Compressed Air Piping Recommendations for Compressor Discharge and Plant Distribution

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Compressed air piping systems are complex and require careful planning.

I. PIPING MATERIAL SELECTION AND RECOMMENDATIONS BY USE

Consult federal, state and local codes before deciding on the type of piping to be used. For industrial plants, ASME B31.1 is the reference standard, while the latest version of NFPA 99 (National Fire Protection Association) Standard is used for healthcare facilities. Compressed air piping materials can be divided into two basic types: metal and non-metal. Non-metal pipe is commonly called thermoplastic pipe. In our experience, thermoplastic should be used only in some air compressor inlet piping situations, which are not
part of the scope of this paper. Metal pipe can be black iron, copper, stainless steel or extruded aluminum alloy.

**Black Iron Piping**

Black iron Schedule 40 piping in compressed air systems is commonly used due to price and durability. Pipe diameters of 3” and below are normally threaded while larger diameter “headers” use welds and flanges. Black iron pipe, however, will corrode when exposed to condensed moisture with the resulting solid particulates becoming a major source of contamination. Internal corrosion becomes even more significant when exposed to the aggressive high-acid characteristics of some types of condensate. Compared to copper and extruded aluminum alloy, it is much heavier and harder to work with—significantly increasing installation time.

Many engineers select galvanized inlet piping for 100 psig (7 bar) piping systems. This pipe coating does help black iron inlet piping resist corrosion better than standard Schedule 40 pipe. Over time, however, when corrosion is present, the galvanizing material peels off. The inlet piping now becomes a source of potentially destructive contaminants able to affect the mechanical integrity of the air compressor. The same holds true for galvanized air compressor discharge and distribution piping. Often, due to the aggressive acidic characteristics of condensate, the life of the galvanized coating may be shorter downstream of the air compressor.

**Copper Piping**

Copper pipe is a common selection for sensitive compressed air systems and when correctly sized and connected is very durable and effective. Type M hard, type L hard and type K soft copper has a working pressure of 250 psig (17 bar). Type K hard copper is rated for 400 psig (27 bar). Copper piping is resistant to high temperatures with limits rated at 400°F (204 °C). Even if copper does fail, it will do so in a predictable manner with the pipe ends separating. 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 (183°C). Silver and hard soldering are forms of brazing and should not be confused with lead-tin soldering. Silver and hard soldering is brazing with a silver alloy type of filler material, which melts in the range of 1145-1800°F (618-982°C).

**Extruded Aluminum Alloy Piping**

Extruded aluminum alloy compressed air piping has
become very popular. It is very resistant to corrosion and is lightweight allowing for easier installation. A lack of internal corrosion translates into a smooth inner surface reducing pressure losses due to friction. Other characteristics offering better air handling include internal flush connections and inside diameters the same size as the pipe size rating. Type K 4” copper pipe, in contrast, has a 3.9” internal diameter. Another important feature of aluminum alloy is the enhanced flexibility of the connections — allowing for a piping system to easily adapt to an industrial plants ever-changing assembly and subassembly production areas. Aluminum alloy can be installed or removed with no skilled labor or soldering and has a broad range of temperature ratings from 4 to 176°F (15-80°C). Note that these ratings will vary from brand to brand.

### Stainless Steel Piping

Schedule 10 stainless steel is lightweight (compared to black iron) and is corrosion resistant. Because it is easy to handle, it will normally have lower handling costs but skilled labor will be required for welding. For welded connections, stainless steel usually requires just one bead while black iron requires three (weld, fill and cover). Stainless steel normally does not seal well when threaded, performing much better with grooved type connections.

### Air Compressor Discharge Piping Materials

Discharge air temperatures from centrifugal, reciprocating and oil-free rotary screw air compressors can range from 250-350°F (121-177°C). Discharge air temperatures from lubricated rotary screw air compressors can range from 200-220°F (93-105°C). Even if the air compressor has

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### Table 1: Piping Material Features and Characteristics

<table>
<thead>
<tr>
<th>Piping Features</th>
<th>Stainless Steel</th>
<th>Black Iron</th>
<th>Copper</th>
<th>Extruded Aluminum Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Schedule 10</td>
<td>Schedule 40</td>
<td>Light</td>
<td>Light</td>
</tr>
<tr>
<td>Corrosion Resistant</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Vulnerable to Friction-generated Pressure Loss</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mechanical Strength</td>
<td>Very Strong</td>
<td>Very Strong</td>
<td>Strong</td>
<td>Strong</td>
</tr>
<tr>
<td>High Temperature Rating</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Installation Ease</td>
<td>Less Difficult</td>
<td>Difficult</td>
<td>Less Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Installation Cost Material%/Labor%</td>
<td>30% / 70%</td>
<td>25% / 75%</td>
<td>40% / 60%</td>
<td>80% / 20%</td>
</tr>
<tr>
<td>Special Tools Required (welder, threader, groove cutter)</td>
<td>Yes</td>
<td>Yes</td>
<td>Some (solder)</td>
<td>No</td>
</tr>
</tbody>
</table>
an after-cooler, considerations should be given to what happens if the after-cooler fails. Piping materials must therefore be able to withstand these temperatures along with oil and condensed moisture, which may be highly acidic.

The main objective of discharge piping is to deliver compressed air to the filters, dryers, receiver tanks and distribution headers contaminant-free and with little or no pressure-loss. The objective should be a 0 psi piping header pressure drop!

This paper recommends using stainless steel or proper extruded aluminum alloy over black iron. They will resist corrosion much better than the standard Schedule 40 black iron and copper piping. Due to connection flexibility and installation costs, aluminum alloy is recommended over stainless steel in piping diameters of less than 8 inches (203 mm).

Some common air compressor discharge piping installation best practices include:

- Upset to larger pipe than the discharge flange opening
- Use stainless steel wire flexible connectors
- Pipe support to the floor
- No weight on the compressor flange

**II. DISTRIBUTION PIPING INSTALLATION GUIDELINES**

Piping systems have many variables to take into account. These include vibration, pulsations, temperature exposure (internal and external), maximum air pressures, corrosion and chemical resistance. In addition, lubricated compressors will always discharge some oil into the air stream, and the compatibility of the discharge piping and other accessories (such as o-rings and seals) with both petroleum and/or synthetic lubricants is critical. Pressure drop between the air
compressor and the point-of-use is irrecoverable. Pipe size should be large enough that pressure drop is held to a minimum. This section reviews installation guidelines for distribution piping including after-coolers, air receivers, drop and drip legs, and pipe slope.

**After-cooler Piping (water-cooled compressors)**

When the after-cooler is not built-in and installed in the system, it should be mounted immediately following the compressor. Bypass connections and valves permit temporary removal of the after-cooler for service and cleaning without shutting down the system.

Cooling water to the after-cooler should flow “counter to the air flow”, i.e. enter the shell at the air discharge end and exit at the air entry. Always enter the shell at the bottom and exit at the top. Never enter the top and out the bottom or you will seriously reduce cooling capacity. All after-coolers need a separator with auto drains with a check valve.

**Air Receivers**

Air receivers contribute greatly to any system by reducing pulsations, separating entrained moisture due to velocity change and improve response times by acting as a reservoir for sudden air demands.

It is important that compressed air flow into and out of the receiver is such that the air does not stagnate. Air flow should go into the bottom of the receiver and come out the top whenever possible. The entrance and exits should be at right angles near or on the same plane. If the inlet and discharge are located directly opposite each other, the tendency for the high velocity discharge air would be to go directly from one to the other without circulating through the receiver and dropping out oil and moisture. The receiver should always be installed so that the bottom condensate drain can be checked often. An automatic drain and trap are preferred.

**Drop and Drip Legs**

Condensation can take place in air piping systems even though after-coolers, dryers, receivers and separators are installed. When air lines are exposed, for example, to low ambient temperatures, moisture can condense. This is why drip legs should be installed at all low points in the piping system.

A drip leg is a pipe extending downward from the bottom of the air line to collect any condensation flow in the pipe. They should be the lowest points in the air line and at any point where the air line dips to go around an obstruction. An automatic trap or drain valve
should be installed on the bottom of the drip leg.

A drop leg 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 an air-operated device. The drop leg is taken off the top of the main line so that condensation does not easily flow into the drop leg. It should be designed with the tool air outlet coming off the side of the drop leg rather than the bottom so condensation will collect below the tool outlet. A drain or trap should be installed at the very bottom.

All drop legs throughout the system should be taken from the top of a tee with a wide sweep return elbow. This reduces the chance of a carryover of condensation from the main header or branch line to the outlet.

**Pipe Slope**

All lines in the system main and branch lines should slope or pitch downward at least 1" per 100 feet or less in the direction of the air flow to a drain point – drop leg, receiver, etc. This will allow condensation to collect at the low points where it can be trapped and removed.

III. DISCHARGE PIPING INSTALLATION GUIDELINES BY AIR COMPRESSOR TYPE

Most compressed air system designers recommend using a velocity of about 20 fps (feet per second) when designing discharge and interconnecting piping systems. It should not exceed 30 fps. When designing the downstream process feed lines, designers recommend using 30 fps, not to exceed 50 fps. There are some specific piping installation guidelines recommended for rotary, reciprocating and centrifugal air compressors.

**Rotary Air Compressors**

Pipe size should always be larger than the discharge connection size of the air compressor. Determine the correct pipe size based on system flow, length of pipe, number of bends/valves and acceptable pressure drop. Pipe so condensate from the air line cannot run back into the compressor. Support the pipe so there is no strain at or on the compressor connection.

**Reciprocating Air Compressors**

Pipe size should be one or two sizes larger than the discharge connection size of the air compressor. Never reduce discharge pipe size from the connection of the unit. Check the pipe size for velocity and calculate pressure loss. Brace or clamp the pipe at regular intervals. Do not have pipe strain
on the compressor connection. Use discharge pulsation bottles when possible on larger units. Avoid critical lengths.

**Centrifugal Air Compressors**

Refer to the manufacturer for detailed location of check valves, back valves and safety valves. 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 could possibly create a “stonewall” effect at the discharge. All turns should be “long sweep ells” to allow a minim of backpressure. This is always recommended in any air system but is more critical in a mass flow centrifugal. 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.

**IV. BASIC CAUSES OF PRESSURE LOSS WITHIN PIPING SYSTEMS**

The selection of pipe materials, as has been reviewed, can have a direct impact on pressure loss by friction. Corrosion resistant piping will have significantly different performance than piping exposed to moisture that has developed significant pipe scale. One of the most common errors seen in compressed air system piping is the use of piping diameters that are too small for the flow. The resulting increases in velocity can create backpressure, turbulence and erratic signals to the air compressor control system.

**Pressure Loss by Friction**

Many pressure drop charts are available indicating the pressure loss for a certain flow in acfm (inlet air) at a continuous pressure. This pressure loss is caused by friction of air in the pipe and is usually shown in the amount of pressure drop per 100 feet of pipe. The pipeline resistance to flow (friction loss) is affected dramatically by the internal wall roughness and scale thickness. These will increase over time with steel pipe as the inner wall rusts with scale and dirt. This is particularly true of black iron pipe.

**Velocity of Air**

The most overlooked area in piping layout and design is the velocity of the compressed air. High velocity can be a significant cause of backpressure, erratic control signals and turbulence. The British Compressed Air Society suggests that a flow velocity of 20 fps (feet per second) or less is desired to prevent the carry-over of moisture and debris past the drain legs. This is a reasonable maximum velocity limitation for main headers, interconnecting piping and main branches. Other experts feel that about 30 fps should be the maximum velocity in branch lines that do not exceed 50 feet in length.

So what is wrong with high velocity? The air is just getting there faster, right? Yes, but what happens the air runs into a blocking valve or a crossing tee? All this energy creates high turbulence and significantly erratic turbulent backpressure. These actions can create pressure losses and have a very negative impact on the system performance. Let's look at an example.

Two air compressors deliver 1500 cfm of air at 90 psi through 200 feet of 4 inch diameter Schedule 40 steel pipe to the compressed air dryers. There is one 90° elbow and the piping system was sized for 40 fps velocity. There is a blocking valve 9 inches away from the elbow. The calculated friction
loss (pressure loss) is only 0.89 psig – less than 1 psig and what would appear to be an excellent piping application.

The actual measured pressure loss between the air compressor discharge and the dryers is 8-9 psig. Why? What’s happening is the high velocity of the air at 40 fps is causing the air to run past the 90° elbow heading towards the dryer and run dead-head into the blocking valve. This creates backpressure and turbulence fighting against the air trying to make the turn towards the dryer-creating the 8-9 psig pressure drop.

The turbulence sent a pressure signal to the capacity control pressure switch sensor to unload the compressor prematurely causing short cycling. This turbulence caused back-pressure, eliminating any effective storage for the 10 psig operating band.

The blocking valve was there to allow the compressor and dryer combinations to be switched. With 6” pipe, the velocity would have fallen to 17.8 fps and with 8” pipe the velocity would have been roughly 10.3 fps. In either case, using one of these larger pipe sizes (instead of the 4” pipe) would have eliminated virtually all of the 8-9 psig pressure loss.

CONCLUSION

The objective of compressed air piping is to deliver compressed air to the end uses without pressure loss and the introduction of contaminants. Proper piping material selection and following guidelines for both distribution and compressor discharge piping can help system designers accomplish this goal. If readers take one thing from this paper remember that larger diameter pipe sizes reduce air velocities (and therefore turbulence) resulting in minimized pressure losses.