Medical Gas Recommending and Regulating Agencies

- **Compressed Gas Association**
- Since 1913, dedicated to developing and promoting safety standards and safe practices in the industrial gas industry
- Develop technical specifications, safety standards, training and educational materials, and promote compliance with these regulations and standards
Medical Gas Recommending and Regulating Agencies

- National Fire Protection Association
  
  To reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically-based consensus codes and standards, research, training, and education

- Methods of fire prevention and protection

- Storage standards
Medical Gas Recommending and Regulating Agencies

- International Standards Organization

The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity.
Medical Gas Recommending and Regulating Agencies

- American National Standards Institute

The Institute's mission is to enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity.

- Coordinates standards for health devices
Medical Gas Recommending and Regulating Agencies

- **Department of Transportation**
  - Regulatory control over handling and shipping

- **Health and Human Services**
  - FDA regulates devices and gas purity

- **Occupational Safety and Health Agency**
  - save lives, prevent injuries and protect the health of America's workers
Gas Cylinders

- **Manufacture**
  - Spun or stamped
  - Heat treated
  - Have a pressure relief

- **Markings**
  - 3A seamless carbon steel
  - 3AA seamless heat treated tempered steel
  - 3AL is aluminum
  - Service pressure
  - Hydrostatic test dates, +
  - Serial #, size, owner’s marks, country
Composite Medical Cylinders

- Carbon-fiberglass
- 22 ft²
- Service pressure 3000 psi
- 4.5 x 15.5”
- 3.2 lbs. Empty
- 5 yr. retest
Gas Cylinder Labels

- Identification of contents
- Lists hazards
- Do not conflict with DOT label or color
- Conspicuously located on the cylinder
- Precautions in the event of accidental contact
- High pressure indication
Gas Cylinder Color Coding

- Primary ID is the label
- CGA color coding allows quick identification
- Gas
  - Oxygen: green
  - Carbon dioxide: gray
  - Nitrous oxide: blue
  - Helium: brown
  - Nitrogen: black
Gas Cylinder Valves

- Direct acting valve
  - needle valve
  - valve seat moves
  - used on cylinders
  - 1500 psi
Diaphragm Valve

- Diaphragm valve
  - valve seat does not turn and is resistant to scoring, which could allow leaks
  - gas is sealed from the stem by a diaphragm
  - used for cylinders < 1500 psi and for flammable anesthetics
Direct-acting and Diaphragm valves compared
Cylinder Safety Relief Devices

- Frangible disc - breaks away under excessive pressure (3305 psi)
- Fusible plug melts at 150-1700 F
- Spring-loaded device
Cylinder Use Rules: CGA and DOT

- do not lubricate
- use soapy water to detect leaks, not a flame
- don’t interchange regulators between gases
- return unlabelled cylinders
- do not expose cylinders to excessive heat in a storage room
- do not modify or repair
- keep valves closed when not in use

- keep valve caps on when not in use
- use appropriate cart to avoid dropping cylinder
- store cylinders in a clean, dry area
- separate full and empty cylinders
- walls must be flame resistant
- restrain large cylinders with a chain
- keep cylinder areas locked/secure
Cylinder Size and Capacity

- Denoted by AA-H, size increases
- E-cylinder: 4 1/4” x 29 3/4”, 22 ft³ or 622 L 02
- H/K cylinder: 9” x 56”, 244 ft³ or 6900 L 02
Cylinder Testing and Inspection

- **Hydrostatic Testing**
  - Required by the DOT
  - Determines elastic expansion and wall thickness
  - Cylinder is pressurized to 5/3 service pressure
  - Emptied
  - Cylinder rejected if permanent expansion exceeds a limit

- Followed by visual inspection
Clinical Applications of Cylinders

- Patient rooms
- Pulmonary function lab (He₂, N₂, CO)
- Home
- Emergency carts
- Intrahospital transport
- Operating rooms: anesthetic gases
- NEVER in an MRI suite
- Variety of gases
- Use the appropriate cart
Attaching Therapy Equipment: American Standard Safety System

- Used for cylinders with threaded valve outlets (>E)
- A matched threaded cylinder outlet, threaded hex nut, and nipple
- Each gas has its own numbered system of thread sizes
- Oxygen and air have right handed, external threads on the cylinder
- Toxic and flammable gases have left-handed, internal threading (BBQ grille)
- These cylinders all are high pressure (up to 2200 psi)
American Standard Safety System

Carbon dioxide—oxygen mixtures (CO₂ not over 7%)
Helium-oxygen mixtures (He not over 20%)

Carbon dioxide and carbon dioxide—oxygen mixtures (CO₂ over 7%)

Carbon monoxide, ethylene, hydrogen, methane, and mixtures containing flammable component

Oxygen and mixtures containing no flammable component except mixtures covered by connections 280, 320, and 580

Argon, helium, nitrogen, and oxygen-helium mixtures (CO₂ less than 20%)

Air for human respiration

Nitrous oxide

(Courtesy Gates-Chimera, Madison, Wis.)
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Attaching Therapy Equipment: Pin Index Safety System

- Used for cylinders with post-type valves (E and smaller)
- High pressure (up to 2200 psi)
- Uses a matched pair of pins in the yoke of the reducing valve and holes on the valve stem
- 6 possible pin locations, 10 combinations
  - 02: 2 and 5
  - air: 1 and 5
Attaching Therapy Equipment: Diameter Index Safety System

- Used for low pressure gases (<200 psi)
- Used for attaching gas delivery appliances to flowmeters and wall outlets
- Consists of matching threaded connections for each gas
- Used for joining 50 psi hoses
- Prohibits use of the wrong gas
Diameter Index Safety System
Attaching Therapy Equipment:  
Key Index Safety System

- Interlocking hardware that attaches a gas delivery device to a wall outlet
- Each gas supply dealer has its own system
- Determined at the time of construction/remodeling
- Puritan, Ohio, NCG, Schrader, Hansen
- May be color-coded
Key Index Safety System

(Courtesy Nellcor Puritan Bennett, Pleasanton, Calif.)

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Pressure Reducing Valves

- Reading a gauge
  - Psig versus psia
- 14.7 psia = 0 psig
- Most gauges read psig, so we leave off the g
Pressure Reducing Valves

- Single stage PRV
  - Reduces tank pressure to working pressure
  - Gas pressure and spring tension oppose to establish working pressure
  - Gas fills the pressure side of the valve
  - Gas pressure on diaphragm compresses a spring, which is connected to a poppet valve
  - Spring tension is preset to the desired working pressure
  - When the pressure in the pressure side of the valve reaches working pressure, the poppet valve closes
  - Gas in the pressure side of the valve does not exceed working pressure
Figure 12-11  A diagram of a modified single-stage reducing valve
Single Stage Adjustable PRV
Multistage PRV

- A series of single stage valves, designed to finely control fluctuations in working pressure
- Used for calibration gases
- Each stage has a pressure relief valve, which opens at 150% of the highest pressure under which it normally operates
A 2-stage adjustable PRV
Bourdon Gauges

- Tapped into the high pressure aide of the pressure reducing valve to indicate tank pressure; an additional Bourdon gauge is tapped into the reducing valve outlet to
- Indicate working pressure in an adjustable pressure reducing valve
- Coiled metal tube, which partially uncoils when exposed to pressure
- Metal tube is connected to a gear mechanism and needle
- Needle indicates pressure
Demand-flow Oxygen Systems

- Flow sensor and valve
- 60% less oxygen for equivalent SpO₂
- Requires flow-sensing nasal cannula
Flowmeters: Theory

- Flow is proportional to:
  - Source pressure – atmospheric pressure

- Flow is indirectly proportional to:
  - Resistance (orifice diameter)

- Flow = P1 – P2/R

- To set flows:
  - Hold variables constant (flow restrictor)
  - Allow P1 to change (Bourdon gauge)
  - Allow R to change (Thorpe tube)
Flowmeters: Flow Restrictor

- Fixed orifice, constant supply pressure (20 or 50 psi)
- Delivers a fixed, non-adjustable flow, proportional to orifice diameter
- Individual devices, calibrated up to 6 L/min
- Safe for home use and transport, cannot be inadvertently changed
- Do not use with any device that creates a back-pressure
Flowmeters: Flow Restrictor

- Have been incorporated in a rotary dial to provide multiple flows
Flowmeters: Bourdon gauge

- High pressure reducing valve with a fixed orifice
- Changing the supply pressure changes the delivered flow
- P1 is changed, while P2 and R are constant
- Recalibrated gauge translates pressure into L/min
- Non-gravity dependent, good for transports
- Should not be used when back-pressure will be applied, since the gauge will read higher than the actual flow (increased P2)
Flowmeters: Bourdon gauge
Flowmeters: Thorpe tube

- Variable orifice, constant source pressure
- Ball floats in a tapered tube, pressure below the ball is higher than pressure above it initially
- Once the ball rises to a point where the air flowing around it, P1 and P2 equalizes, the ball stays in one position
- Calibrated against a constant pressure of 50 psi
- Needle valve is downstream from the flow tube
- Back pressure <50 psi will not affect indicated or actual flow
- Float jumps when plugged-in, label indicates pressure compensation
Uncompensated Thorpe Tube

- Calibrated to ambient pressure
- Needle valve between source gas and thorpe tube
- Back pressure results in an increase in actual flow, but a false low flow indication
Clinical Use of Flowmeters and PRVs

- Combination of PRV and flowmeter is a regulator
- Connection of a regulator to a threaded valve
- Connection of a regulator to a post-type valve
Calculating Tank Duration

- Relation of pressure drop to gas volume
- Cylinder factor
- \((L/\text{psig}) = \text{ft}^3 \text{ of full cyl} \times 28.3 \ (L/\text{ft}^3)\)
  - pressure of full cyl in psig
- Factors to know: \(E = 0.28, \ G = 2.41, \ H/K = 3.14\)
- \(\text{ft}^3\) of cylinder in Egan’s table 37-3
Calculating Tank Duration

- tank duration (min)

\[ \text{tank duration (min)} = \text{pressure in tank (psi)} \times \text{factor} \]

- desired flow

- Allow 500 psi for safety
Bulk and Liquid Gas Systems

- Liquid Oxygen

- Kept liquid in a Thermos bottle type container by layers of insulation and vacuum

- Liquid passes into a vaporizer, where it warms, expands, and becomes gaseous

- Gaseous oxygen passes through a PRV and is delivered to the hospital piping system

- Bulk system is defined as > 20,000 ft³ connected and ready for use, or > 25,000 ft³ on site ready for use

- May be a fixed container or a trailer-mounted unit
Bulk and Liquid Gas Systems
Portable Liquid Systems

- Used in the home or hospital for much smaller consumption
- More convenient than cylinders, since 1 ft³ of LOX = 862 ft³ of gaseous oxygen
- Similar in construction to the large units
- Have fixed orifice flow metering devices
- Hold about 3 lbs of LOX, 341 l/lb
- Keep unit upright, do not touch metal parts having contact with LOX, do not obstruct vents
Portable Liquid Oxygen System and Reservoir

(Modified from Lampton LM: Home and outpatient oxygen therapy. In Brasher RE, Rhodes M, editors: Chronic obstructive lung disease, St Louis, 1978, Mosby.)

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Portable Liquid Systems

- duration of flow based on weight of LOX:
  - gas remaining (L)
  
  \[ \text{gas remaining (min)} = \frac{\text{gas remaining (L)}}{\text{L/min}} \]

- \( = \text{liquid weight} \times \frac{860 \text{ ft}^3 \text{ gaseous/ft}^3 \text{ liquid}}{2.51 \text{b.}/\text{L}} \)
Manifold oxygen systems

- Two banks of two or more cylinders
- Each cylinder lead must have a check-valve to prohibit leakage if it ruptures
- All cylinders in a bank are opened together, and left open until the changeover alarm sounds
- Often used for Nitrous Oxide for anesthesia
Piping systems

- Begins with the PRV from the manifold or LOX tank
- Pipes of differing diameter are used to maintain 50 psi
- Each area of the hospital is designated a ZONE; each zone has a shutoff valve, to be used in emergencies and during maintenance of the system
- System is carefully cleaned after construction
- System is pressure checked at 75 psi

(Courtesy Nelcor Puritan Bennett, Pleasanton, Calif.)
Zone Valve
Piping systems

- Each connection to the system is called a station outlet
- Outlet incorporates a quick connect fitting for a particular gas
- Color coded
- If the station outlet malfunctions, call maintenance
Air compressors

- Small piston or diaphragm
  - A piston rod moves the piston or diaphragm to create an air flow
  - Used for delivery of nebulizer treatments
  - Usually discarded if malfunctioning
  - Monitor condition of any filter
Air Compressor

- Large piston or rotary
  - Hospital supply
  - Air is dried and filtered, delivered to piping system
  - 50 psi
Oxygen concentrator: OED

- Plastic membrane < 1.0 micron thick separates two chambers
- The membrane is more permeable to oxygen and water vapor than it is to nitrogen
- A constant vacuum is exerted across the membrane
- Results in humidified 40% oxygen
Oxygen concentrator: Molecular Sieve

- Air is compressed into one of two molecular sieves.
- Each sieve contains sodium aluminum silicate pellets to absorb nitrogen.
- Once one sieve is saturated with nitrogen, a purging system flushes it, while the other sieve is activated.
- Results in up to 90% O2 at 2 L/min, less % with higher flows.
Oxygen concentrator applications

- Un-piped areas of the hospital
- Home use
- Check filter, flow, and FiO₂ periodically
- If FiO₂ begins to fall, the sieves need to be emptied and refilled with zeolite
- Now portable
Portable Oxygen Concentrators

- 18 lbs, 90% oxygen
- Continuous or pulse delivery
- 1.8-5 hrs/charge

**Alarms/Alerts**

- Loss of power
- Low Power Cartridge
- Low Therapeutic Oxygen Output
- Oxygen flow outside normal limits
- No inspiration detected in Pulse Flow Unit Malfunction

<table>
<thead>
<tr>
<th>Device name</th>
<th>Oxygen Production Capabilities per minute (ml)</th>
</tr>
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<tbody>
<tr>
<td>Eclipse® 2 (SeQual Technologies Inc)</td>
<td>3000 ml</td>
</tr>
<tr>
<td>EverGo™ (Respironics Inc)</td>
<td>1050 ml</td>
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<tr>
<td>XPO²™ (Invacare Corporation)</td>
<td>950 ml</td>
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<td>LifeStyle™ (AirSep Corporation)</td>
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<tr>
<td>Inogen One™ (Inogen, Inc.)</td>
<td>750 ml</td>
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<tr>
<td>FreeStyle™ (AirSep Corporation)</td>
<td>~500 ml</td>
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