Piped Gas Supplies

Most hospitals have oxygen distributed by pipeline to areas which are frequent or large users. Often areas such as operating theatres, labour wards and dental surgeries have nitrous oxide supplied in a similar manner. Although precise details may differ from one hospital to another, the general construction principles and patterns are similar, and are the same for nitrous oxide and oxygen. Medical breathing air and vacuum suction may be supplied also by pipeline, but both have different supply requirements from oxygen and nitrous oxide and so are considered separately. Piped gas systems can be considered in three parts; the supply, the distribution or reticulation, and the outlets.

MEDICAL GAS SUPPLY

Gas is delivered to a central supply point either from a liquid bulk supply such as is common for oxygen, or from a bank of cylinders. Whatever the normal source, there must be a secondary supply. This secondary supply should be of a similar size to the primary supply. For cylinder supply, normally there are two banks of cylinders, the primary and the secondary supplies. These are normally of the same size and the oxygen supply is drawn from one bank which acts as the primary while the other bank backs up and is ready to supply at a slightly lower initial pressure. Once the primary bank is almost exhausted, the regulator is reset on the secondary to the higher pressure and it becomes the primary bank. The exhausted primary bank is replaced with fresh full cylinders to become the secondary bank and the regulator set to the lower secondary pressure. Thus each side of the system is used alternately. In addition to these normal supplies, on most installations a back-up or emergency supply can be fitted during maintenance or repairs. This must be sufficient for several hours anticipated demand and may be a single large cylinder or a cylinder bank.

Supply systems with an anticipated peak demand of less than 300 litres/minute (600 cubic feet/hour approximately) are generally supplied by banks of cylinders. For oxygen, a Vacuum Insulated Evaporator (VIE) liquid system is likely to be suitable for the daily requirement if the peak demand is above 300 litres/min of gas. The supply system using a VIE is usually rated for a much greater peak flow, commonly over 2000 litres/minute (4000 cubic feet/hour). However, the anticipated peak flow plays an important role in the design of the system.

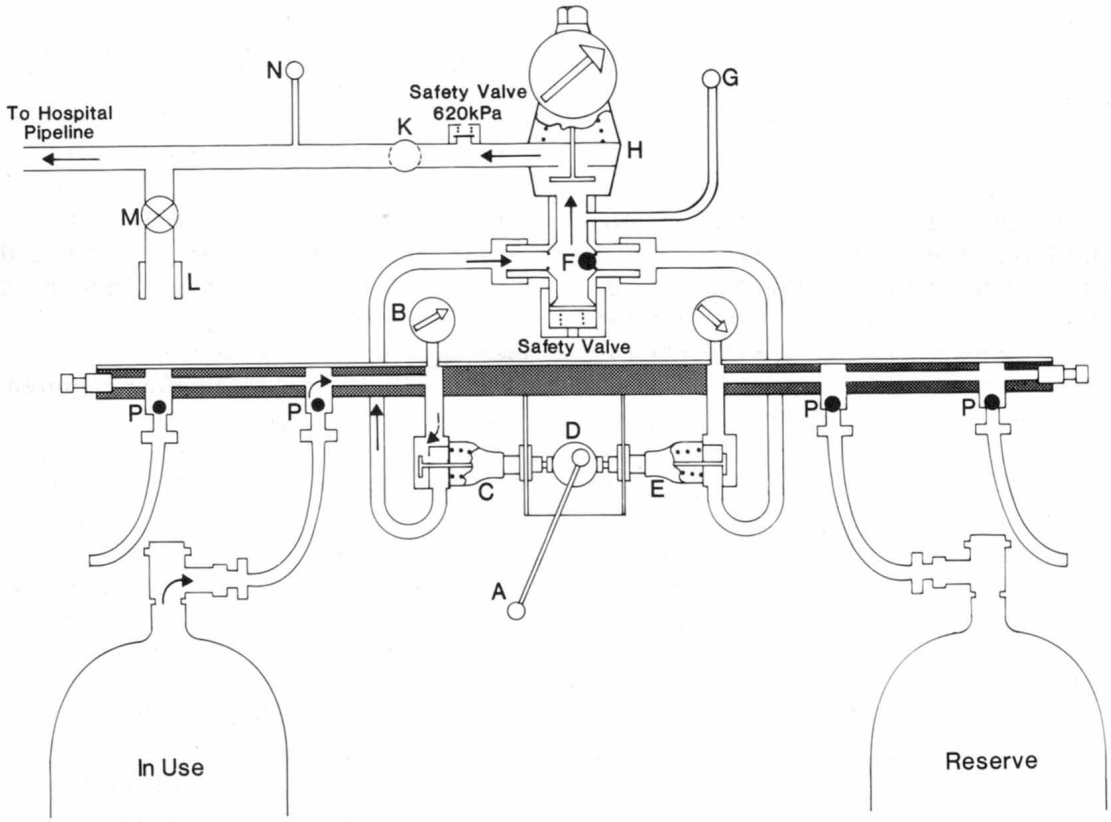


Figure 5.1. An automatic medical gas manifold. This supplies gas from one bank of cylinders (only one cylinder of each bank is shown). If this bank is exhausted, gas is supplied to the second stage regulator at a slightly lower pressure from the secondary bank. The pipeline pressure remains unaltered.

With high flows, pressure is lost across piping, valves and regulators and it is essential to ensure that this pressure drop during maximum demand does not trigger the very low pressure (red) alarm. In some systems a very heavy demand may cause sufficient pressure drop to trigger the reserve (amber) alarm. This light would normally indicate cylinder exhaustion of the active bank but as a high demand alone may cause the pressure fall, the pressure within the cylinder bank 'IN USE' should be checked before the cylinders are replaced. The Australian Standard AS2896 gives some guidance on the flows which may be required for various sites.

The primary gas supply 'IN USE' delivers gas from the first stage regulator at a pressure set usually between 1 030 kPa (150 psi) and 690 kPa (100 psi). The secondary cylinder bank first stage regulator is set to supply at a lower pressure, usually between 690 kPa (100 psi) and 550 kPa (80 psi). Thus when the primary supply is exhausted the secondary cylinder bank automatically begins to supply gas at the lower pressure. A second stage regulator reduces the pressure to a final supply pressure of 410 kPa (60 psi).

Within the system are pressure sensitive switches which are activated at set pressures as warning and alarm devices. One example of a medical gas manifold is shown in figure 5.1. Gas from the cylinder bank passes from each cylinder through a non-return valve (P) to the first stage regulator (C) set to 705 kPa (102 psi). A pressure gauge (B) indicates the bank pressure. From the first stage pressure regulator gas passes to a non return valve (F) which isolates the supply bank from the reserve bank. A safety relief valve is mounted between the first and second stage pressure regulators to prevent any excessive pressure being transmitted to the second stage regulator or pipeline. It is usually set to relieve pressure at about 930 kPa (135 psi). A low pressure warning circuit (G) is inserted just before the second stage pressure regulator. This circuit operates amber warning lights in strategic locations around the hospital when the primary bank is exhausted and the reserve bank has cut in.

Normally the amber light comes on at a pressure below that set on the first stage supply pressure regulator but above the pressure set on the first stage secondary pressure regulator (E). In the system shown in figure 5.1 the supply pressure is specified at 705 kPa (102 psi), the amber warning is set at 655 kPa (95 psi), and the secondary first stage regulator is set at 550 kPa (80 psi). The heart of the system is the first stage regulators (C and E) and the cam (D). Moving the lever (A) to the right, rotates the cam (D) which adjusts the tension on the springs of the two first stage regulators. The secondary regulator (E) is reset to deliver 705 kPa (102 psi) and regulator (C) is reset to 550 kPa. The left cylinder bank now becomes the secondary bank and the exhausted cylinders can be replaced. The second stage regulator (H) is set to the hospital pipeline pressure of 410 kPa (60 psi). Thus the pipeline pressure is unchanged even when the secondary cylinder bank is in use. In practical systems an isolating valve (K) is incorporated just beyond the manifold, so that the manifold can be repaired or serviced. During these procedures, an emergency cylinder or bank with regulators set to 410 kPa (60 psi) is connected to the fitting at (L), the emergency valve (M) is opened and the valve K closed. A supply pressure failure circuit is connected to the pipeline (N) just beyond the manifold. This is usually connected to a red light alarm and bell. It operates when the pipeline pressure falls to 345 kPa (50 psi).

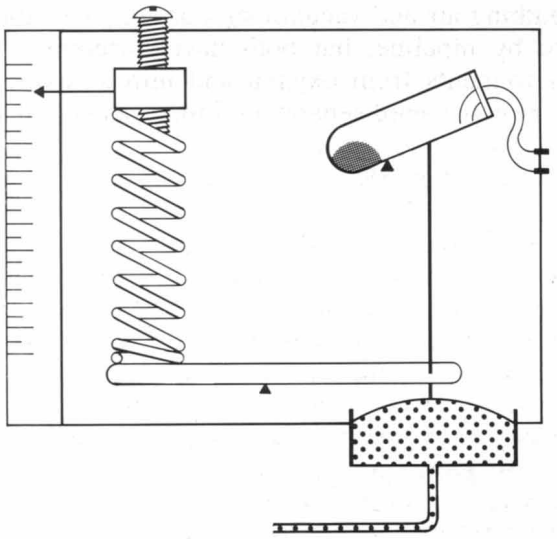


Figure 5.2. Diagram of a mercury pressure switch. The pressure diaphragm pushes against the tension spring. As the pressure falls the diaphragm moves down until the mercury switch is tilted below the horizontal. Mercury then runs down and covers both wires completing the electrical circuit.

In large hospitals similar alarms may be set up in special areas to detect local supply failures. Alarm and warning circuits generally consist of a pressure sensitive switch (Fig. 5.2) with a battery and charging circuit connected to a set of lights and bells. The pressure switch can be set to activate at any given pressure by tensioning the spring.

In hospitals with large flow requirements, the peak flow of the system may exceed the specification of the commonly used first stage regulator. In this situation, very large capacity first stage regulators will be required, and as an automatic changeover is not available for these larger regulators, these will have to be reset manually from primary to secondary and secondary to primary pressures on their respective cylinder banks as necessary.

MEDICAL BREATHING AIR

Medical compressed air may be supplied by a cylinder bank or from a plant on site. Methods of cylinder supply have already been considered. A compressor plant on site is likely to be economic only if the supply of cylinders is expensive or unreliable or a large amount of air is required. The initial equip-

ment is expensive and continued careful maintenance is required. Generally, compressors require at least fifty outlets to either supply air or generate venturi suction before the cost is justified. If engineering staff are not available to check and maintain the quality of the medical breathing air, it may be cheaper to supply as many as 100 outlets for breathing air by manifolded cylinders and use ordinary compressed air for venturi suction.

Normal air may contain several substances which are unacceptable in compressed medical breathing air and the compression process itself must not add contamination. The air intake into compressors must be arranged so that clean air is collected. Downwind of a chimney or where a diesel or petrol engine is operating would be unsuitable. For this reason only electric motors are used for power. At least two compressors are necessary to ensure continuity of air supply during maintenance or in the event of a breakdown of one motor. In practice, contamination of medical breathing air, particularly with water, can occur easily unless great care is taken and regular maintenance is unfailing. The quality required for medical breathing air is defined in AS2568. This specifies the purity of the gas in terms of the maximum allowable concentration of contaminants such as water vapour, carbon monoxide, and hydrocarbons (oil), which could affect the patient or the performance of equipment.

Usually one compressor is set to operate at about 690 kPa (100 psi) and the second at about 550 kPa (80 psi). Thus in the event of heavy demand or a failure, the second compressor will automatically operate. A switching arrangement is commonly installed which will allow the compressors to be alternated between working and reserve functions to equalise wear.

Compressors should not contaminate the air with oil and so generally oil free compressors with Teflon or carbon sealing rings are used, often with water lubrication.

Compressed air is normally heavily contaminated with water vapour which must be removed. Water in air is present as vapour, which means the partial pressure of the water vapour is a function only of temperature. Compression results in condensation of water vapour, as there is no increase in the partial pressure of water vapour above the saturation pressure.

Condensed water is removed in an 'after-cooler' cooled by air or water (Fig. 5.3). An air receiver holds a reservoir of air to supply a sudden demand and to smooth the working of the compressor. Further water may condense in the air receiver. A final air filter (5 micron) and drying column are inserted after the receiver. The drying columns not only remove water vapour but also may remove other significant contaminants such as carbon monoxide. Filters and driers are usually duplicated in parallel so that a column or filter may be isolated and replaced without interruption of the air supply. Usually this air is supplied at 410 kPa (60 psi) for distribution. Higher air pressure up to 690 kPa (100 psi) may be used to drive air tools, although oil free dry nitrogen from a cylinder is sometimes used for power. It is essential that air for power tools be very dry so that gas expansion within the tools does not cause condensation and freezing. Air which is highly compressed and then rapidly expanded, such as Tool Air must have a water content of less than 100 ppm. This level of dryness requires chemical desiccant driers and continual maintenance. For operating theatres, which use tool air but do not have a very high consumption, a simple dual manifold of medical breathing air cylinders may suffice.

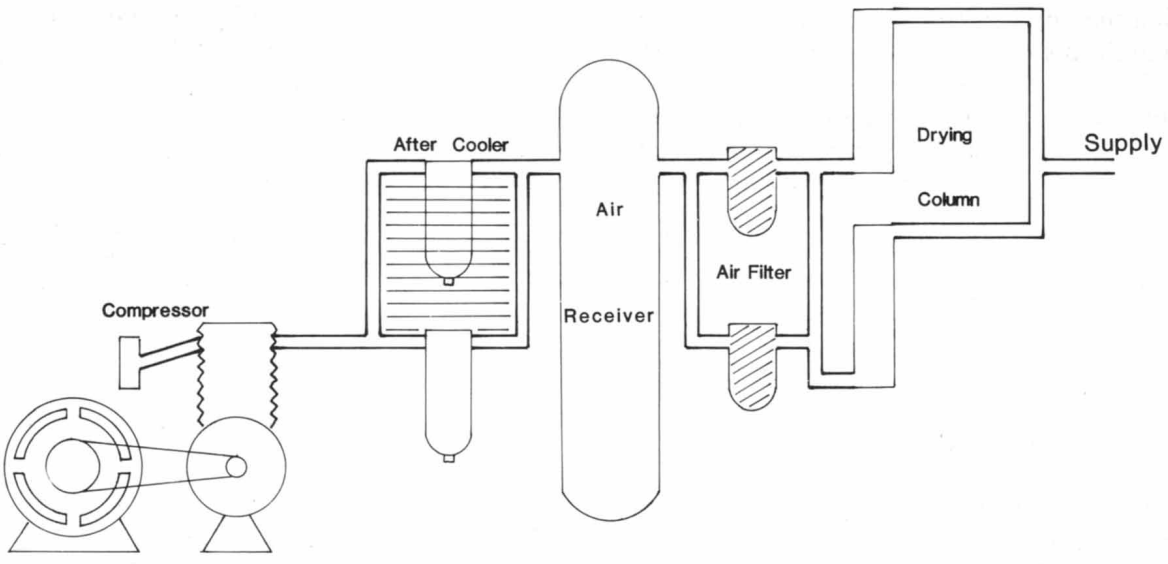


Figure 5.3. Diagram of an air compressor plant for a hospital to supply medical breathing air. An electrically powered compressor feeds compressed air to coolers and a receiver. Intake filtering is also usually done. After the air receiver the air is filtered by very fine filters and then dried. The drying columns may include a preliminary refrigeration stage before the final chemical drying. Coolers, filters and driers are usually arranged in parallel sets so that servicing can be performed without interrupting supply.

TABLE 5.1: **Design Flow for Suction Installations (Initial bed allocation)**

Locations per bed	*Plant Design flow litres/min (free air)*	*Pipeline Design flow litres/min (free air)*	*Minimum number of suction service points*
Operating theatre	20	40	4
Anaesthetic room	20	40	1
Delivery room – Mother	40	40	2
Baby	10	15	1
Recovery Ward	10	40	3
Intensive Care Unit – 1-4 beds	40	40	3
5 + beds	20	40	3
Plaster room	20	40	1
Casualty resuscitation area	40	40	2
Coronary care	20	40	1

SUCTION

Each suction outlet in the operating theatre or intensive care unit should be capable of 40 litres/min free flow and a negative pressure of at least -60 kPa (approximately 500 mmHg or 20 inches Hg suction). For effective vacuum, the time constant at the wall outlet should not be greater than four seconds. This depends on the capacity and flow resistance in the system. The time constant is the time taken to achieve 63% of the final value, ie if the final pressure is -60 kPa a pressure of -38 kPa must be achieved within four seconds.

In a ward area, where it is reasonable to anticipate that not all suction outlets will be used simultaneously, a suction pipeline system may be designed for less than the theoretical maximum. Thus an intensive care bed should have three outlets. The designed flow for the piping should be 120 litres/minute as all may be required at that bed, but the flow for the suction plant can be reduced as not all beds are likely to need full flow simultaneously, and plant flow may be reduced with more than 4 beds. Recommended figures from Australian Standard AS2896 and AS2120.3 are shown in Table 5.1. Suction may be derived from a vacuum source and piped to the area where it is needed or it may be generated from compressed air adjacent to the area.

If a large number of beds or units are installed, then the amount of flow required may be reduced by a diversity factor which takes into account the intermittent pattern of use over a wider range.

PIPED VACUUM

A vacuum source with piping to remote areas must consist of at least two pumps, each capable of meeting the peak demand, so that in the event of a breakdown suction is not lost. Automatic switching should be installed to maintain supply. The pumps should operate via a large tank to act as a reservoir of negative pressure. Minimum and maximum pressure switches should be arranged so that a compromise is set between frequent running of the pumps and the amount of pressure fluctuation in the suction line. Piped vacuum may require a large diameter pipe to accommodate a high demand either from several very active areas or from a wide distribution.

VENTURI SUCTION

Local generation of suction is usually done by ejecting compressed air through a venturi (Fig. 5.4). This may be medical air or simply a source of low moisture air. If both gases are piped in a hospital it is important that pipelines are not crossed as an ordinary compressor will contaminate the air with oil. Oil contaminated air is hazardous if used for breathing and could be flammable if mixed with

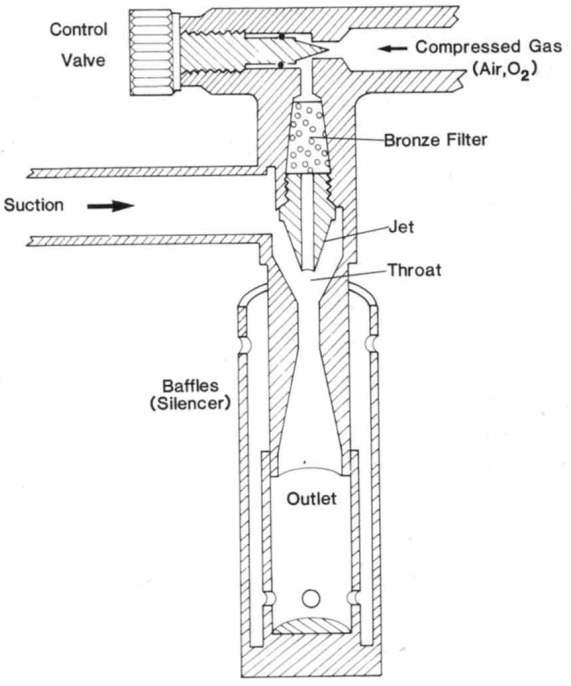


Figure 5.4. Venturi Suction fitting. Compressed gas, usually air or oxygen enters through a screw control valve. The driving gas passes through a metal filter to a fine nozzle or jet which directs a fast stream of gas across the throat into the venturi neck. Here gas is entrained to generate suction. The outlet of the venturi is normally covered by baffles to reduce noise and also to prevent accidental occlusion of the outlet, if this is fitted to a wall outlet. Venturis operating within a wall cavity are as shown but do not have the silencer. These are the usual type in the theatre or intensive care unit. Here the outlet pipe is ducted away to a suitable discharge point.

compressed oxygen. Contaminated air is also unsuitable for gas powered surgical tools, or ventilators.

Venturi suction operates by entraining air into a gas stream powered by a source of compressed gas, usually air or oxygen. The energy of compression is converted to kinetic energy as the driving gas passes through a fine nozzle (jet). The high kinetic energy means gas is entrained in the throat of the venturi and discharged at the outlet with the source or driving gas. Thus a negative pressure develops and can be used for suction. If the outlet becomes blocked, the free flow of gas from the venturi is impeded and instead the pressure of the driving gas develops in the throat and gas under pressure emerges from the suction connection. In some situations, such as chest drains, application of positive pressure would be disastrous. In these circumstances venturi suction should not be used or a check valve should be incorporated. Venturi suction which is supplied to theatres, recovery areas and similar places as a piped service should have a safety device incorporated to prevent driving gas from pressurizing the suction system above 0.5 kPa (4 mmHg or 5 cmH_2O). Venturi suction devices which are designed to screw on to oxygen or air wall outlets generally have no protection against pressurization of the suction line, and many piped services also lack protection. Suction powered by venturi requires a driving pressure of at least 410 kPa (60 psi). Some situations may require a pressure as high as 830 kPa (120 psi). This may be necessary if a long pipeline is required between the compressor and the venturi, if an area requires large amounts of suction or if the venturi design specifies a higher pressure for optimum efficiency.

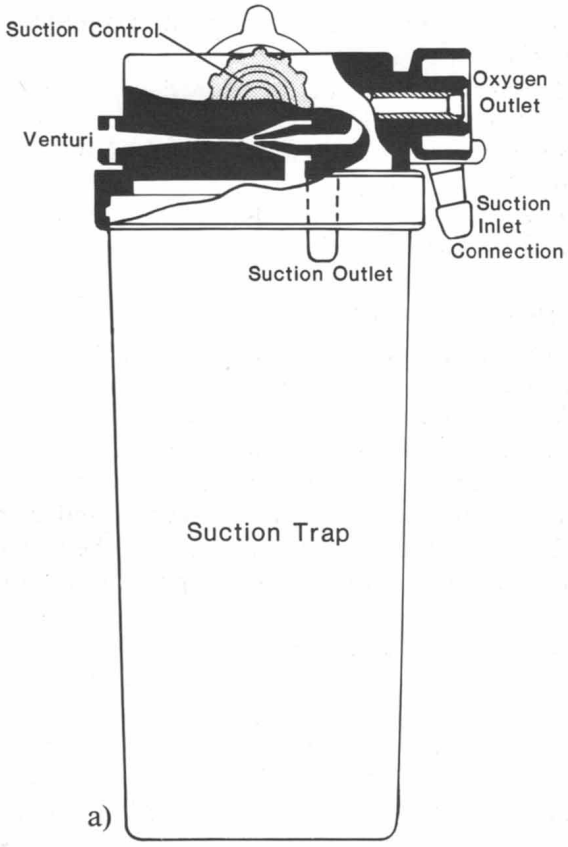
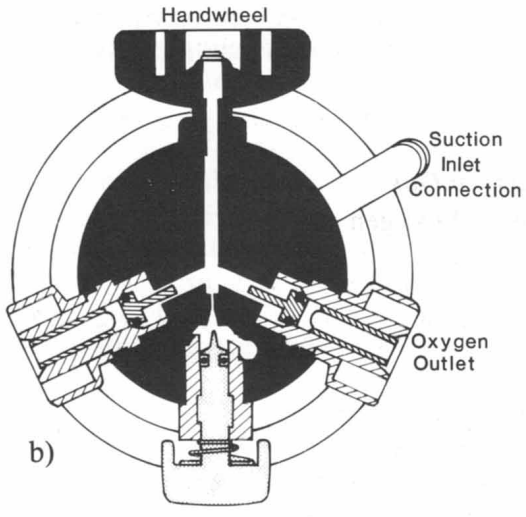


Figure 5.5. Twin-O-Vac suction and oxygen unit. a) Semi cutaway view from the front. The central knob controls flow to the venturi which discharges at the side of the head. b) Section from above. Flow from the wall outlet enters through the hand wheel and may divide three ways. In the centre is the flow control spindle to the venturi which is below the plane of sectioning. On either side are sleeve indexed oxygen outlets.

Twin-O-Vac

This is a means of obtaining two oxygen outlets and suction from a single oxygen outlet with a sleeve index screw (SIS) connection. A unit in good working order develops a suction of approximately -55 kPa (400 mmHg) with a free air flow potential of 16 litres/min. Oxygen consumption is about 22 litres/min for full suction.

Modest flows of oxygen up to 10 litres/min may be obtained simultaneously from the oxygen outlets. The high vacuum unit (TM117G) usually has the standard 400 ml polycarbonate suction jar (Fig. 5.5). The low vacuum (-25 kPa) unit may have the smaller 200 ml jar. Functionally the unit has a three-way channel from the wall coupling. Two of these end in appropriate sleeve indexed connections on either side of a central flow control knob for vacuum. Each sleeve indexed connection is fitted with a check valve so that no oxygen flows until a hose or equipment is connected. The third channel has a spindle flow control which regulates oxygen to the venturi driven vacuum. Oxygen from the flow control passes down in the head to a small venturi unit positioned across the diameter of the head and



discharging from its side. The venturi suction side arm, protected by a metal gauze, sucks directly from the suction jar below. The suction tube connection is positioned also on the head opposite the venturi outlet. After use it is important that the unit is cleaned carefully. Regular service is important as the venturi suction easily entrains debris from the suction jar.

Although these units do not meet the pressure and flow requirements of the Australian Standard AS2120 on medical suction, they do provide a convenient and reliable source of emergency suction in hospital wards. These units may also be fitted with Multepoint oxygen connections. However Multepoint fittings cannot be attached to a normal screw SIS outlet.

PIPELINE INSTALLATION

The installation of a medical pipeline requires great care and should not be done by anyone who lacks a wide experience in these installations. Apart from the problem of poor connections and leaks, the frequent reports of misconnection and cross connection, particularly between oxygen and nitrous oxide, mean that at least one error is to be expected in a large new installation on the precommissioning check.

As well as being colour coded, medical gases should be clearly labelled as in Table 5.2 and Fig. 5.6. It is important that anyone inspecting a new installation should be aware that medical gas colours are not exclusively reserved for medical installations and the Australian Standard for identification of industrial piping conduits and ducts, AS1345 1972, calls for colours which may be misunderstood if thought of in a medical context. Three pipeline identification colours are particularly important. Pipes containing steam should be silver-grey; this may be confused with white in dim light and thought to be oxygen. Pipes containing non-medical compressed air should be light blue which may be confused with nitrous oxide. Pipelines containing dangerous material or material with ionising radiation should be safety yellow with black and may be confused with vacuum.

TABLE 5.2: **Labelling of Medical Unit Pipelines**

Name of Gas	*Colour*
Medical oxygen	White
Medical vacuum	Primrose (yellow)
Medical Nitrous Oxide	French Blue
Medical breathing air	Black and White

Label must be at least 70 mm wide.

During construction it is essential that the provisions of the Australian Standard AS 2896 be complied with. Apart from requiring good design of the construction such as proper pipeline supports, the standard specifies also the material and techniques to be used. Pipelines must be of seamless copper tubing designed for working pressure of 1400 kPa (approximately 200 psi). All pipes, valves and other fittings must be internally cleaned of oil, grease, and other flammable material and be odour free before assembly. In construction, brazing flux containing combustible substances such as alcohol are forbidden. Failure to observe these precautions may cause contamination inside the pipe and may result

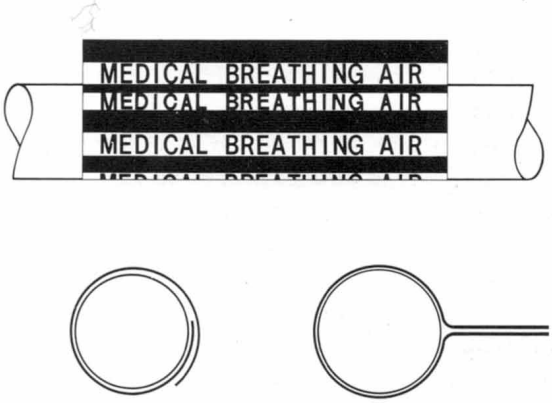


Figure 5.6. An example of identification of a medical gas pipeline, not in an exposed area. In addition to colour coding, the pipeline should be labelled as shown about every 2 metres. Labels can be wrapped around the pipe or stuck back onto themselves to form a tag.

in an explosion when oil comes into contact with oxygen or nitrous oxide under pressure. The pipeline should be constructed with a carbon dioxide purge during the brazing operation and when a pipeline has been completed it must be blown clear with medical air. Water or other liquid must not be used. Final testing should include a static test for several hours or more at the working pressure. When temperature changes are accounted for, there should be no pressure loss. Every outlet must be individually tested by the construction engineer to ensure that only the correct gas is released. When non-respirable gases such as nitrous oxide are being piped, this test should be repeated under the supervision of an experienced medical graduate from the anaesthetic department before commissioning. After each examination the system must be purged with the specific gas for which it is designed. Although this procedure is time consuming and repetitive, it is essential if any mistake in construction is to be found before the pipeline is used for care of patients.

Apart from misconnection, errors in calculating pathways and dimensions can be costly and difficult to correct. The installation of pipelines in partition walls which are later removed may result in additional cost and the hazard of cross connection. Although the cost of small bore copper pipe is less than large bore, the cost of subsequently duplicating or replacing the pipeline is always much greater than the initial savings with the smaller bore. Similarly, severe pressure drops can occur in pipelines with poorly constructed joints or bends. The use of pipe which is too narrow for the maximum gas flow is very hazardous, as pressure may only occasionally and unpredictably be inadequate. For example, narrow piping may cause a pressure driven ventilator to fail only when the oxygen demand in an adjacent ward is sufficiently high to reduce its driving pressure. Pipelines supplying oxygen and nitrous oxide usually have a pressure of about 410 kPa (60 psi). Pipelines supplying medical breathing air operate also at 410 kPa (60 psi) but medical breathing air is commonly used as a power gas for surgical tools. This pipeline may be set at a higher pressure from about 600 kPa to 1200 kPa

and a separate surgical tools sleeve index is used. Some tools use a large air flow and may require a large diameter pipeline and a high flow pressure regulator to avoid an excessive pressure drop in the supply system during use.

Suction may be generated by a venturi in the wall cavity adjacent to the suction point and driven by compressed air. Venturis for suction are also attached to wall outlets supplying either compressed air or oxygen. Although in some ways simpler, piped vacuum is limited in the distances it can be conducted as the maximum acceptable pressure drop is 40 kPa (approximately 6 psi).

If pipeline gases are used for pressurised flow meters or in blenders, the level of pressure regulation may be important. Pressurized flow meters may vary slightly but not substantially if the line pressure deviates moderately. However, some older blenders may not deliver the indicated % of oxygen if the line pressure deviates more than about 25% from their nominal working pressure (usually 400 kPa). Poorly isolated blenders have been associated with back-leaks of air into oxygen pipelines. These blenders may not be immediately apparent as many ventilators for ICU now incorporate blenders within the machine. The best oxygen/air blenders are designed so that the outlet pressure is held below the pressure of both the air and oxygen supplies. In this arrangement, the problem of air back-leak into the oxygen supply is circumvented as the mixing pressure is less than the supply pressures. Blenders purchased for use in ICU should have their performance specification and construction checked carefully before purchase.

WALL OUTLETS

Today the only wall outlets which are acceptable have some form of non-interchangeable connection indexed for each gas and suction and some form of integral labelling. Usually the labelling is the name of the gas supplied, printed immediately below the outlet. For oxygen, the word 'OXYGEN' is in white letters; for nitrous oxide, the words 'NITROUS OXIDE' are in french blue lettering and for suction, the word 'SUCTION' is usually in primrose yellow.

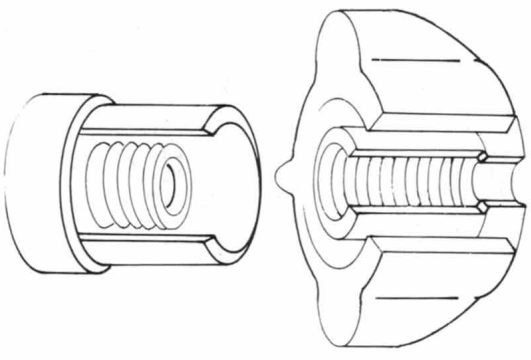


Figure 5.7. Wall outlet and hose coupling. The internal thread is the same for all gases and vacuum. Only the sleeve on the outlet and its corresponding groove on the hand wheel of the hose coupling are indexed to prevent interchangeability.

Air may be labelled in white or black and should be specified as 'MEDICAL BREATHING AIR' if intended for patient use because the distinction between air and medical breathing air was not always maintained in older systems. In some hospitals not all outlets labelled 'AIR' supply gas suitable for breathing. Three types of indexed wall outlets are in use in Australia today; the sleeve indexed system developed by CIG (Ohmeda), the indexed circumferential lugs used by Liquid Air, and 'quick connect/disconnect' of the Schrader type. The Australian Standard, AS2896, specifies the SIS screw connection for medical gases to ensure that cross-connections cannot occur and that outlets and hand wheels from different manufacturers are compatible.

SLEEVE INDEXED SYSTEM (SIS)

This system has a screw thread and a sleeve (Fig. 5.7). The thread is nominally 1/4 inch British standard pipe thread (1/4 BSP). This thread is Whitworth in form and has an overall diameter of about 13 mm. There are 19 threads per inch.

Indexing is by the diameter of the sleeve (Table 5.3) and normally the sleeve prevents connection of fittings with different indexes. Thus nitrous oxide, oxygen and air cannot be cross-connected. It is important to be aware that the same thread is used in all fittings so that no connection should be used without the sleeve.

In some operating theatres the quick connect-disconnect fittings such as designed by BOC are preferred. Although these fittings are convenient, the rapid disconnect may allow the residual pressure in the hose to act as a jet and cause the hose to move sharply away from the fitting. The explosive disconnection may injure the person disconnecting, particularly if the fitting is mounted vertically on a pendant or boom. The threaded connections which have to be unscrewed cannot be disconnected suddenly so there is time for the pressure in the hose to dissipate, and the risk of hose whip is avoided.

Male/Male 1/4 BSP fittings without sleeves are hazardous and should not be used to join gas hoses

TABLE 5.3: **SIS Gas Specific Dimensions**

GAS	*SLEEVE INDEX (nominal) mm*	
	Outside	*Inside*
Nitrous oxide	19.8	16.8
Entonox	20.8	17.8
Carbon Dioxide	21.8	18.8
Carbogen (oxygen with 5% CO_2)	22.8	19.8
Scavenging	23.8	20.8
Oxygen	24.9	21.9
Medical Breathing Air	25.9	22.9
Suction	26.9	23.9
Compressed Gas (Surgical Tools)	27.9	24.9
Variable Air/Oxygen mixtures	28.9	25.9

The corresponding groove is approximately 0.25 mm larger than the sleeve.

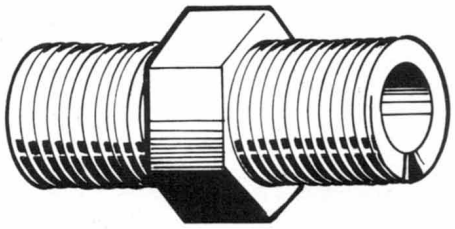


Figure 5.8a. A dangerous 'cheater' coupling. This is capable of cross connecting different hoses, e.g. nitrous oxide and oxygen.

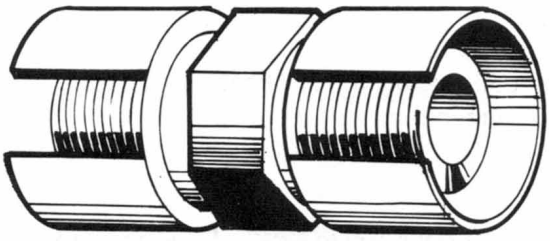


Figure 5.8b. A partially cutaway sleeve indexed coupling which shows the common threading. Only like sleeve-indexed hoses can be joined with this coupling.

(Fig. 5.8a). A suitable sleeve indexed fitting is available (Fig. 5.8b). Early versions of the sleeve indexed system had some special female connections with grooves to accommodate both air and oxygen. These fittings were originally intended for use with ventilators. All such fittings should be replaced as these special connections may be accidentally used on an oxygen hose for an anaesthetic machine. The use of air instead of oxygen with nitrous oxide could result in hypoxia. Also confusion between air and oxygen driving a ventilator with a venturi might result in a patient receiving a much lower inspired oxygen than intended.

Once a pipeline is installed it is often used without further thought or attention. However, all pipelines installed before the mid 1980s should have the terminal outlets upgraded to the current pattern so that the sleeve index system is part of the fitting and cross connections are prevented. Early wall fittings had the sleeve screwed onto the thread so that removal and replacement of the wall panel could result in the wrong sleeve on the wrong gas outlet. From the beginning of the 1970s until the 1980s, the terminal block fitting was fixed onto the gas pipe by two or three locating pins which passed through the wall panel and into holes on the sleeve body (Fig. 5.9). Although these fittings have been superseded, they are still in common use. However, all these fittings should be replaced with terminal units with the sleeve integrated with the thread in any upgrade.

This pin system ensured the correct sleeve mated with each gas. The size and location of pins and holes in this through-wall pinning are very impor-

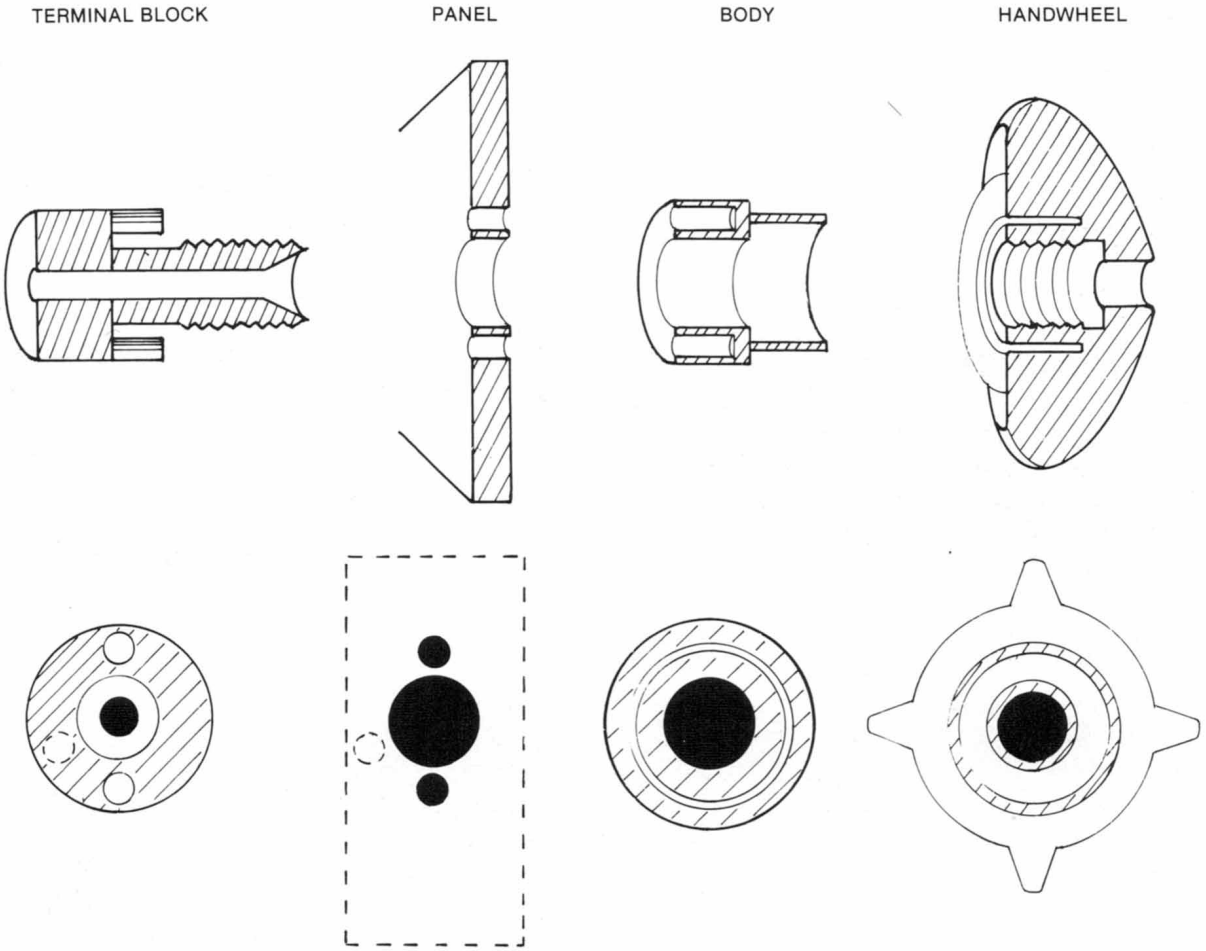


Figure 5.9. An indexed medical gas panel. The terminal block which is welded on the end of the pipeline has two or three pins in indexed positions so that each gas has its specific pin locations. The panel has corresponding indexed holes, and has the name of the gas displayed for the user. The sleeve body fits over the index pins. The sleeve body and the hand-wheel groove are also gas specific.

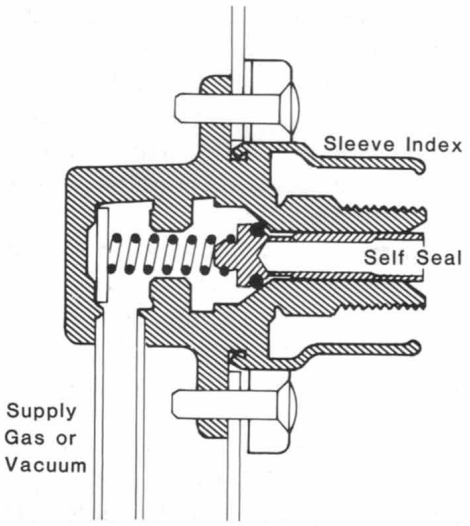


Figure 5.10. An integrated sleeve indexed outlet with a self-sealing valve. The sleeve index is bonded with the connecting thread. The protruding tip inside the screw thread allows it to be pushed back when the hose is connected. The self-sealing valve is held in place by a spring which is strong enough to prevent spontaneous opening with medical vacuum.

tant and form a gas specific index for the common gases and suction. More recently, the danger of separation of the sleeve and the thread with this indexing has been addressed by a new specification that the terminal unit be constructed so that the gas line cannot be connected if the sleeve is removed. This has led to designs with integrated sleeve and thread connections. It is important that these fittings are obtained from an experienced manufacturer. One such integrated fitting is shown in Fig. 5.10. A self-sealing outlet is usually installed with the SIS connection. This is a plunger with a neoprene 'O' ring for sealing. On suction outlets the plunger is spring-loaded. The plunger is held shut by gas pressure or the spring when nothing is connected to the outlet. The female connection on a hose or flowmeter has a nipple inside the thread which pushes the plunger back in the outlet and lifts it away from its seal allowing gas flow in either direction. This self-sealing device can be used with all gases and with vacuum.

On an anaesthetic machine, a self-sealing outlet may be used for a power take-off for a gas driven ventilator and will allow the ventilator to be driven from piped gas or, in the event of pipeline failure, from cylinders on the machine. In this respect it differs from a non-return valve which allows flow in only one direction. Some anaesthetic machines have SIS outlets for connection to the pipeline supply with a non-return valve to prevent the return flow of oxygen from the cylinders if the pipeline is disconnected. The non-return valve in these outlets on the anaesthetic machine may prevent a ventilator being powered by cylinders on the machine if the pipeline fails.

'QUICK CONNECT' SIS SYSTEMS

The Sleeve Indexed System has been extended to quick connect fittings which can also accept a common screw fitting (Fig. 5.11). The Multepoint quick connection outlet can be distinguished from the common wall fitting as it has a slot at the top of the sleeve to ensure that flowmeters and similar devices must be vertical or correctly positioned. The free fitting of a Multepoint system cannot be attached to a standard screw wall fitting.

A more recent quick connecting attachment which like the Multepoint connects to the Sleeve Index is the Esco QuickConnect fitting. However, unlike the Multepoint, the Esco QuickConnect does not require a special terminal unit and will screw directly onto any Sleeve Indexed wall fitting. The width of the hand wheel is greater and the body is longer to accommodate the sleeve coupling. The principle is that there is a core which can slide about 5 mm out of the hand wheel body (Fig. 5.12). This core has a 1/4 BSP but it is split into six segments along the initial 80% of the core length. When the core is seated within the hand wheel, the segments form a female thread to attach to the male thread of the wall terminal unit. When the core slides out of the hand wheel, the segments expand and open the thread which releases the male thread

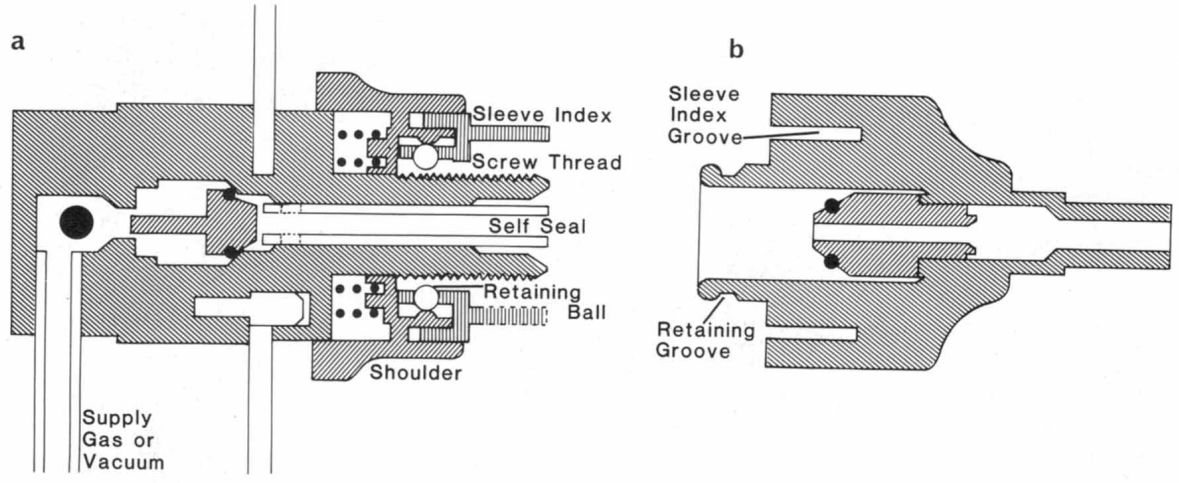


Figure 5.11. The Medishield (Ohmeda) Multepoint connection. (a) The final installation connection. The fitting accepts SIS screw-threaded fittings and also quick connectors. With the quick connection, pushing the shoulder in frees the locking ball. After the hose fitting is connected, the ball sits in the retaining groove and holds the fitting. A gas-tight seal is achieved by the 'O' ring on the hose fitting. (b) The Multepoint quick connect hose-fitting. The Sleeve Indexed System is used but instead of a screw-thread, coupling is achieved with a retaining groove.

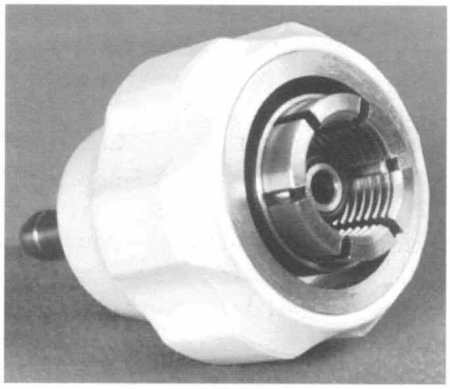


Figure 5.12. Esco QuickConnect. The central core split into six segments can be seen just within the sleeve index groove. Before attachment, the core is normally protruding from the body to allow the threads to open.

of the terminal unit. To attach the QuickConnect to a terminal unit, the hand wheel with the core extended and the thread opened is pushed onto the terminal unit. As the core thread engages the thread on the terminal unit, the core is pushed back into the hand wheel and the core thread closes and mates with the thread of the terminal unit. Once the core is fully in and the hand wheel and the threads are engaged, a further half turn winds the hand wheel along the thread, seals the nipple against the outlet and opens the self-sealing plunger to allow gas to flow. To release the QuickConnect, the hand wheel is unscrewed about half a turn and then the hand wheel body is pulled away from the terminal unit. This action draws the core out and opens the thread to release the connector from the terminal unit.

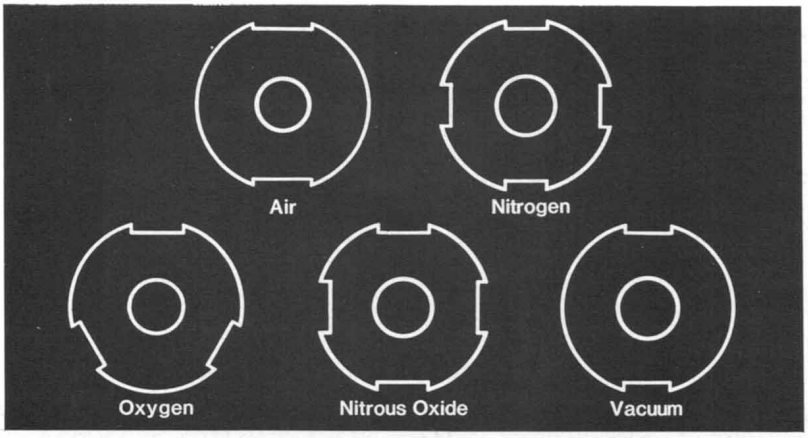
INDEXED CIRCUMFERENTIAL LUGS

Quick release pipeline outlets are manufactured by Liquid Air and are installed in some hospitals in Australia (Fig. 5.13). In this system, gas indexing is achieved by specification of the diameter of the engaging nozzle and of the size, number and position of circumferential lugs which attach to slots on the rim of the outlet. Three symmetrical configurations of two, three and four lugs are used and each configuration is used for more than one gas. Further indexing is done by varying the lug/slot width and the diameter of the central gas nozzle. The system is arranged so that as the nozzle diameter increases, the lug size decreases. Both nitrous oxide and nitrogen use the four lug/slot configuration. For nitrous oxide the lug/slot is 7 mm and nozzle diameter is 6 mm. For nitrogen the slot is larger, 8 mm, and nozzle diameter is smaller, 5 mm. A three lug/slot configuration is used for oxygen/nitrogen mixture, oxygen and carbogen. Oxygen/nitrogen is allocated the largest lug/slot and the smallest diameter of nozzle. Oxygen and carbogen have decreasing slot widths and increasing nozzle diameters. A two lug/slot configuration is used for air and vacuum, air having the large lug/slot size and the smaller diameter nozzle.

Connection is made by a slight rotation to engage the lugs on the outlet rim. Sealing is achieved by a flat neoprene washer around the central hole in the outlet which is pressed lightly by a ridge around the nozzle. Upon disconnection the outlets may be self-sealing. In this type, the cylindrical nozzle entering the outlet unseats a plunger in the outlet. Loss of the neoprene washer means the gas seal is lost and leaking can occur.

QUICK CONNECT/DISCONNECT CONNECTIONS

A probe quick coupling device has been used in medicine and industry for many years. One of the earliest and now the most common pattern is the Schrader design and this is the basis for the design used in the United Kingdom by BOC-Ohmeda. It is a blunt conical probe which engages in a socket and achieves a gas-tight seal by pressing against a neoprene ring within the socket (Fig. 5.14). The coupling is held together by tongues engaging into a groove. The groove is on the probe just behind the conical nose which pushes the two or three circumferential tongues apart as it enters the socket. These are sprung so that when the locking groove of the probe and the tongues are in line, the tongues close



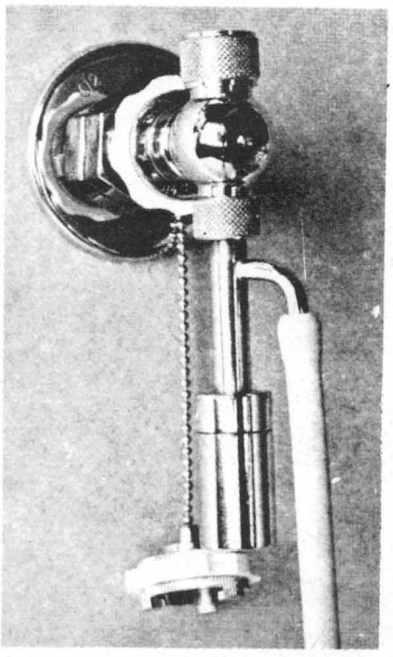


Figure 5.13. Schematic of index system showing differences in configuration, slot width and nozzle diameter used to achieve indexing. Once engaged, the socket collar is rotated to hold the fitting to the outlet. Example of a Liquid Air quick release outlet for oxygen with a venturi suction attached (right).

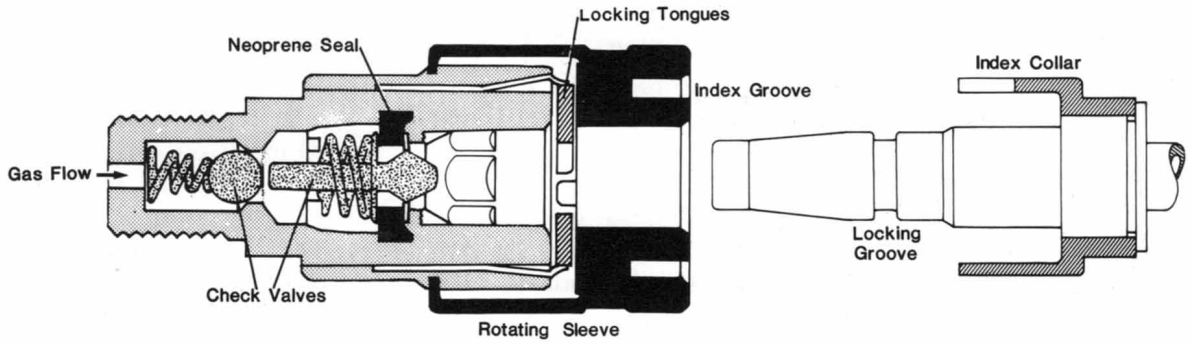


Figure 5.14. Quick connect/disconnect of the 'Schrader' type. The nose of the probe disengages the check valves. The shoulder behind the nose fits against the neoprene seal. The locking tongues spring into the groove and hold the probe firmly in the socket while the index collar is fitted into the index groove. Once engaged, the probe and socket allow gas flow in either direction.

into the groove and lock the probe in place. For disconnection, the tongues are released from the groove by either rotating the body of the socket or pushing it back, depending on the design. Medical gas outlets and hoses with quick coupling connections must be indexed to prevent cross connection of hoses. Although some special systems designed exclusively for medical gases have used the shape of the probes or the diameter of the probes, the systems most commonly used which are based on the Schrader coupling have diameter indexed collars. The conical nose of the probe is 28 mm long and the 2.5 mm groove is located 18 mm from the top which is 7.8 mm in diameter. The probe for each gas is allocated a collar which has a different diameter from all others. This indexed collar must fit into a circumferential indexed groove on the socket before the probe can enter far enough to achieve a gas-tight seal and lock into the tongues. The diameters of the commonly used collars are listed in Table 5.4. Most collars have a slot cut halfway in so that equipment such as a flowmeter which requires a specific orientation will engage in the correct position. Only when the slot on the collar fits a pin in the socket groove can the probe penetrate sufficiently to lock firmly.

TABLE 5.4: **Quick Connect/Disconnect Gas Specific Dimensions**

Supply	*Identification Symbols (BS 5682)*	*Nominal Outer Diameter mm*
Medical Oxygen	O_2	20.6
Medical Nitrous Oxide	N_2O	23.8
Oxygen/Nitrous Oxide nominal 50/50	O_2/N_2O	23.0
Medical Breathing Air 400 kPa.	MA4	25.4
Medical Air 700 kPa (Power tools)	MA7	22.2
Medical Vacuum	MVAC	24.6