DESIGN AND MAINTENANCE OF COMPRESSED AIR SYSTEMS

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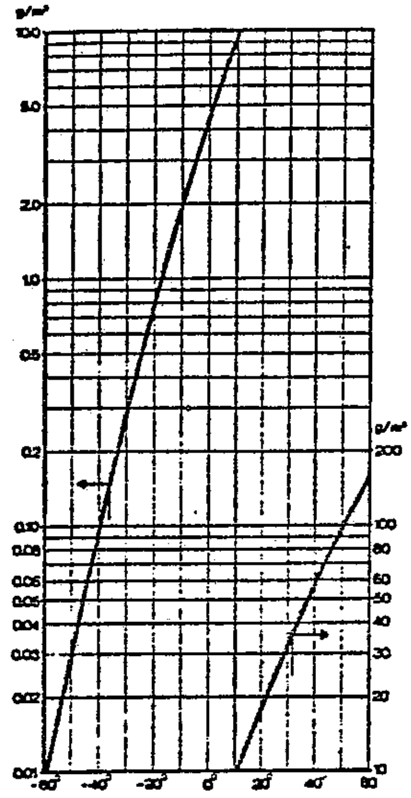
This paper is a general one and the Rules and Practices mentioned can be applied to any application for compressed air.

The air we use is that in the atmosphere around us. It is found to contain 78% nitrogen, 21% oxygen, 1% inert gases etc. It also contains water vapour and dust. It is these last two which concern us.

Dust can be filtered out at the inlet of our compressor but water vapour is more difficult. Air can, for each condition of temperature and pressure, hold a certain amount of water before condensation takes place. When this condition is reached we say the air is "saturated". From the chart shown, Figure 1, we can see the number of grams of water held in each cubic metre of air if the air is saturated for a range of temperatures. The actual amount of water in the area can be measured using a hygrometer which expresses this amount as a percentage of the saturated value for the temperature at the time. This percentage is called the Relative Humidity.

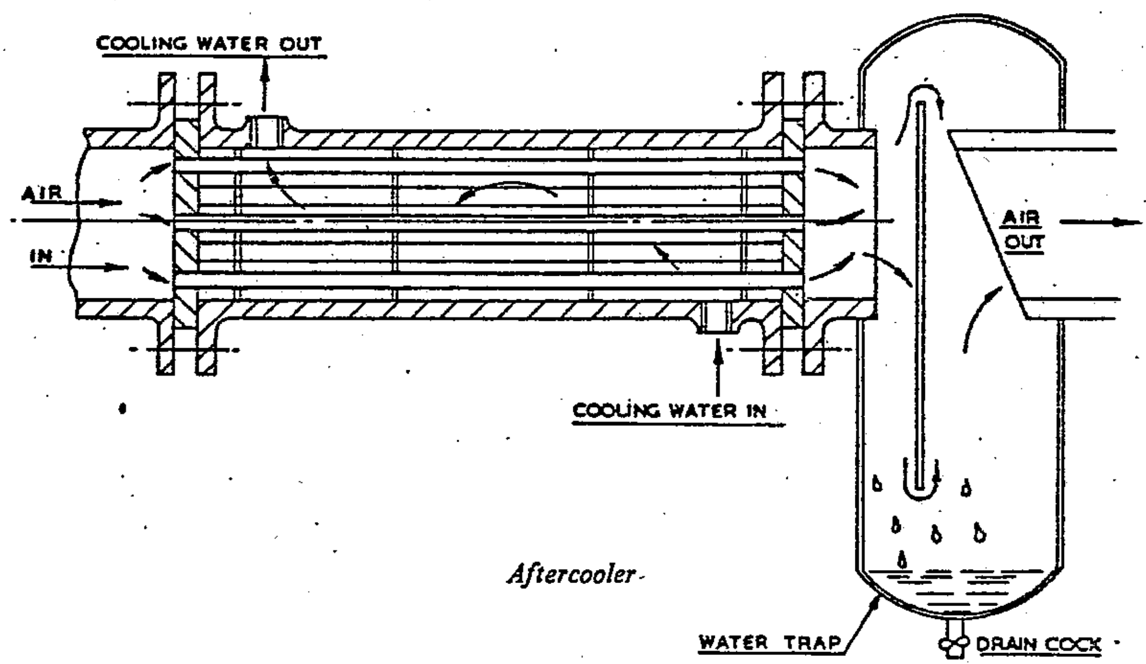
Figure 1:



The molecules in the air around us are travelling at a high speed (452 m/sec) and hitting on objects in the room. The striking force per unit area is called atmospheric pressure and at sea level and 15°C is found to be 14.7 pounds per square inch or 101.3 kilopascals (1 pascal = 1 newton/square metre). As we go up in altitude or as the temperature rises the air becomes less dense. Therefore the pressure is less as there are not as many molecules striking the specified area.

As the air is compressed in a mechanical device known as a compressor, heat is generated and so the temperature of the air rises. As before, the hotter the air the more water it can hold. The only way to reduce the water content is to cool the air down. We can help do this in several ways. The intake air must be the coldest we can find. This way it does not contain much water to start with. After compression we can cool the air in an after cooler. See Figure 2.

Figure 2:



Aftercooler

Compressors have many forms but we shall consider only the piston compressor. It has a bore and stroke like a car engine. With this information we can find the swept volume for each stroke the compressor does. The compressor is driven by either an electric or petrol motor and knowing the speed we can find the number of strokes our compressor does per minute. We can then find the swept volume per minute or piston displacement. = A x S x N

where A = area of piston
S = stroke length
N = No strokes per minute

Piston compressors are not 100% efficient. There must be a clearance volume between the piston and the head of the compressor. When we compress air to say 100 psi we reduce its volume to 1/7th of its original volume. To get that air at 100 psi back to atmospheric pressure we must expand the air 7 times. Therefore if we have a small clearance volume, before the inlet valve on our compressor can open the piston must move through 7 times the clearance distance so this part of every stroke is wasted. Other losses are due to friction and heat generated in the compression process. The normal efficiency of this type of compressor is 55-75%. The actual amount of air our compressor will put out then is the swept volume multiplied by the efficiency.

The action of our compressor is that the piston moves down the bore from top dead centre and when it creates a slight vacuum the inlet valve opens letting air into the chamber. At bottom dead centre the piston reverses direction and once a small pressure is formed the inlet valve closes. The piston then compresses the air in the chamber until it reaches the outlet pressure required.

The outlet valve then opens and the air passes through an after-cooler to the receiver. The capacity of this receiver depends on the air demand from the plant. If it is reasonably constant, then the volume of the receiver should

$$= \frac{\text{compressor output x atmospheric pressure}}{\text{outlet pressure required.}}$$

If the demand is variable we should multiply the above valve by 3. This is the rule used by the British Compressed Air Society.

The receiver should be fitted with a safety valve big enough to discharge to atmosphere all the air the compressor can produce. The receiver should be a proper pressure vessel designed for this purpose. One should not use any old tank unless it has been hydraulically tested to 2½ times the normal working pressure. Too often we have seen old hot water cylinders and the like used as receivers. This can have disastrous consequences. If such a cylinder should fracture, it would explode as the air inside tried to expand back to atmospheric pressure. In one instance such an explosion lifted the roof off a building.

A compressor will keep pumping until a set pressure is reached then either it will stop by means of a pressure switch stopping the motor or it will run unloaded by the inlet valve being held open. When air is used the pressure drops to a pre-set minimum and the compressor will restart or the inlet valve will be allowed to function again in its normal way.

Maintenance of a compressor comprises oil changes, filter cleaning and checking valve operation.

Signs of trouble are:

(1) Compressor pumping too long i.e. it is taking too long to compress air and fill the receiver. Either it is losing efficiency or the demand is too great.

(2) Excessive heat.

(3) Compressor oil is getting past the rings and burning during compression. This forms a vapour which travels through the air lines coating them with a tar like substance. It will cause valves to stick, "o" rings to swell and oil in lubricators to turn milky.

Pipes from the receiver should be either black steam pipe or galvanised pipe to British Standard No. 1387. This is the locally used standard for pressure pipes. Some locally produced galvanised pipe does not come up to this standard and should not be used.

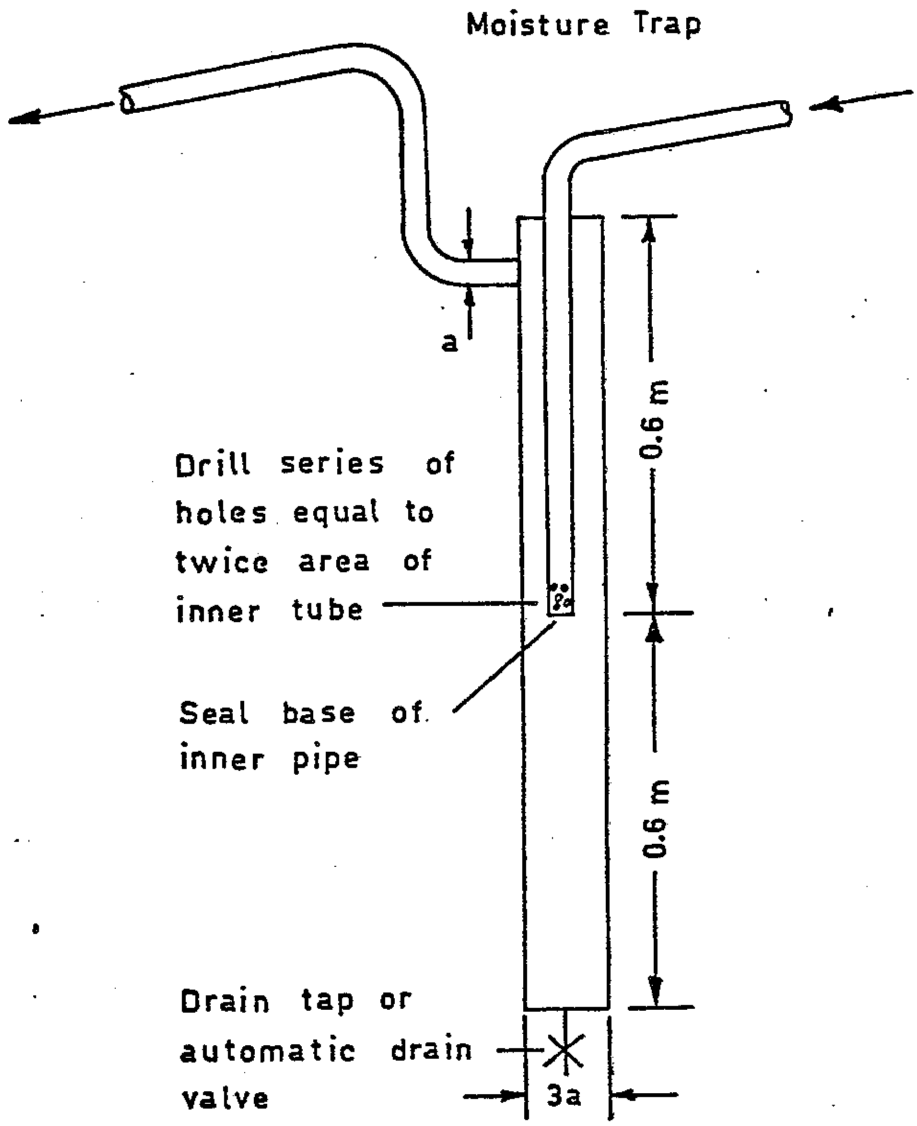
These pipes should be suitably sized to give a minimum pressure drop across the pipe line.

Important Points on Air Line Layout

(a) A fall away from the compressor receiver of between 1:40 and 1:80 where practical is necessary in assisting the flow of condensate to low points for collection.

(b) Moisture Traps and Automatic Drains should be utilised in dispersing condensate from main line collection points. This condensate is always present in air lines due to drops in temperature within the system. The exception being where the air has been pre-dried, i.e. below average dew point. An effective moisture trap of simple manufacture is shown in Figure 3.

Figure 3:



(c) The use of mac unions is recommended for the fitting and maintenance of Moisture Traps.

(d) Take-off points must always be from the top of main supply lines and a suitable drain leg extension fitted (as shown in the Layout Diagrams). Drain legs act as further moisture traps and are often fitted with Automatic Drain Valves.

(e) Pipes must be sized using peak consumption or flow figures and practical formulae or charts for pressure drop estimation as per examples.

At the takeoff points in the system, we put a filter, regulator, lubricator set to process the air.

The filter is used to trap all solids and any moisture which has condensed before the filter.   It will not remove water vapour.

The regulator is used to stabilize the pressure in the system so fluctuation of pressure is removed and a constant pressure available. This means consistent results are achieved by the system.

The lubricator injects an oil vapour into the air as it passes through. This carries to the control valves and cylinders in the system keeping them well oiled.

After the filter all the air lines should be non ferrous to prevent rust forming and travelling into control valves and cylinders destroying their seals. We normally use copper, cylon or nylon armoured PVC hoses for this purpose. Leaks in the piping are to be avoided at all costs as a small hole will amount to a large air loss. For example, a 1/16" diameter hole, at 100 psi, will discharge 6.5 cu.ft. per min. to atmosphere. This is the equivalent of running a 2 HP motor just to cover air loss from the hole. After a year the cost of such a leak is approximately $325.

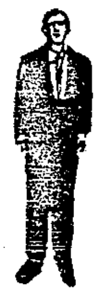
From the lubricator we pipe to the control valve or air tool. Control valves take many forms and on the Christchurch Brill tram No. 178 at Ferrymead there is the brake controller which also controls the doors and steps, the deadman control, windscreen wiper control, and the automatic accelerator. Care must be taken with the air exhausting from these valves. There must be no back pressure build up and if the exhaust is piped away the pipe must be large enough to let the air escape quickly.

The control valves normally control the movement of an air cyclinder. On the Brill there are several cylinders ranging from the small 1½" diameter wiper cylinder to the 10 inch diameter brake cylinder. The thrust put out by the brake cylinder when working at 80 psi is 6200 lbs. The bore of the cylinders must be smooth. If water is allowed to enter the system it can pit the lining of the cylinder and cause the failure of the seals. When a cylinder is installed it must be properly aligned so that there is a minimum side thrust on the piston rod. An excessive side load will cause the cylinder to stall or wear out the bearing and piston rod seals.

Safety is a very important part to consider when using compressed air and I conclude with the following 10 point code for the safe use of compressed air:

10 POINT CODE *FOR THE SAFE USE OF COMPRESSED AIR*

Eyes are particularly vulnerable to flying grit and air streams.



If air forces its way into the bloodstream through any part of the body, it can cause death by travelling to the brain and bursting blood vessels.

Air entering the nose, ear, scratches or other body openings can result in the appearance of very large swellings accompanied by severe injury and possible death.

Compressed air creating a draught near a fire or stove can produce a tremendous fire hazard.

1. Use only sound, strong hose with secure couplings and connections.
2. Be sure there are no sharp points on metal hose parts.
3. Close control valve in portable pneumatic tools before turning on air.
4. Before changing one pneumatic tool for another, turn off air at control valve. Never kink hose to stop air flow.
5. Wear suitable goggles, mask, protective clothing, or safety devices.
6. Never use compressed air for clearing away swarf or dust. Flying particles can be dangerous.
7. Never use air to blow dust or chips from the hair, body or clothing.
8. Never point the hose at anyone. Practical jokes with compressed air have caused many painful deaths.
9. When using compressed air, see that no nearby workers are in the way of the air flow.
10. Ensure that there are no naked flames which could be spread by a draught from an air line.