CHAPTER IV

Bulk Gas Storage

Bulk gas supply may be provided by liquid storage at low pressure in a cryogenic tank or by a bank of cylinders. The bank may be individual cylinders, each with its own valve, or it may be a manifolded collection of cylinders permanently linked together.

CRYOGENIC STORAGE

Hospitals with a continuous large oxygen requirement may find it economic to store oxygen in liquid form and to supply major areas by pipelines. This method stores oxygen compactly, as each litre of liquid evaporates to 840 litres of gas at ambient pressure and generally the cost is about 1/100 or less per gaseous litre of oxygen stored by cylinder. Other gases can also be stored in a liquid form. Commercially this is done with argon at large welding installations, and with nitrogen where frozen food is being prepared.

Some hospitals use liquid nitrogen in their catering. In this situation, a bulk storage tank in a hospital being filled with nitrogen instead of oxygen is a possibility and such an accident has been reported in North America. In Australia, tankers are used exclusively for liquid oxygen or for liquid nitrogen. The tanker couplings are different and non-interchangeable. Adaptor couplings are not permitted to be carried on the tankers.

Low temperature (cryogenic) liquid storage systems can conveniently store liquid oxygen, nitrogen and argon. Only oxygen is in common use in Australian and New Zealand hospitals. However a few hospitals are now being supplied by pallet-tank with liquid nitrous oxide. The tank for storing the liquefied gas is called a vacuum insulated evaporator commonly abbreviated to VIE (Fig. 4.1). Sometimes it is also referred to as a VIV (vacuum insulated vessel)

The tank consists of two shells, like a domestic vacuum flask used for storing hot or cold liquids. The inner shell is made of a special stainless steel to withstand the temperature and precisely welded to give an extremely good gas-tight seal. The outer shell is made of good quality carbon steel (Fig. 4.2). The space between the two shells is evacuated to a high quality vacuum and filled with an insulating powder to minimize the heat transfer.

Oxygen can be liquefied at -118.4°C, its critical temperature, but this requires 5 000 kPa (about 750 psi). Liquid oxygen is stored at approximately -150°C and at this temperature requires only about 1 000 kPa (150 psi) to become liquefied. This is well within the design pressure of the tank. The oxygen is kept cold by the latent heat of vaporization as gaseous oxygen is removed. Every 100 litres of oxygen gas taken from the tank also removes about six calories of heat, so that vaporization of liquid oxygen can effectively cool the tank if it is well insulated.

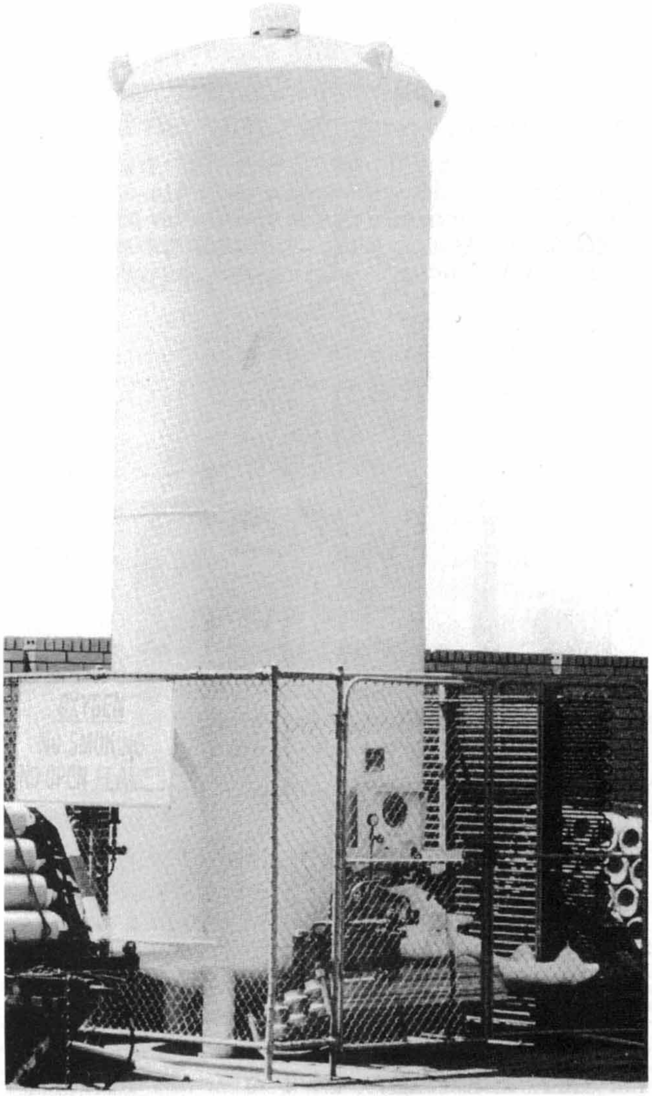

Figure 4.1. A typical Vacuum Insulated Evaporator installed in the grounds of a large hospital.

Usually the heat uptake is much less than that lost by vaporization and in most VIE installations the temperature tends to fall. If the temperature falls, the pressure within the tank, which is the vapour pressure of oxygen, also falls. However, if the pressure were to fall below about 650 kPa (100 psi) there would be insufficient pressure to supply the oxygen pipeline. To maintain pressure,

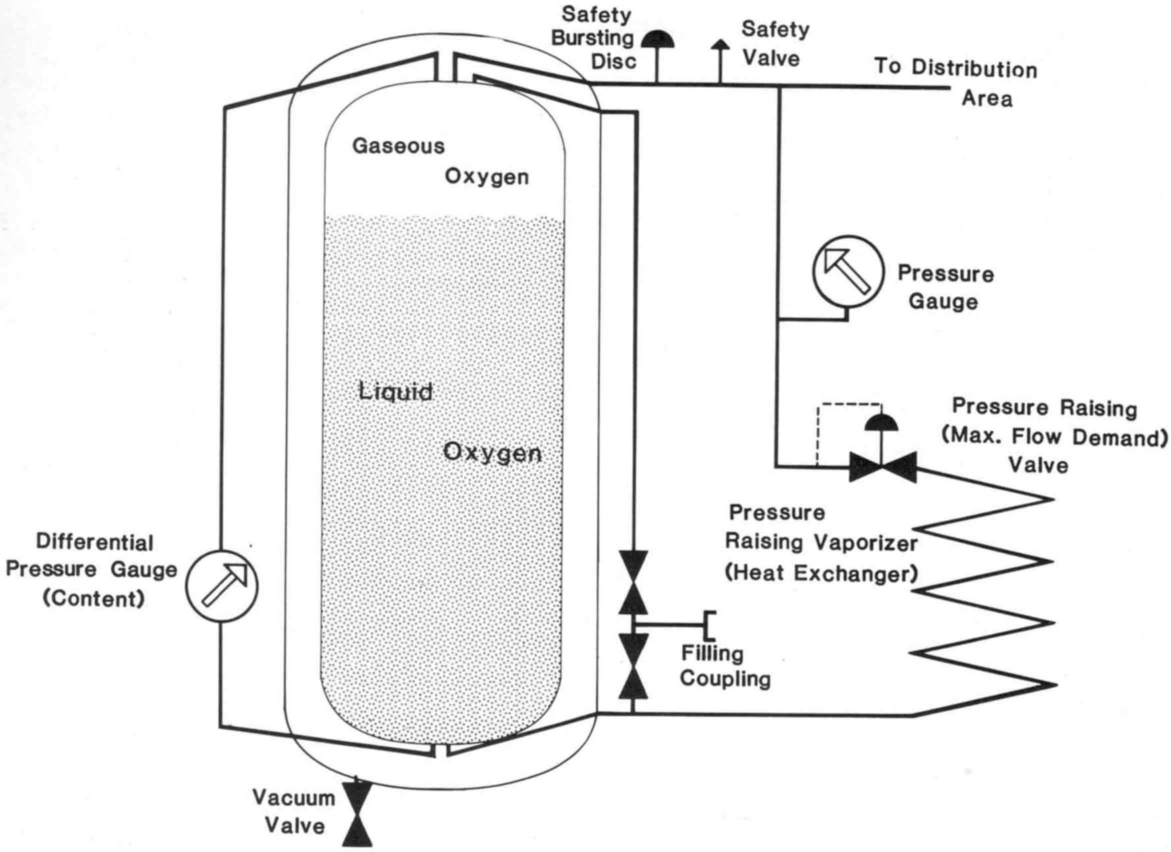

Figure 4.2. Diagram of a Vacuum Insulated Evaporator. A double wall maintains the liquid oxygen at a low temperature. If the temperature falls too low as oxygen is vaporized, the pressure raising valve opens as the pressure falls and allows cold liquid oxygen to run into the heat exchanger and warm the gas which returns to the top of the VIE. This continues until the oxygen vapour pressure rises enough to close the valve. Liquid oxygen level is sensed by a differential pressure gauge between the top and bottom of the VIE.

liquid oxygen is removed from the tank by a special pressure raising valve (Fig. 4.2). If the pressure falls below 1 000 kPa (150 psi), the liquid oxygen is passed by gravity through heat exchanger coils under the VIE which allow the liquid to take up heat from the surrounding air and to vaporize. These coils are termed the pressure raising vaporizer. The pressure raising valve, by controlling the amount of vaporization within the tank, controls the tank temperature and so maintains an adequate supply pressure.

If little oxygen is being used, there may be insufficient vaporization to keep the tank cold. In this case the temperature and the pressure within the tank rise until a preset safety pressure is reached. Usually the safety limit is about 1500 kPa (225 psi) when oxygen gas is released. For efficient use of liquid oxygen stores it is important that oxygen consumption is reasonably continuous and that there are not long periods when no oxygen is used. Generally if an annual consumption exceeds seven million litres in a hospital, it may be economical to use liquid bulk storage. With any consumption over one million litres annually, liquid oxygen storage should be considered. Bulk oxygen VIE stores are available for approximately 100 000 litres of gas up to ten million litres. For large users they are cheaper than gas cylinders, and usually oxygen power will be cheaper than compressed medical breathing air for driving ventilators and other devices. In Australia and New Zealand a cylinder bank is always connected as a back-up supply. Measurement of how much oxygen remains in a VIE cannot be done by a simple pressure gauge as there will be little fall in pressure until all the liquid is evaporated.

In the early VIE tanks the contents were measured by weight, as for cylinders of nitrous oxide, carbon dioxide and cyclopropane. The whole pressure vessel rested on a balance or load cell and its weight was indicated on a weighing gauge calibrated for oxygen content. The modern VIE has its liquid oxygen content measured by differential pressure (Fig. 4.2). Liquid oxygen is heavier than water, and has a density of about 1.1 kg/litre at -150°C. Thus the pressure difference between the top and the bottom of a VIE containing liquid oxygen two metres deep is about 22 kPa (3 psi) and is proportional to the depth of liquid in the tank. In this way the differential pressure gauge measuring between the top and the bottom of the tank is an accurate linear measure of liquid oxygen content in a cylindrical tank. Oxygen which is supplied from a VIE installation is extremely cold and must be warmed to ambient temperature. This is done by passing the gas through a series of loops which act as a heat exchanger with air to warm the oxygen before it is delivered to the distribution point. This second heat exchanger is not shown in Fig. 4.2.

Because the liquid oxygen supply is used for large installations which have a high demand and many of these consume oxygen rapidly, most VIE systems have the lower 20% to 30% of the liquid tank set as a 'secondary' supply. When the set level is reached, an alarm or warning is triggered to ensure that more oxygen is ordered. This 'secondary' supply is further backed up by a reserve cylinder system (see Chapter 5).

LIQUID TANKS AND PALLETS

For some situations, which have modest requirements, but a fairly steady demand, it may be appropriate to install a small liquid system. These tanks or pallets are different from those installed at a hospital site as, when they are empty, they are replaced on site by a full one and refilled at the factory. However, the principle of evaporating liquid to supply gaseous oxygen and controlling the delivery pressure by controlling the temperature within the tank are the same as in the on-site VIE.

BULK CYLINDER STORAGE

Although large oxygen requirements can be supplied from a VIE it is not possible to supply air in the same manner. Air is a mixture mainly of 21% oxygen with a boiling point of -183°C and 78% nitrogen with a boiling point of -196°C. The differences in boiling points allow very pure oxygen and nitrogen to be produced commercially by fractional distillation of liquefied air. Any attempt to supply air from a liquid source would result in oxygen poor gas initially and an oxygen rich gas as the last liquid evaporated. The instability in the composition means it is not practical to supply air from a single liquid source. In very large installations bulk supplies of liquid oxygen and nitrogen are sometimes used and the evaporated gases are remixed to supply medical breathing air. This is not done anywhere in Australia or New Zealand at present. Medical air must be dry and free of contaminants such as oil or carbon dioxide, and for this reason may be supplied by a bank of cylinders. Large requirements may be met by manifolded cylinders on a pallet (Fig. 4.3). The steel pallet holds a group of 6 000 litre (G) cylinders. Twenty are illustrated in Fig. 4.3 but the number of cylinders interconnected varies and there may be over thirty cylinders on a single pallet. Pallets may also be mounted on a trailer for convenience of moving. This must be firmly secured when being used. Trailers may easily tip or roll away, either of which can interrupt supply. All cylinders are fixed to the pallet. Each is fitted with a threaded block which has no valve but connects via pipe work to the other cylinders. A single common pipe passes to an outlet valve fixed to the pallet frame. A pressure gauge is also connected to the pipe network. Manifolded cylinders are used and refilled without being removed from the pallet. Quantities from 11 000 litres to 240 000 litres are supplied in this form.

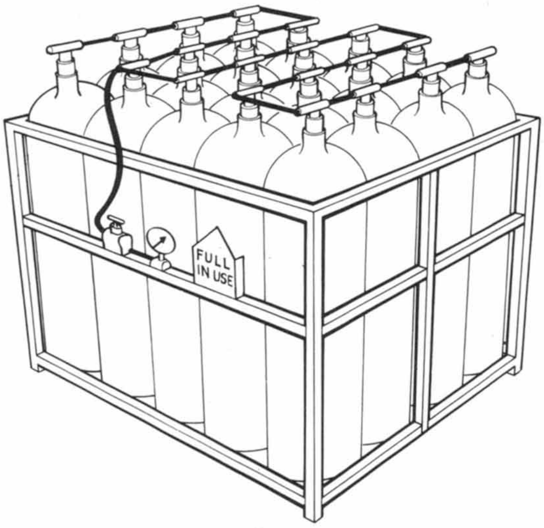

Figure 4.3. Manifolded cylinders on a pallet. Note that only a single valve is provided and cylinders are interconnected to this. Both gas supply and refilling are done through the single valve. The pressure gauge is similarly connected and shows the pressure of the whole group.