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S Ahanatha Pillai

Foreword
J Renganathan

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chapter

4

Medical Gas Pipeline System

Medical gas pipeline system (MGPS) is the provision of storing the medical gases oincluding oxygen, nitrous oxide and air in a central point, and supplying these medical gases through pipeline to the point of use through out the hospital.

As vacuum is included in this pipeline system along with the gases some name it as piped medical gas and vacuum (PMGV).

The vacuum is for suctioning as well as for scavenging waste gases.

This is governed by the law HTM 02-01 of UK (Department of Health. Health Technical Memorandum 02-01) and NFPA 99 (National Fire Protection Act Standards) of USA.

IS 12827 (1989): Nonflammable medical gas pipeline systems [MHD 11: Anesthetic, Resuscitation and Allied Equipment] is the law that governs this.

Medical gas pipeline system provides a safe, convenient and costs effective supply of medical gases. It eliminates many problems associated with the use of gas cylinders.

PIPELINE OF MEDICAL GASES

It includes three components:

1. A source of gas supply—cylinders
2. A pipeline extending from the source to the point of utility
3. A terminal unit at each point of use.

- In bigger hospitals, four pipelines would be running along the walls to operation theater, postoperative ward, intensive care unit (ICU) and other wards.
- These are pipelines carrying *oxygen, nitrous oxide, compressed air* and *vacuum* to various destinations.
- Usually pipelines to the operation theater supply the anesthetic gases—oxygen, nitrous oxide, compressed air and vacuum.
- Compressed air supplied by pipeline is used in modern anesthesia machines. It is used for driving pneumatic equipment such as drills and for operating ventilators as well.
- For other wards of the hospital, pipelines supply oxygen and vacuum necessary for applying suction.
- The central pipeline receives gas from large cylinders kept elsewhere in the hospital and that place is known as *Manifold room.*

Advantages of Central Pipeline Supply

Asepsis

- Cylinders transported from distant place of manufacture are likely to carry dirt and contamination.
- The large D-Type cylinders (also known as bulk cylinders or 50 L water capacity cylinders) are used in the manifold of central pipeline supply.

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- They are not brought into the operating theater complex. Hence, this source of contamination is eliminated.

Simple

It is practically easier to use pipeline supply of gases in anesthetic machines by plugging probes and flexible hoses from the self-sealing valve of the outlet (Schrader self-sealing valve). Flexible hose carries the gas to the machine.

Economical

- Cost of gas in bulk cylinders are relatively less compared to the cost of gas in small cylinders used in anesthesia machines.
- Investment on cylinders is considerably reduced, as the number of bulk cylinders required is significantly less.

Efficient

Continuous uninterrupted supply is possible without much wastage of gases.

Reliable and Safe

Automatic changeover in manifold control panel maintains uninterrupted supply of gases and assures safety.

Saves Space

- Manifold room occupies relatively less space away from the main building.
- Storing small cylinders for anesthetic machine in large number is cumbersome and occupies more space.

Psychological Effects

- The sight of an oxygen cylinder causes a big psychological impact on the patient and relatives.
- Particularly an oxygen cylinder near the postoperative bed makes them feel anxious.
- In central pipeline system, the cylinders are far away from the sight of patient and relatives.

The station where bulk cylinders are kept for feeding the central pipeline is known as the Manifold Room.

MANIFOLD ROOM

- A convenient well-ventilated spacious room in the ground floor well away from the operation theater and wards for easy transportability of bulk cylinders.
- It is a fireproof room **(Fig. 4.1A)**, constructed with non-flammable material and must have easy accessibility for transporting vehicle to reach.

Gas Manifold and Control Panel

- When a number of cylinders are connected simultaneously into a single pipe through many side connections which has a single outlet, it is called a Manifold **(Figs 4.1A to C)**. It is a terminology of automobile industry.

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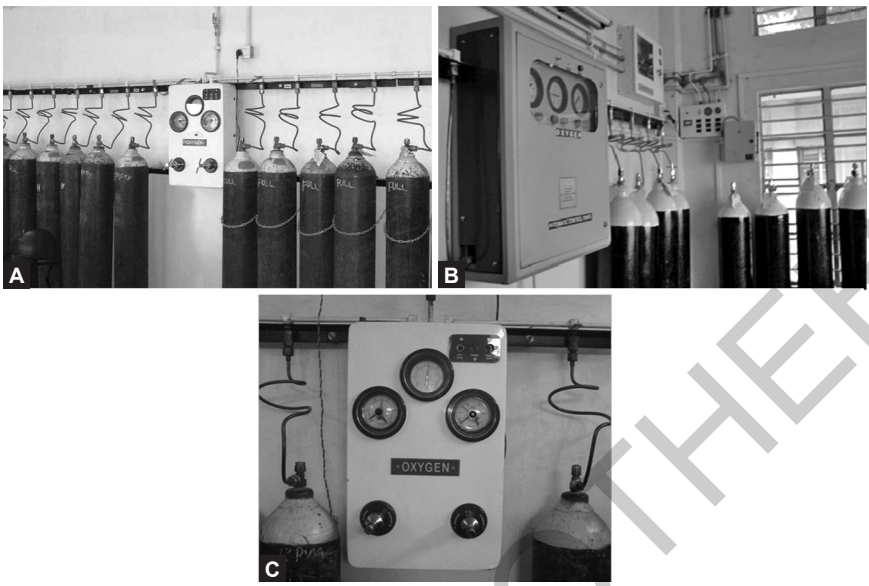

Figs 4.1A to C: Oxygen manifold in the manifold room: (A) Oxygen manifold with two banks and control panel; • The coiled copper tail pipes connect the cylinder to the manifold, manual control panel is seen; • (B) It is a well-ventilated room; • Manifold with electronic control panel; • Four spare cylinders are seen on the side; • There are three pressure gauges; • The two pressure gauges on the sides show the pressure of the cylinders in each bank while the one pressure gauge in the center shows the pipeline pressure; (C) Manual control panel (semi-automatic) with the three pressure gauges; • Three pressure gauges; two on the sides for manifolds with minimum contact gauge, the one on the center is for pipeline pressure; • There are three indicator lamps seen on the top; one in the center indicates that the pipeline is ON; • The other two warning lights are to indicate the exhausted bank of cylinders

- Usually, the manifold room houses the manifolds for oxygen and nitrous oxide.
- There are two 'manifold systems' with central control panel for oxygen and nitrous oxide.
- Ideally, the air compressor and tank for oil-free filtered air "medical air" and vacuum pump and vacuum tank are not housed in the same room, though some hospitals prefer to have it for convenience of operation.

Oxygen Pipeline

- Uninterrupted supply of oxygen through pipeline is derived from two manifolds that are provided on either side of an automatic device in the center known as Central control panel.
- *D-Type* cylinders (50 LWC or Bulk cylinders) with 'Bull nose' valves are connected to the manifold through especially designed coiled copper 'tail pipes' **(Figs 4.2A to C)**.
- The tail pipes have 'gas specific threads' and hexagonal nuts. It is not possible to connect a wrong gas in the manifold **(Figs 4.2A to C)**.
- To prevent 'transfilling'—flow of gases from one cylinder to another 'non-return valves' are used **(Figs 4.3A and B)**.

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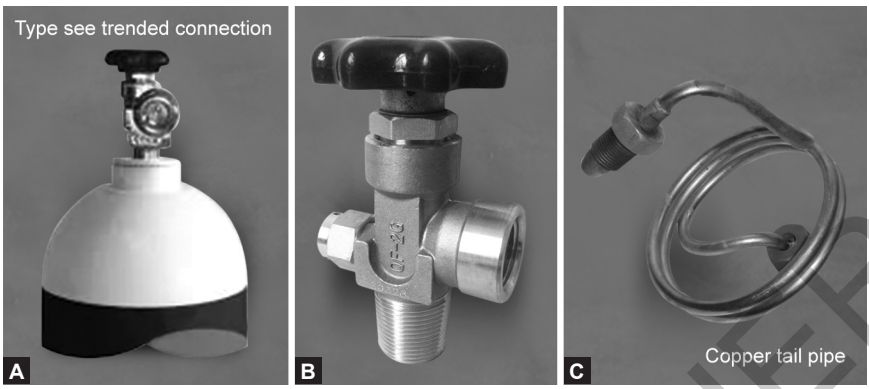

Figs 4.2A to C: Cylinder with Bullnose valve, bullnose valve and the tail pipe; • The cylinder has 'Bullnose' valve with hand wheel; • The bullnose valve has hand wheel and a pressure release valve; • Some Bullnose valves do not have hand wheel but special wrench is used to open

- The number of cylinders connected to each manifold depends upon the requirements of the hospital.
- Each side of manifold (known as 'bank of cylinders') must contain an average four day's supply and a minimum of two cylinders at least.
- One of the manifolds will be the *Running bank* of cylinders (Duty bank) from which the gas flows into the pipeline, while the other manifold will be the Reserve bank.
- A 'control panel' with double shut off valve and a central pressure reducer is used.
- When the *Running bank* is near exhaustion, the *Reserve bank* automatically takes over and maintains uninterrupted supply in the pipeline.
- Simultaneously, two warning lamps one situated on the control panel and another in the theater complex are activated to warn the anesthesiologist that the Running bank is getting exhausted.
- The double shut off valve makes the *Reserve bank to automatically* take over.
- A simple design of this unit with multiple cylinders on each side is shown in **Figure 4.1A**.
- The changeover done at the control panel may be fully automatic by electronic controls **(Fig. 4.1B)** or it can be partially automatic **(Fig. 4.1C)**.
- For automatic changeover during use, all the cylinders in both the manifolds will be kept open.
- Apart from the cylinders connected to the manifold, spare cylinders in the number equal to one bank must be stored in manifold room.
- While servicing of the manifold is being carried out, the outlet valve from the panel to the line may be closed.
- There will be provision for connecting a single bulk cylinder with pressure reducing valve in the pipeline for feeding the pipeline during this time.

Control Panel

It may be *Fully automatic electronic control panel* or *Semiautomatic mechanical control panel* **(Fig. 4.1)**.

Purpose

- Reducing the cylinder pressure to the pipeline pressure (60 psi or 4 bar—working pressure of the machines)
- Maintaining uninterrupted supply of gas in the pipeline.

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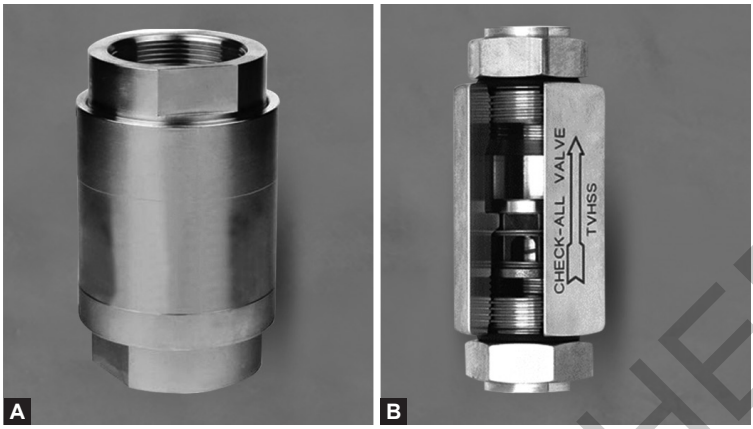

Figs 4.3A and B: Non-return valve. Non-return valve to be fixed in the manifold where tail pipe joins; • This valve prevents reverse flow of gases and transfilling of cylinders; • The mechanism is shown in the Figure B

The control panel consists of *six components:*

1. *Two pressure reducing valves* for reducing the output pressure of the two manifolds to a level just above the final outlet pressure.
2. *Two pressure gauges* to assess the pressure in each manifold **(Fig. 4.1C)**. This is a special gauge known as *'minimum contact gauge*. It is provided with *a central knob that can adjust set the pressure desired to activate the warning lamp*. Usually, it is set at a pressure little higher than the final out let pressure–say 5 or 6 bar. It will have electrical contacts which are connected to a low voltage control system to activate the warning lamp and alarm **(Figs 4.4A and B)**.
3. *A shuttle valve* to make the automatic changeover.
4. *A common outlet pathway with a central pressure reducing valve* that reduces the pressure of the common outlet as 4 bar (60 psi) **(*See* Fig. 4.1C)**.
5. *Two handles fixed to the pressure reducing valves* of the manifolds that can be turned to set the 'Running bank' and 'Reserve bank' as required.
6. *Two red warning lamps* for each manifold to indicate exhaustion and an amber lamp to indicate that the pipeline is on.

Modern control panels 'the pressure difference' between the running and reserve banks is used for automatic switch over of reserve bank when the running bank is exhausted **(Fig. 4.5)**.

Instead of 'Minimum contact gauges' sensitive 'Pressure switches' which work on low voltage DC current are used on the manifold outlets to activate warning lamps in present day manifolds **(Fig. 4.5)**.

For N_2O electrically operated, thermostatically controlled heating system maintaining at 47°C is used in the control panel to prevent freezing of gas within and choking the flow (In countries where ambient temperature falls very low to freezing levels).

Partial Automatic System

- When 'Running bank' is exhausted and the warning lamp is activated with alarm.
- Now, the technician will *manually* turn a lever of the pressure reducing valve (RV) of that side, so that the Reserve bank will now become the Running bank.

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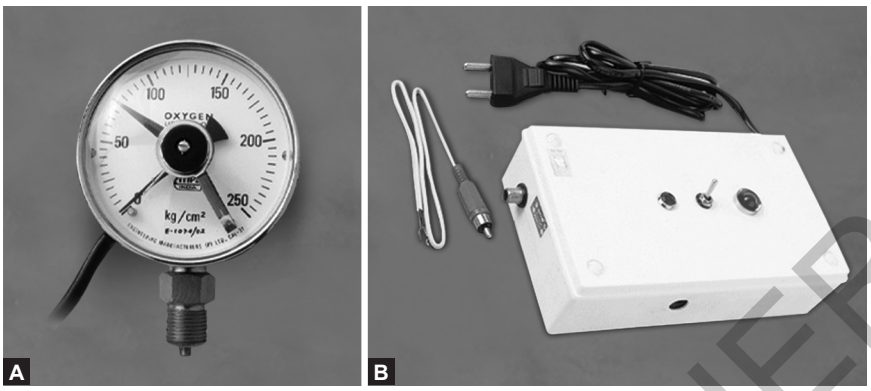

Figs 4.4A and B: Minimum contact gauge and its alarm device; • The central knob on the dial can be rotated to adjust the lowest pressure at which the electrical contact should be made to activate the audiovisual indication

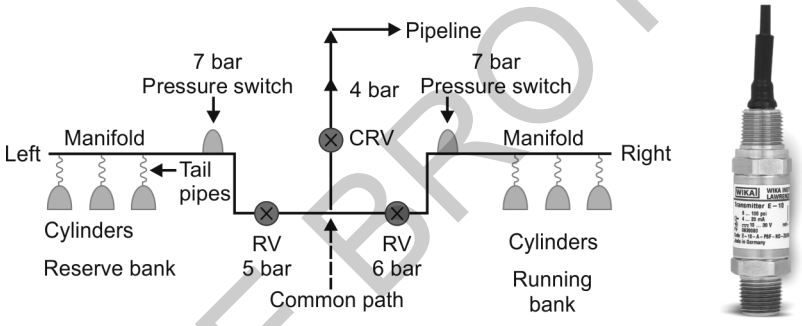

Fig. 4.5: Schematic representation of modern control panel and pressure switch • The pressure reducing valve (RV) in the 'Reserve bank' is set as 5 bar • The pressure reducing valve (RV) in 'Running bank' is set as 6 bar (1 bar higher) • The central reducing valve (CRV) is set at 4 bar • On both sides the pressure switch is set at 7 bar to activate the warning lamp, • All the cylinders in both the banks (Reserve and Running) kept fully open. Because the Running bank outlet pressure is set higher (6 bar) than the outlet pressure of Reserve bank (5 bar), preferential flow occurs from the Running bank to the Central reducing valve (CRV) where it is reduced further to 4 bar and flows into the pipeline • When the pressure drops to 7 bar in the 'Running bank', the warning lamp is activated to indicate that the bank is nearing exhaustion • When the pressure drops below 5 bar automatically preferential flow from the Reserve bank will start and it will take over the supply

- Then he will replace the empty cylinders with full cylinders and open them and change the lever to 'Reserve'.
- Now the new cylinders connected will form the "Reserve bank".
- Once the reserve bank is full and is open, the warning lamp will go OFF.
- In case, the exhausted cylinders are not replaced with full cylinders, the warning lamp continues to be 'ON'.
- Now the 'Running bank' is empty and the supply to the pipeline is from the reserve bank.
- When the second bank also is nearing exhaustion, as it reaches the set pressure, it activates a second warning lamp.

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- Now, there will be two warning lamps 'on' on both sides. This indicates that central pipeline supply will fail soon, if the cylinders are not replaced.
- There are two sets of warning lamps **(Fig. 4.1C)** one set on the panel and the other set at the operation theater.
- Even at this time, if cylinders in the manifold room could not be replaced with new ones to re-establish the pipeline supply, the A-Type spare cylinders attached to the machine must be used as standby until the pipeline supply is restored.

Bulk Gas Cylinders

- The cylinders used for feeding the manifolds of central pipeline system are known as D-Type cylinders (Note that different countries have different names for this cylinder).
- In India, D-Type cylinders are of 50 L water capacity (LWC).
- In a cylinder with *1 L water* capacity *150 bar* pressure will compress 150 L of O_2 into it.
- The water capacity of D-Type cylinder is approximately 47 L and the exact volume is usually seen printed on the shoulder of the cylinder. However, for convenience, we take 50 L as the volume.
- Full pressure in oxygen cylinder is 150 bars (2,000 psi). Therefore, the full cylinder has $150 \times 50 = 7500$ L of gas.
- Hence, if there are four "D-Type cylinders in a bank, then the total gas available is $7,500 \times 4 = 30,000$ L (Approximately).
- These cylinders come with "Bullnose valves" which have screw threaded outlets to which the screw threads of "Copper tail pipe" is connected and tightened. These screw threads are 'gas specific' and cannot be connected other gas cylinders **(Figs 4.2A to C)**.
- The outlets may be pointing upwards or on the sides and depending upon that the suitable type of tail pipes are used.
- At the manifold end, a 'non return valve' is incorporated to allow unidirectional flow and to prevent transfilling of cylinders **(Figs 4.3A and B)**.
- There may be small variations in the tail pipes of different gas suppliers.

Safety Precautions in a Manifold Room

- The manifolds must be housed in a well-ventilated room constructed with fireproof material such as concrete.
- Ventilators must be provided at the top and bottom of the room.
- It must have adequate space for handling trolleys, bulky cylinders, for easy changing of cylinders on the manifold, keeping extra reserve cylinders, etc.
- No oil, grease, or any other flammable material should be brought into the room.
- There should be no "High Voltage" electricity cable in the vicinity.
- There should be no drains or gulleys where gas can collect.
- The compressors and reservoir for the central vacuum plant and the plant for medical compressed air should not be housed in the manifold room.
- Provision should be made for securing the cylinders to the wall **(Fig. 4.1A)**.
- All the personnel should be made to understand that compressed gas, particularly; oxygen can be dangerous, if mishandled.
- Fire extinguishers of adequate size in adequate numbers must be available at strategic points.

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INDICATORS AND ALARMS

- Since the manifolds are usually situated remote from the users and the staff who are responsible for changing the cylinders (a Senior Anesthesia Technician in the name of manifold room technician), indicators are installed to indicate and warn about the status of gas source in the manifold.
- Indicators will be available in manifold room and in operating theater suite so that the anesthesiologist as well as the person responsible for changing the cylinders is informed.
- The indicators or alarms are of two types: it may be "visual alarm" or "audible alarm". Commonly both are present in the same unit. If needed audible alarm may be silenced.
- The visual indicators are in the form of lights (green, red and amber).
- Normally, running is indicated by green light. Red light or flashing orange when a bank is nearing empty.
- When a cylinder bank nears exhaustion, as sensed by a predetermined pressure, the indicator is activated.
- It is activated by the minimum contact gauge. The system is shown in **Figures 4.4A and B**.
- When the cylinders are replenished, the alarm stops.
- The contact gauge has electrical contacts. It should be connected to the pipeline gas failure alarm, which has two signal lights, a buzzer and an "ON/OFF" switch **(Figs 4.4A and B)**.
- When the contact gauge is connected to the power supply and the ON/OFF switch of the alarm is switched "ON", green light will show indicating that the electrical supply serving the contact gauge and alarm are working correctly.
- The green light should show at all-times when the pipeline is in use.
- The other red light is a warning light which is automatically switched ON and the buzzer rings when the pressure in the running cylinder has fallen to a determined value.
- Put the switch to OFF position after which the reserve cylinders should be brought into operation (running) by turning the handle provided, promptly to ensure continuity of supply.
- After this, the empty cylinders are replaced with full cylinders in the exhausted bank and are opened fully. Now the warning lamp will go OFF. Switching the handle to "Reserve" will make the steps complete.

Pressure Sensors or Switches

- In modern manifolds, instead of the *Minimum contact gauge*, more sensitive and safe *Pressure sensor switches* working on low voltage are used on the manifolds of both right and left banks to activate the warning device **(Fig. 4.5)**.
- The desired pressure to activate the warning lamp can be set in the switch and connected to the warning lamps.
- When the pressure in the outlet of the bank falls below the set value (usually 7 bar), it activates a warning lamp on the panel as well as in the operating theater to indicate that the respective bank is nearing exhaustion (Empty).

Modern Control Panels

- Modern control panels are simplified.
- Double shut off valves are eliminated and automatic takeover is done by the drop in pressure of the manifold outlet.

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- Schematic representation shown in **Figure 4.5**.
  The pressures set in the system in the following way: (1bar is approximately 1 kg):
  Pressure switches - 7 bar
  Running bank reducing valve (RV) - 6 bar
  Reserve bank reducing valve (RV) - 5 bar
  Central reducing valve (CRV) - 4 bar
- In the semi automatic control panel the reserve bank will start working as soon as the running manifolds outlet pressure becomes equal to the reserve banks outlet pressure (5 bar).
- As the running banks cylinder pressure has gone down the reserve bank takes over to feed the pipeline.
- It will not wait for the pressure to go down further as a very small differential pressure is sufficient for change over.
- The 'nonreturn valves prevent transfilling into the other side.

The **Figure 4.5** shows the right manifold (Bank) and the left manifold having 3 cylinders connected by coiled tail pipes.

- The pressure switch is connected to manifold pipe on both sides before the pipe enters the pressure reducing valves (RV).
- The pressure switch is set at 7 bar. This means that when the pressure in the cylinders falls from 150 bar to a level below 7 bar (almost nearing empty), the switch will activate the warning lamp.
- The pressure of the cylinders in the bank (2000 psi or 150 kg/sq cm or 150 bar) is reduced by the pressure reducing valves RV.
- This outlet pressure in the pressure reducing valve is set a little lower than the pressure (7 bar) set in the set in the pressure switch.
- Taking right bank as 'Running bank' the outlet pressure in the reducing valve is set as 6 kg or 6 bar.
- The left bank is now the 'Reserve bank'. So, the outlet pressure in the reducing valve is set one kg lower, 5 kg or 5 bar.
- Both these outlets from the banks join at the centre and proceed as a single pipe (common path) towards the central valve (CRV).
- This central reducing valve (CRV) further reduces the pressure to 4 bar (60 psi) and allows to flow into the pipeline to the operating theater.
- When all the cylinders in both the banks are open, the outlet pressure of the running bank (Right) 6 bar, which is 1 bar higher than the outlet pressure of the reserve bank (Left) 5 bar. Hence, the flow from the left bank is opposed and there will be flow only from the right bank to the pipeline.
- This flow of gas will continue till the outlet pressure of the right bank drops a little lower than that of the left bank, say 4.5 bar.
- At this point, because the right bank outlet pressure is lower than the left bank outlet pressure, flow of gases start from the left bank and left bank automatically takes over.
- This allows uninterrupted supply of gases to the pipeline.
- Now, the empty cylinders in the right bank are replaced with new cylinders and the controls are set as "Reserve" on the right side and "Running" on the left side by turning the handles provided for that. This will reset the outlet pressure of right and left banks.

The most important things to be remembered at this point are:

- *The pressure switches are set at 7 kg and so the warning lamp will be activated sufficiently before the supply of the gas exhausts.* It means still there is gas present

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in the cylinder (2 bar pressure) to feed the pipeline for some more time before the reserve bank takes over.
- So, when the running bank cylinders are nearing exhaustion, and sufficiently before the reserve bank cylinders takeover automatically, the warning lamp is activated, and indicates it in control panel of manifold room as well as in operation theater.
- At the earliest possible time, technician visits the manifold room, replaces the exhausted cylinders and fixes full cylinders to the manifold, and then turns the control in such a way that the newly fixed cylinders now become 'Reserve bank' and the other side is 'Running bank'.
- When this change is done the warning lamp goes 'OFF'.

PIPELINES AND ISOLATION VALVES

- The pipes are made of medical grade copper and the joints are made with gas welding.
- Copper to brass welding is generally not permitted on site as flux is used for brazing which can leave a residue, which will be difficult to clean and degrease on site.
- So copper-to-copper brazing only is permitted with a special CP104 brazing rod which has silver, copper and phosphorous alloy.
- The pipes of suitable size is used depending upon the volume of use and are color coded. Some countries use same color entire length where as in India 3" strip of color is painted at specific intervals.
- There are shut off valves which help to isolate specific areas of pipeline system for maintenance service purpose **(Fig. 4.6)**.

Terminal Outlets (Wall Outlet of Pipeline)

- From the main pipeline that runs near the roof, smaller pipes are drawn down perpendicular to the main line as drops in the required points of use in operating room, postanesthetic care unit (PACU), postoperative wards, ICU, etc.
- These pipes end in wall outlet units. All these outlets have self-sealing valve that prevent gas leak.

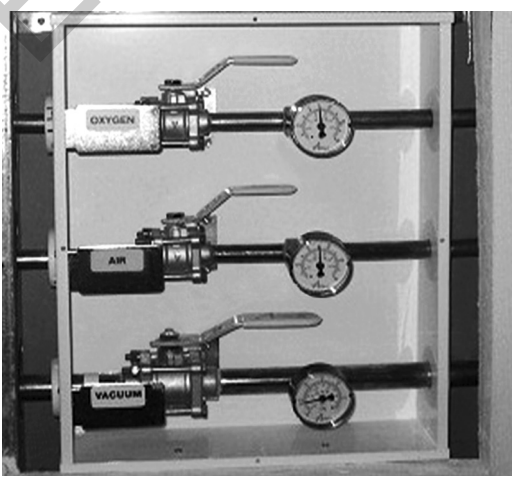

Fig. 4.6: Isolation valves (Regional shut off valve in a box) of the line. • These valves can be closed to isolate the region, so that there is no gas flows in the pipeline that region of supply; • Necessary service can be done in that region without interruption of supply to other regions

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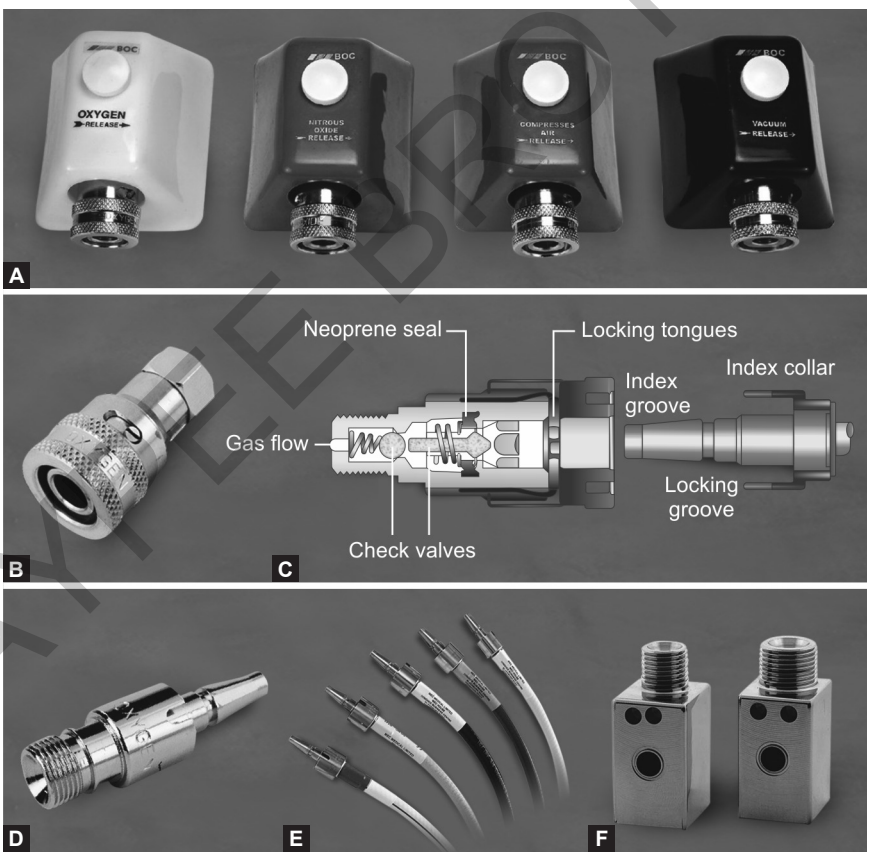
- Commonly "Schrader self-sealing valves" are in use (**Figs 4.7B and C**).
- Usually, the terminal unit provided on the wall as a unit. All the outlets arranged in a row (oxygen, nitrous oxide, medical air and vacuum) **(Fig. 4.7A)**.
- Color-coded flexible hoses carry gases from the outlet point to the machine.
- There are color-coded hoses with gas specific; 'collar indexed' (diameter) probes at one end of the hose and pin indexed 'Yoke Block' **(Fig. 4.7F)** at the other end are used for connecting the machine to the wall outlet **(Figs 4.7D and E)**.
- The probes have a protruding "collar index" that is gas specific with different diameter for each gas **(Fig. 4.7D)**.
- It is impossible to connect a wrong probe (Collar indexed) into an outlet.
- Similarly, it is impossible to connect the 'Yoke block' (Pin-indexed) to the wrong yoke.
- The pin indexed 'Yoke block' **(Fig. 4.7F)** is kept fixed permanently in the yoke assembly and the probe is plugged into the wall outlet to make connection instantly.
- It is easy to insert or remove the probe using one hand. The Schrader valve socket assembly has a spring loaded outer ring which when depressed releases the mechanism that holds the probe and ejects it.



Figs 4.7A to F: Schrader type self-sealing valves, probes and hoses with probes. • Color-coded Schrader self-sealing outlet valve with color coded casing for oxygen, nitrous oxide, air and vacuum; • Schrader valve • The self-sealing mechanism of the Schrader valve • Diameter-coded probe 'Collar indexed' • Different 'Gas specific' - 'Collar indexed' probes fixed with color-coded hoses • Yoke Block with pin index

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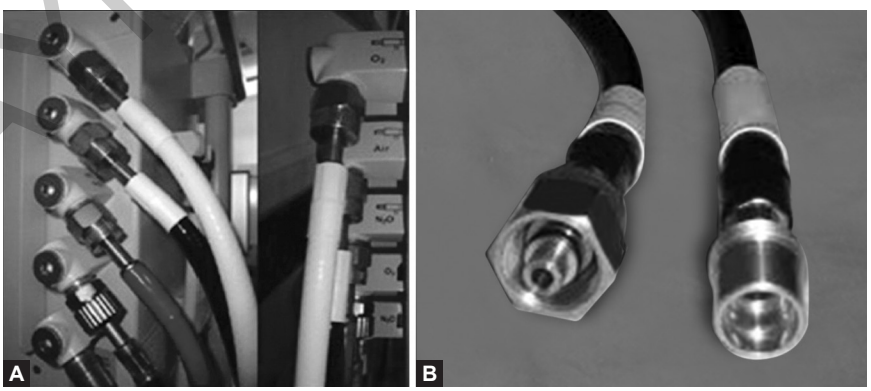
- In modern Anesthesia Workstations at the machine end of the hose non-interchangeable screw threads (NIST) are provided to prevent wrong gas connections **(Figs 4.8A and B)**.
- These are actually not noninterchangeable screw threads, but the unique connector probes are gas specific and non-interchangeable. The nuts have the same diameter and screw threads for all the gas services. Hence, the name NIST is a misnomer and misleading.
- For use in wards, for individual beds, usually oxygen and suction (vacuum) are provided as individual wall outlets.
- In Schrader self-sealing valves the probes can be plugged in from below.
- Some wall outlets have provision that the probe can be plugged in from the front **(Fig. 4.9)**.
- These valves (plugging from front) have double locking type with a 'parking, position. When the probe is plugged in with the first lock, it will stay on (parking), no gas flow will be there. When it is pushed to the second lock the valve opens and gas flow starts. Similarly to remove the probe both the locks have to be released.
- All these outlets and probes together are known as "quick couplers"
- Series of wall outlets in operating room may have one for anesthetic gas scavenging also. This has wider probe and tube **(Fig. 4.10)**.

It has to be remembered that except Schrader valves all other outlet units are not similar in dimensions. It varies with every manufacturer. Hence, it is essential to check whether the probe available in the machine belongs to the same unit and fits in.

Outlet Points from Ceiling

- The hoses lying lose on the floor from the wall outlet to the anesthesia machine may cause severe interference to the movement of personnel as well as sterile instrument trolleys, other equipment, etc.
- For preventing this, swinging overhead 'Hose Booms' were in use in earlier days.
- Now, as the position of the operating table and the anesthesia machine are all almost fixed, the gases delivery through flexible hoses is drawn from the ceiling.



Figs 4.8A and B: Noninterchangeable screw-threaded hose connections

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