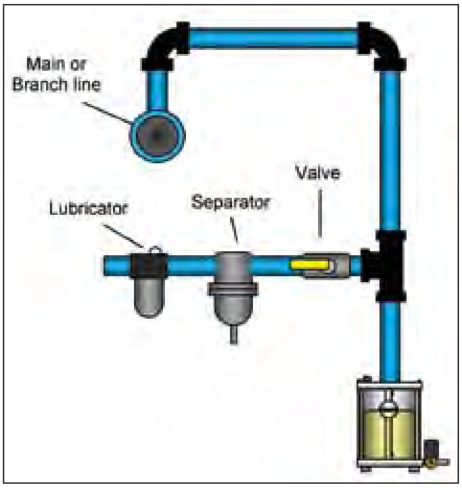
5. Install a safety valve between the compressor and shut-off valve at 5 to 10 psi above compressor operating pressure. Never exceed the working pressure rating of any ASME vessel in the system

6. Plan for future emergencies and establish a tie in point to install a temporary compressor with power and aftercooler (if required)

7. Consider bypass lines or valves on all items that may require future maintenance

8. Use a loop design system if possible, both around the plant and within each production zone





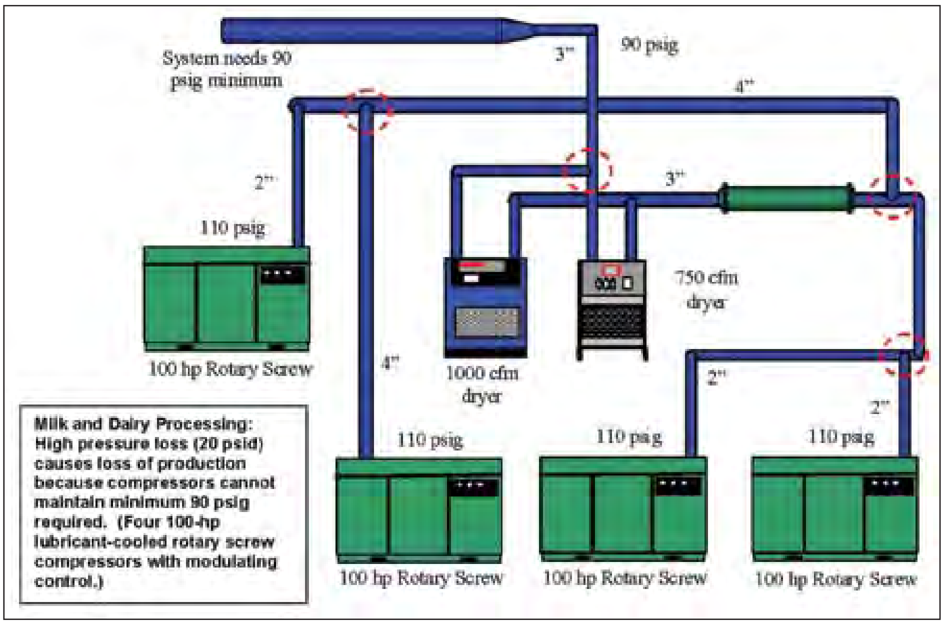
COMPRESSOR INLET PIPING

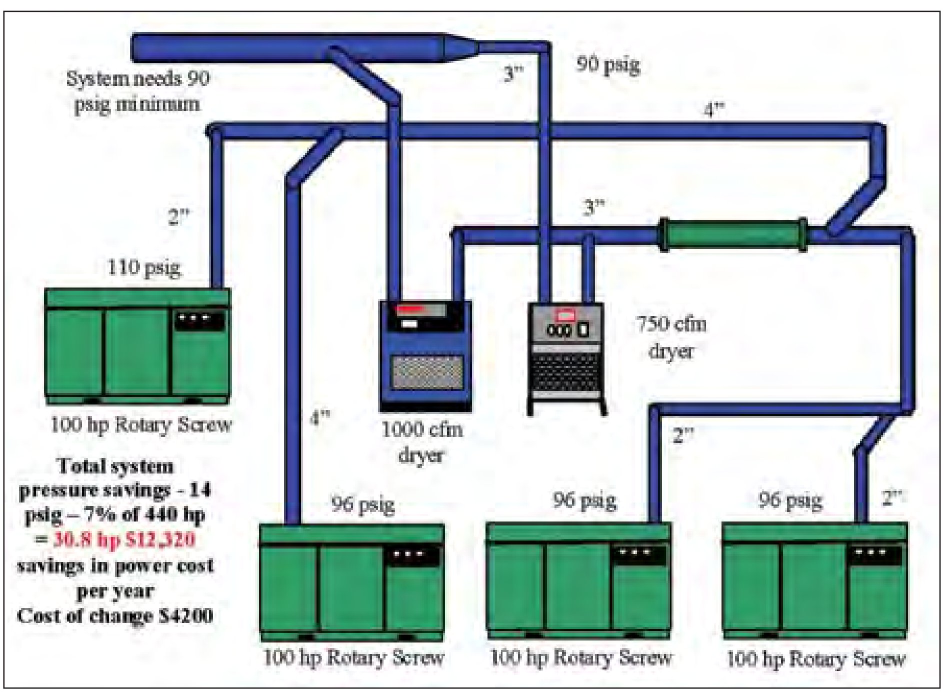
9. Consider a second air receiver at end of the line or loop only if you have peak demands for air near that point

10. Locate outlets from the main header as close as possible to point of application. This helps limit large pressure drops through hose

11. Outlets should always be taken from the top of the pipeline to alleviate carryover of condensed moisture to tools

12. All piping should be sloped so that it drains toward a drop leg moisture trap or receiver away from the compressor and/or process





Flexible connections should be used to reduce or absorb vibration and mitigate the effect of thermal expansion. *They should not be used to correct misalignments.* Any flex connection used should be investigated to be sure its specification fits the operating parameters of the system.

It is important to note that improper or incorrectly applied piping and material in an air system can result in mechanical failure, damage, and serious injury or death.

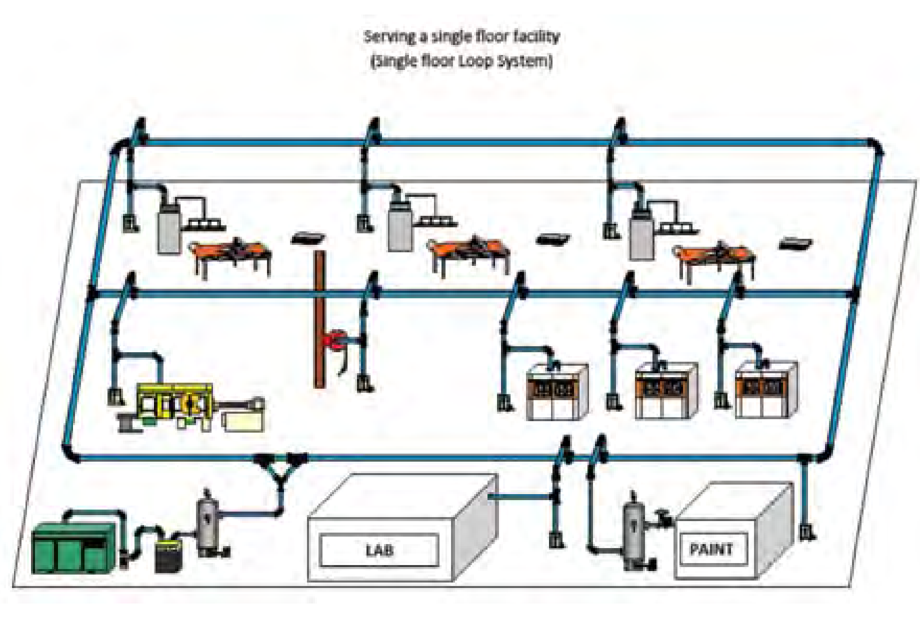
Summary

1. If proper copper piping is used, be sure the copper and solder used has the proper characteristics to handle the anticipated temperatures at full load

2. Use of plastic piping. There are many negatives that have accumulated over the years around the use of plastic piping
   - Lack of resistance to failure due to fatigue caused by vibration
   - Lack of resistance to softening crazing, cracking and from lubricants, particularly diester synthetics
   - Susceptibility to a catastrophic failure results from something like and aftercooler failure
   - Potential catastrophic failure caused by an outside fire
   - Potential catastrophic failure from a pipeline fire or detonation
   - Potential to be attacked from outside or within from airborne chemicals and condensate (inside)
   - A failure in plastic or PVC pipe under pressure may explode or shatter, endangering personnel in the area

3. There have been new product introductions of plastic piping systems which claim to have solved most of the negative problems including the shattering characteristics. New plastic pipes are based on *specially modified formulation or acrylonitrile butadiene styrene (ABS) resin*

4. Many people feel that any type of non-metallic (i.e. plastic) piping is a high risk because in any air system (particularly lubricated) the potential for a pipeline fire always exists. Even though it may be a most unlikely occurrence, plant safety is certainly enhanced if the pipeline fire stays in the pipe and does not burn through the wall



COMPRESSOR INLET PIPING

Poor Piping Configuration in Action

The plant was running four 100 hp lubricant-cooled rotary screw compressors under modulating control. It was losing productive capacity because a 20 psi pressure drop made it impossible to maintain the required minimum 90 psig in the header. This piping schematic shows the original piping. Four 100 hp, 490 cfm oil-cooled rotary screw compressors delivered air to a 6" main header. The velocity in the 4" interconnecting piping was as follows:

- 13.2 fps @ 490 cfm
- 26.4 fps @ 980 cfm
- 39.6 fps @ 1,470 cfm
- 47.4 fps @ 1,760 cfm

Four crossing tees added turbulence at these velocities. The total pressure loss with all machines at full load was 20 psig. When demand increased, the pressure in the main fell below 90 psig, shutting down production. Two changes solved the problem. First, the 4" crossing tees were changed to directional angle entry. The pressure drop fell to 6 psi and the main system now receives 104 psig that is easily regulated to a steady 90 psig. The connections were prefabricated and installed during a one-day maintenance shutdown at a cost of $4,200. This eliminated the production interruptions that had occurred for twenty years. Second, the compressor discharge pressure was reduced to 98 psig, which represents a power savings of 6%, equivalent to about $9,585 annually. BP

For more detailed piping guidelines, consider purchasing the Air Power USA, Piping Guide.

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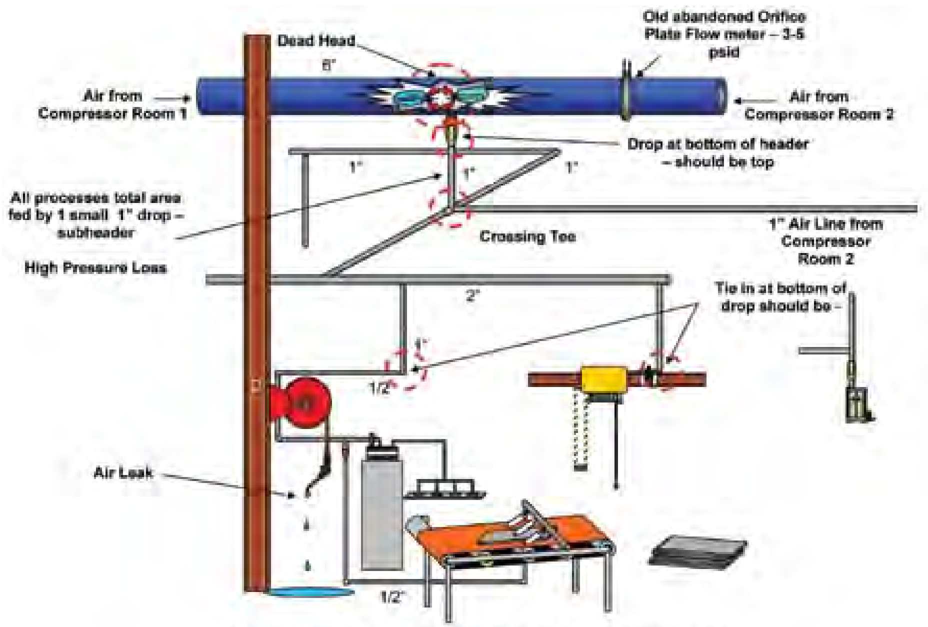

Common Compressed Air Distribution Piping Mistakes