CHAPTER 6

AIR COMPRESSORS AND PNEUMATIC CONTROL SYSTEMS

6-1. Description of compressed air and pneumatic control systems

Compressed air is used in many operations and processes and as a source of energy for heating, ventilating, and air conditioning (HVAC) and process actuators and motors. It may also be supplied for low pressure systems and used for pneumatic control. Air can be compressed in several different ways and supplied at varying pressures and degrees of filtration depending on its use. Paragraph 6-3, General compressed air equipment description and operation, explains the operation of various types of compressors and dryers.

a. Compressed air system. A typical compressed air system is shown in figure 6-1, Schematic of a typical compressed air system. The system is capable of producing instrument quality air for pneumatic HVAC controls, tools, conveying systems, and general plant air. The system consists of a single motor driven single stage rotary screw compressor with inlet air filter, a safety relief valve, aftercooler, air/oil separator, air receiver with safety relief valve, prefilter, air dryer, afterfilter, oil/water traps, and oil/water separator.

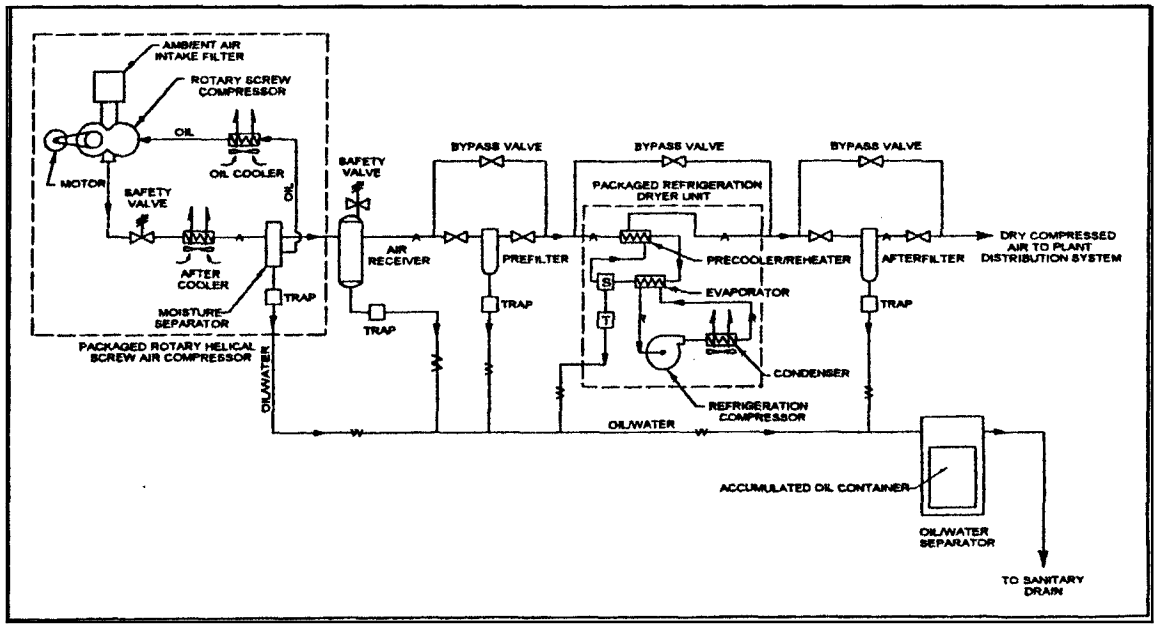

Figure 6-1 Schematic of a typical compressed air system

b. Pneumatic control system. For a description of a pneumatic control system refer to chapter 4, Heating, ventilating, and air-conditioning (HVAC) equipment and controls, paragraph 4-1, Description of HVAC systems.

c. Compressed air and pneumatic control systems. More information on design, maintenance, and testing of compressed air systems is found in theAmerican Society of Mechanical Engineers (ASME):

B19.1 Safety standard for air compressor systems, B31.1 Power piping, and Section 8. Boiler and pressure vessels. Also the Department of the Army TM 5-810-4 Compressed Air, TM 5-692-1 Maintenance of Mechanical and Electrical Equipment at Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities, Recommended Maintenance Practices, chapters 16 and 17, and TM 5-692-2 Maintenance of Mechanical and Electrical Equipment at C4ISR Facilities, System Design Features, chapters 16 and 17 deal with the subject.

6-2. Operation of compressed air systems

Refer to figure 6-1, Schematic of a typical compressed air system. Ambient air is pulled through a 5 to 10 micron filter and compressed by the helical rotors of the rotary screw compressor. A safety relief valve is installed in the discharge line and set at the design pressure of the system. The compressed air flows through an after cooler to remove the heat of compression. The compressed air temperature is reduced to within 15 to 20°F of ambient in the aftercooler. The air next flows through a moisture/air separator. This separator removes most of the oil. The oil is cooled and returned to the compressor where it provides sealing, lubrication, and some cooling. From the moisture separator a mixture of condensation water and oil is discharged through a trap to an oil/water separator. This separator removes oil from the condensate down to 2 parts per million (ppm) so that it can be discharged to a sanitary sewer. The oil is accumulated in a filter or collection container, is usually considered hazardous waste, and must be properly disposed of. The air may now flow to a receiver with a safety relief valve. Not all compressed air systems incorporate a receiver. The needs of process equipment and the type and size of the compressors determine the need for a receiver. The receiver provides a cushion for compressed air pulses when a reciprocating compressor is used, a storage volume of air to handle peaks of high usage, and a storage volume of air to allow operation of systems during periods of power loss. Receivers usually provide one gallon of capacity for each cubic foot of flow. A liquid trap discharges accumulated condensate and oil to the oil/water separator. Downstream of the receiver a prefilter may be installed followed by a dryer and an afterfilter. All of these devices are provided with shutoff valves upstream and downstream and a bypass valve to allow servicing. These devices also are supplied with traps which allow accumulated condensate/oil mixtures to be processed in the oil/water separator. There are several different types of dryers. The most common is a refrigerant dryer, as presented in the typical system. In this dryer a refrigerant cycle cools the compressed air temperature down to about 33 to 40°F. The water content of the cool air is much less than that of hot air. The air is considered dry at this point. Other types of dryers can lower air temperature further for special process requirements. Refrigerant dryers are sufficient for HVAC control systems. The afterfilter removes moisture from the air stream down to 0.5 ppm and filter particulate down to 1 micron. Finer filters can be installed if required by the operating process. Drip legs should be provided in the piping system header and branch lines to collect condensate and should include a trap. The header should be supplied from both ends thereby making a loop of compressed air around the building. Branch lines should be tapped from the top of header lines to prevent condensate and rust accumulation from entering the line. Lines should be sloped toward drip legs.

6-3. General compressed air equipment description and operation

Compressed air systems can use multi-stage compressors and/or provide multi-compressor installations with or without multiple course to fine filters depending on process needs. Following is some of the equipment used in various combinations in compressed air systems. A description of the equipment and its operation is provided below.

a. Air compressor types. Compressors are most often supplied skid mounted as a packaged unit. The assembled package includes all major components, controls, and a sound attenuation enclosure. The unit only requires mounting to a foundation, hook up to system piping, connection to the oil/water separator, and power connection. Following is a discussion of various types of compressors.

(1) Rotary helical screw air compressors are positive displacement machines. A twin-screw compressor consists of accurately matched rotors [one lobe (male) and one helix (female)] that mesh closely when rotating within a close tolerance common housing. One rotor is motor driven while the other is gear driven, turning it in a counter-rotating motion. The rotors uncover inlet posts at one end allowing air to flow in. As the rotors continue to rotate the air is compressed by the diminishing volume between the rotors. At the end of the rotors, ports allow the now compressed air to exit. One or more stages may be used. These compressors are used in systems up to 3000 cubic feet per minute (cfm). They are usually oil injected to increase sealing, lubricate rotors, and provide cooling. They can also be oil free. One or two stages can be used. They have a low initial cost, no pulsation, are almost free of vibration, and do not require special foundations.

(2) Centrifugal compressors compress air as it enters the center of a fluted casting, housing a rotating impeller. The impeller imparts kinetic energy to the gas which turns into potential energy as the gas velocity slows, thus increasing pressure. Compression is a continuous process. One or more stages may be used. Centrifugal compressors are used in large systems up to 18,000 cfm. A blow-off silencer is needed to control noise. Centrifugal compressors require no lubrication in contact with the air stream and therefore provide oil free air.

(3) Reciprocating or positive displacement compressors use a piston in a cylinder to compress air up to a capacity of 6,000 cfm. Air enters the cylinder through a valve when the piston is going down. The valve closes when the piston starts to go up. As the piston approaches the top of the cylinder, the air is compressed by the decreasing volume. An exhaust valve opens when the piston is near the top of the cylinder allowing the compressed air to exit. The cycle is them repeated. These compressors can be specially constructed to operate as oil free. One or more stages can be used. Multiple stages are used with inter-cooling between stages in large applications. Because of their reciprocating mass they pulsate, vibrate, create harmonics in piping systems and, for larger sizes, require special foundations and special noise attenuation.

(4) Rotary sliding vane compressors use a rotor eccentrically mounted in a cylinder. The rotor has eight or more slots cut along its length. Vanes are placed in the slots. As the rotor rotates, the vanes move out from centrifugal force. As the rotor continues through a rotation, the rotor housing causes the vanes to move back in the slot of the rotor. The volume of air between the housing, eccentrically mounted rotor, and two vanes changes as the rotor rotates, compressing the air. An outlet port is located in the housing where the rotor is closest to it. An inlet port is located just past the outlet port. One or more stages may be used. These compressors are used in systems up to 3000 cfm. They can be oil injected or oil free. One or two stages can be used. They have a low operating cost, no pulsation, are free of vibration, and do not require special foundations.

b. Dryers. Compressed air dryers are most often supplied skid mounted as a packaged unit. The assembled package includes all major components and controls mounted and pre-wired, requiring only that they be anchored to a foundation, hooked up to the compressed air piping system and oil/water separator, and connected to power. Following is a discussion of various compressed air dryers.

(1) Refrigerant dryers use a refrigeration cycle to cool the compressed air down to 33°F as a minimum. Below this temperature the condensate will freeze and stop air flow. This type of dryer has a low initial cost, low operating cost, and is inherently reliable. It is the most common type of dryer used for plant air, air operated tools, pneumatic instrumentation for HVAC systems, and material conveying.

(2) Regenerative dryers using desiccant to dry compressed air, can dry air to minus 150°F. Twin towers of moisture adsorbing desiccant are used. One is in operation while the other is being regenerated with a heat source or compressed air. Initial cost varies from low to high and operating costs vary from moderate to high. These dryers are used where very dry air is needed.

(3) Deliquesent dryers use an absorbent material and can only dry air to a maximum of 20°F below inlet temperature. The moisture and absorbent react and form a liquid which is drained from the dryer. The effluent is corrosive, must be disposed of as a hazardous material and carryover into the system may be possible, causing maintenance problems downsteam. These problems along with minimal moisture removed reduce the attractive low initial cost and low to moderate operating cost of the system.

6-4. Pre-functional test plan and functional performance test plan for compressed air systems

This manual assumes that individual components and packaged equipment have been tested by the manufacturer. As part of the commissioning effort each component should be checked for damage, deterioration, and failures by a procedure using inspections and tests as defined by the specific equipment manufacturers. Equipment manuals from manufacturers identify the minimum required receipt inspections, handling and installation procedures, drawing and wiring verification, field inspection and installation checks, verification of removal of shipping braces, inspection of installation against drawings and nameplates, inspection of components for damage and cleanliness, inspection of insulators and grounding, inspection of anchorage and alignment, adjustment checks, mechanical operation and interlock checks, lubrication application, and verification that local safety equipment is in place.

a. Safety, compressed air system. Many tests on equipment involve the use of high voltages, high currents, pressurized air, pressurized gas, and rotating or moving equipment. These can be dangerous to personnel and damaging to equipment. In addition, compressed air systems employ safety valves which must be properly installed, vented, and the relief pressure must be properly set. A procedure should be followed to insure adequate safety rules are instituted and practiced to prevent injury to personnel performing the tests and other personnel who might be in the local area.

b. Test equipment, compressed air system. It is important that in any test program the proper equipment is used. The equipment should be calibrated, in good condition, and used by qualified operators as required by a procedure. Any test equipment used for calibration shall have twice the accuracy of the equipment to be tested. All equipment should be operated in accordance with its instruction manual. A procedure defining installation inspection and a system test needs to be provided.

c. Inspection checklist, compressed air system. An inspection checklist for the system is presented in figure 6-2, Example of a completed DA Form 7482-R, compressed air system inspection checklist.

6-5. Possible failures and corrective measures for compressed air systems

Table 6-1 on page 6-7 lists general problems that may arise during the testing of equipment and systems along with possible troubleshooting techniques. For all problems, consult equipment and component

manuals for troubleshooting directions. Check fuses/lights/breakers/etc. for continuity, check equipment calibration and settings, check for clogged filters and strainers, check for closed manual shut off valves and dampers, check for improperly adjusted valves and equipment, and look for faulty equipment and connections.

COMPRESSED AIR SYSTEM INSPECTION CHECKLIST

For use of this form, see TM 5-697; the proponent agency is COE.

SECTION A - CUSTOMER DATA

1. PLANT	2. LOCATION	3. JOB NUMBER
West Building	Arlington, VA	WB - 34
4. EQUIPMENT	**5. SYSTEM DESIGNATION**	**6. DATE (YYYYMMDD)**
Ingersol Rand		20021126
7. TEST EQUIPMENT		**8. TESTED BY**
		Roger Swanson

SECTION B - EQUIPMENT DATA

9. COMPRESSOR MANUFACTURER	10. MODEL NO	11. SERIAL NO	12. FLOW RATING CFM
Ingersol Rand	7100E15V	67-95863	50 cfm @ 175 psi

13. TYPE	14. HP @ RPM	15. PRESSURE RATING PSIG
Reciprocating	15 @ 1750	175 psig

16. DRYER MANUFACTURER	17. MODEL NO	18. SERIAL NO	19. EXIT FLOW RATE @ DP°F

20. OIL/WATER SEPARATOR MFG	21. MODEL NO	22. SERIAL NO	23. FLOW RATE CFM
			19 cfm

SECTION C - VISUAL AND MECHANICAL INSPECTION

24. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
EXTERIOR OF EQUIPMENT	A		EQUIPMENT IDENTIFICATION	A	
COMPLETENESS OF ASSEMBLY	A		BRACING	A	
EQUIPMENT ROTATION	A		LABELING AND TAGGING	A	
ELECTRICAL/MECHANICAL INTERLOCKS	A		SAFETY INTERLOCKS	A	
INSTRUMENTS	A		WORKING SPACE	A	
PROPER GROUNDING	A		ANCHORAGE	A	
PROPER INSULATION	A		CONDENSATE DRIP LEGS	A	
TIGHTNESS OF BOLTED CONNECTIONS	A		COMPARISON TO DRAWINGS	A	
PROPER LUBRICATION	R		CONTROL SYSTEM	A	

SECTION D - CALIBRATION AND SET POINT

25.	DESCRIPTION	NOTES
SENSORS	NA	
CONTROLLERS	Pressure control set on at 90psi, off at 115 psi.	
ACTUATORS	NA	
RELIEF VALVES CHECKED	Pressure relief set at 125 psi.	1.

SECTION E - COMPRESSED AIR SYSTEM TESTS

26.	OPERATING MODES	TEMPERATURES	PRESSURES	FLOWS	LEVELS	NOTES
AIR COMPRESSOR	Auto	130 degrees F	100 psi	NA		
AIR DRYER	Auto	60 degrees F	65 psi	10 scfm		
OIL/WATER SEPARATOR	Clean	NA	65 psi	NA		
PRESSURE TEST	NA	NA	NA	NA		
FILTERS, TRAPS	Clean	NA	65 psi			
SYSTEM TEST	NA					

27. NOTES

1. Pressure relief actually lifted at 130 psi per tank gauge.

*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE

DA FORM 7482-R, DEC 2002 USAFAV1.00

Figure 6-2: Example: DA Form 7482-R

Table 6-1. Possible failures and corrective actions for compressed air system

	Areas to Check
General Controls	
Devices will not close/trip	Check mechanical alignment of limit switches Check interlocks and safeties Check relay and protective device settings and operation Check for mis-wired circuits Check control circuit Check controller set point
Devices trip inadvertently	Check relay and protective device settings and operation Check for mis-wired circuits Check the control circuit Check for system overload or short Check grounds
Compressor	
Will not start or starts but shuts down	Check PLC Check power supply Check controls, switches, starters, and disconnects Check controller set points, temperatures, pressures, levels Check sensors, actuators, and indicators Check filters Check oil level Check safeties and interlocks to fire protection systems Check condensate/oil trap
Incorrect air pressure or no air flow	Check compressor Check controls and set point Check filters Check for closed shut off valves Check safeties and interlocks to fire protection systems
Dryer	
Will not start or shuts down	Check PLC Check power supply Check controls, switches, starters, and disconnects Check controller set point Check sensors, actuators, and indicators Check refrigerant Check refrigerant heaters Check condenser fan Check safeties and interlocks
Wet compressed air supply	Check dryer condensate trap Check compressor condensate trap Check receiver condensate trap Check dryer sensors, controllers, and set point Check for closed drain valves
Oil/Water Separator	
Will not operate or shuts down	Check air or electric power supply Check controls, float levels, switches, starters, and disconnects Check drains and traps Check oil container/filter Check safeties and interlocks