SpaceTEC®

National Aerospace Technical Education Center

Vehicle Processing Readiness Course

Fluid Systems

Instructed by: Bill Fletcher

www.spacetec.org

Agenda

- Units of Measure
- Definitions
- Hydraulics
- Cryogenics

Units of Measure

Metric Prefixes

yotta, (Y), meaning 10^{24}	deci, (d), meaning 10^{-1}
zetta, (Z), meaning 10^{21}	centi, (c), meaning 10^{-2}
exa, (E), meaning 10^{18}	milli, (m), meaning 10^{-3}
peta, (P), meaning 10^{15}	micro, (u), meaning 10^{-6}
tera, (T), meaning 10^{12}	nano, (n), meaning 10^{-9}
giga, (G), meaning 10^{9}	pico, (p), meaning 10^{-12}
mega, (M), meaning 10^{6}	femto, (f), meaning 10^{-15}
kilo, (k), meaning 10^{3}	atto, (a), meaning 10^{-18}
hecto, (h), meaning 10^{2}	zepto, (z), meaning 10^{-21}
deka, (da), meaning 10^{1}	yocto, (y), meaning 10^{-24}

Metric Prefixes

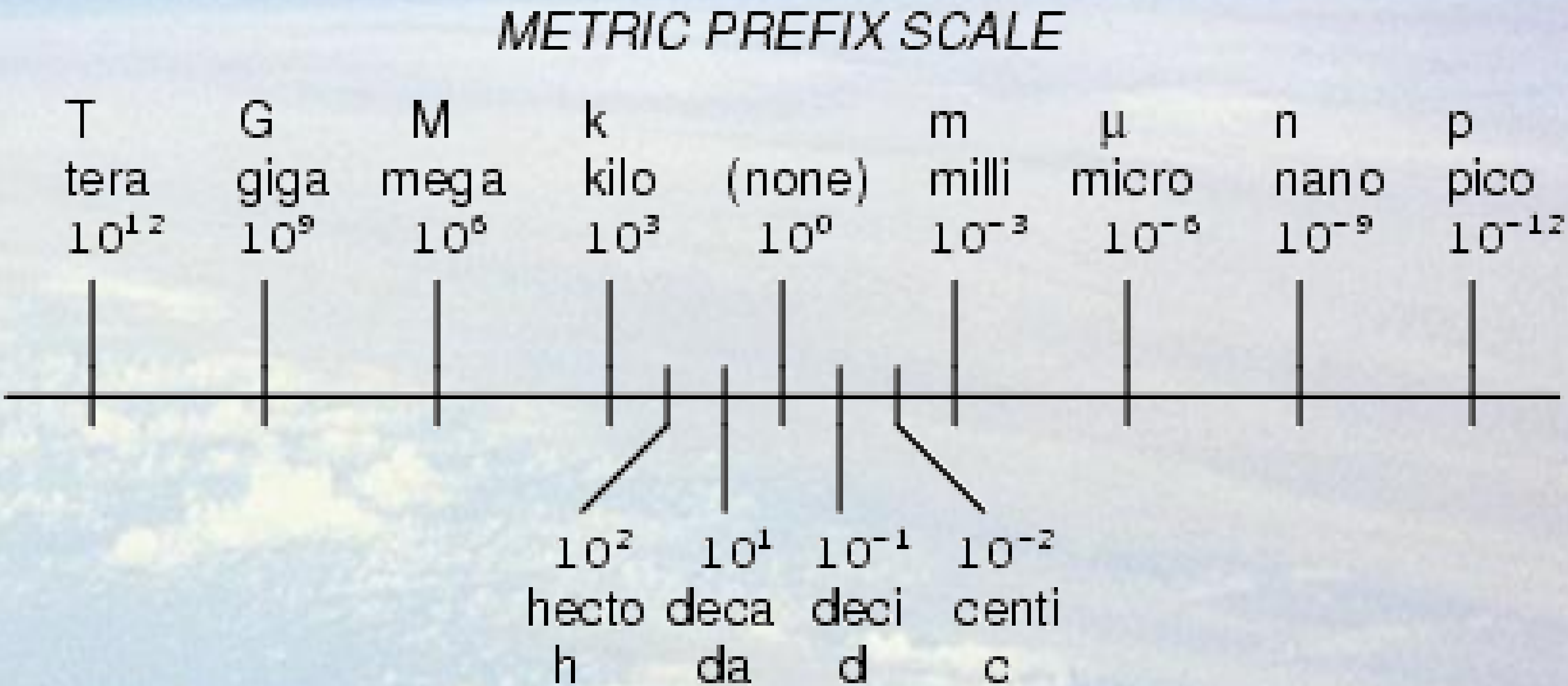
Prefix	Symbol	Factor	Numerically	Name
giga	G	10^9	1 000 000 000	billion**
mega	M	10^6	1 000 000	million
kilo	k	10^3	1 000	thousand
centi	c	10^{-2}	0.01	hundredth
milli	m	10^{-3}	0.001	thousandth
micro	µ	10^{-6}	0.000 001	millionth
nano	n	10^{-9}	0.000 000 001	billionth**

Units of Liquid Volume

10 milliliters (mL)	= 1 centiliter (cL)
10 centiliters	= 1 deciliter (dL) = 100 milliliters
10 deciliters	= 1 liter[1] = 1000 milliliters
10 liters	= 1 dekaliter (daL)
10 dekaliters	= 1 hectoliter (hL) = 100 liters
10 hectoliters	= 1 kiloliter (kL) = 1000 liters

Units of Mass

10 milligrams (mg)	= 1 centigram (cg)
10 centigrams	= 1 decigram (dg) = 100 milligrams
10 decigrams	= 1 gram (g) = 1000 milligrams
10 grams	= 1 dekagram (dag)
10 dekagrams	= 1 hectogram (hg) = 100 grams
10 hectograms	= 1 kilogram (kg) = 1000 grams
1000 kilograms	= 1 megagram (Mg) or 1 metric ton(t)


METRIC PREFIX SCALE
T tera 10^12
G giga 10^9
M mega 10^6
k kilo 10^3
(none) 10^0
m milli 10^-3
µ micro 10^-6
n nano 10^-9
p pico 10^-12
10^2 hecto h
10^1 deca da
10^-1 deci d
10^-2 centi c

- **Conversion factors for temperature**
  - $^oF = (^oC)(9/5) + 32$
  - $^oC = (^oF - 32)(5/9)$
  - $^oK = {^oC} + 273.15$
- **Conversion equivalencies for volume**

  1 US gallon (gal)

  = 231.0 cubic inches (in3)

  = 4 quarts (qt) = 8 pints (pt)

  = 128 fluid ounces (fl. oz.)

  = 3.7854 liters (l)
- **Conversion equivalencies for distance**

  1 inch (in) = 2.540000 centimeter (cm)

- **Conversion equivalencies for weight**

1 pound (lb)

= 16 ounces (oz)

= 0.45359 kilogram (kg)

Conversion equivalencies for force

1 pound-force (lbf) = 4.44822 newton (N)

- **Conversion equivalencies for pressure**

1 pound per square inch (psi)

= 2.03603 inches of mercury (in. Hg)

= 27.6807 inches of water (in. W.C.)

= 6894.757 pascals (Pa)

= 0.0680460 atmospheres (Atm)

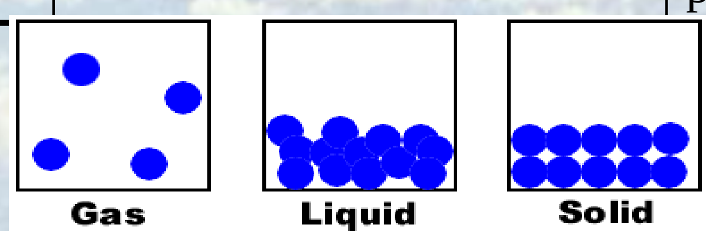
= 0.0689476 bar (bar)

Definitions

States of Matter

– Generally accepted three States of Matter:

Some Characteristics of Gases, Liquids and Solids and the Microscopic Explanation for the Behavior		
gas	**liquid**	**solid**
assumes the shape and volume of its container particles can move past one another	assumes the shape of the part of the container which it occupies particles can move/slide past one another	retains a fixed volume and shape rigid - particles locked into place
compressible lots of free space between particles	not easily compressible little free space between particles	not easily compressible little free space between particles
flows easily particles can move past one another	flows easily particles can move/slide past one another	does not flow easily rigid - particles cannot move/slide past one another



Compressible vs. Incompressible

- **Fluids can be gas or liquids**
- All fluids are compressible to some extent, that is changes in pressure or temperature will result in changes in density.
  - Gases will compress a great deal under pressure
- Incompressibility: Under high pressures the volume of a fluid can decrease in a small proportion, but is considered to be negligible.
- Results in advantage of liquid over gas in transfer power in hydraulic system

Specific Gravity

- The **density** of a material is defined as its mass per unit volume**.**
  - At 4°C pure water has a density (weight or mass) of
    - about 1 g/cu.cm, 1 g/ml, 1 kg/litre, 1000 kg/cu.m,
    - 62.4 lb/cu.ft
- **Specific gravity** is defined as the ratio of the density of a given solid or liquid substance to the density of water at a specific temperature and pressure, typically at 4°C (39°F) and 1 atm.
  - Dimensionless
  - Ex: Lead has a specific gravity of 11.35, so it is 11.35 times as dense as water
- Specific Gravity is measured with a **hydrometer**

Viscosity and Viscosity Requirements

- **Viscosity**, a measure of the resistance of a fluid which is being deformed by either shear stress or extensional stress.
- Results in the resistance of a liquid to flow, or its "thickness“ and may be thought of as a measure of fluid friction.
- Eg: Water is "thin", Vegetable oil is "thick"

Viscosity and Viscosity Requirements

- One of the most important criteria in the selection of a hydraulic fluid is viscosity
- Too low in viscosity:
  - Can reduce the volumetric efficiency of pumps
  - Cause fluid overheating
  - Can lead to increased friction and pump wear.
- Too high in viscosity:
  - Can cause poor mechanical efficiency
  - Startup issues
  - Wear due to cavitation

Viscosity and Viscosity Requirements

- High temperatures can result in viscosity changes
- Viscosity Index highlights how a lubricant's viscosity changes with variations in temperature
  - Low viscosity indexes (VI) indicate that a liquid will vary greatly in viscosity with changes in temperature
- Because of additives, etc. liquids derived from the same source may not have the same viscosity

Streamline flow

- **Flow** - any uninterrupted stream or discharge
- **Streamline flow** - flow of a gas or liquid in which the velocity at any point is relatively steady laminar flow - nonturbulent streamline flow in parallel layers (laminate)
- Friction losses in a system are higher in turbulent flow than in streamline flow

Measuring Fluid Flow

- Both gas and liquid flow can be measured in volumetric or mass flow rates (such as litres per second or kg/s)
- Gases are compressible and change volume when placed under pressure or are heated or cooled. A volume of gas under one set of conditions (pressure and temperature) is not equivalent to the same gas under different conditions
  - The standard flow rate is the volume flow per time that the measured gas would take up if it was under a standard set of conditions [e.g., Standard cubic feet per minute (SCFM)]
- For liquids, other units are used depending upon the application and industry but might include gallons per minute, liters per second, etc.

Pressure

- **Pressure** (symbol: p or P) is the force per unit area applied to an object in a direction perpendicular to the surface.
  - Can be created by resistance to flow
- **Gauge pressure** is the pressure relative to the local atmospheric or ambient pressure.
- **Absolute pressure** is the pressure relative to the zero pressure
- **Differential Pressure** is difference in pressure between two systems

Standard Atmosphere

- **Atmospheric pressure** is defined as the force per unit area exerted against a surface by the weight of air above that surface at any given point
- The standard atmosphere (symbol: atm) is a unit of pressure and is defined as being equal to 101.325 kPa.
- Other standard units are equivalent: 760 mmHg (torr), 29.92 inHg, 14.696 PSI, 1013.25 millibars. Taken at 0^0 C
- One standard atmosphere is standard pressure used for pneumatic fluid power (ISO R554), and in the aerospace (ISO 2533) and petroleum (ISO 5024) industries.

Barometer

- A **barometer** is an instrument used to measure atmospheric pressure
  - **Water-based barometers**
    - glass container with a sealed body, half filled with water
  - **Mercury barometers**
    - A standard mercury barometer has a glass tube of about 30 inches (about 76 cm) in height, closed at one end, with an open mercury-filled reservoir at the base. Mercury in the tube adjusts until the weight of the mercury column balances the atmospheric force exerted on the reservoir. High atmospheric pressure places more force on the reservoir, forcing mercury higher in the column

Barometer

– **Aneroid barometers**
  - Uses a small, flexible metal box called an aneroid cell.
  - The evacuated (or partially evacuated) capsule (or usually more capsules) is prevented from collapsing by a strong spring. Small changes in external air pressure cause the cell to expand or contract

Inerita

- All matter has inertia, since mass itself is a measure of inertia. Since gases and liquids have mass, they also have inertia which means they resist movement or rate of change of movement.
- The inertia of these fluids would not be related to their viscosity.

Static factors

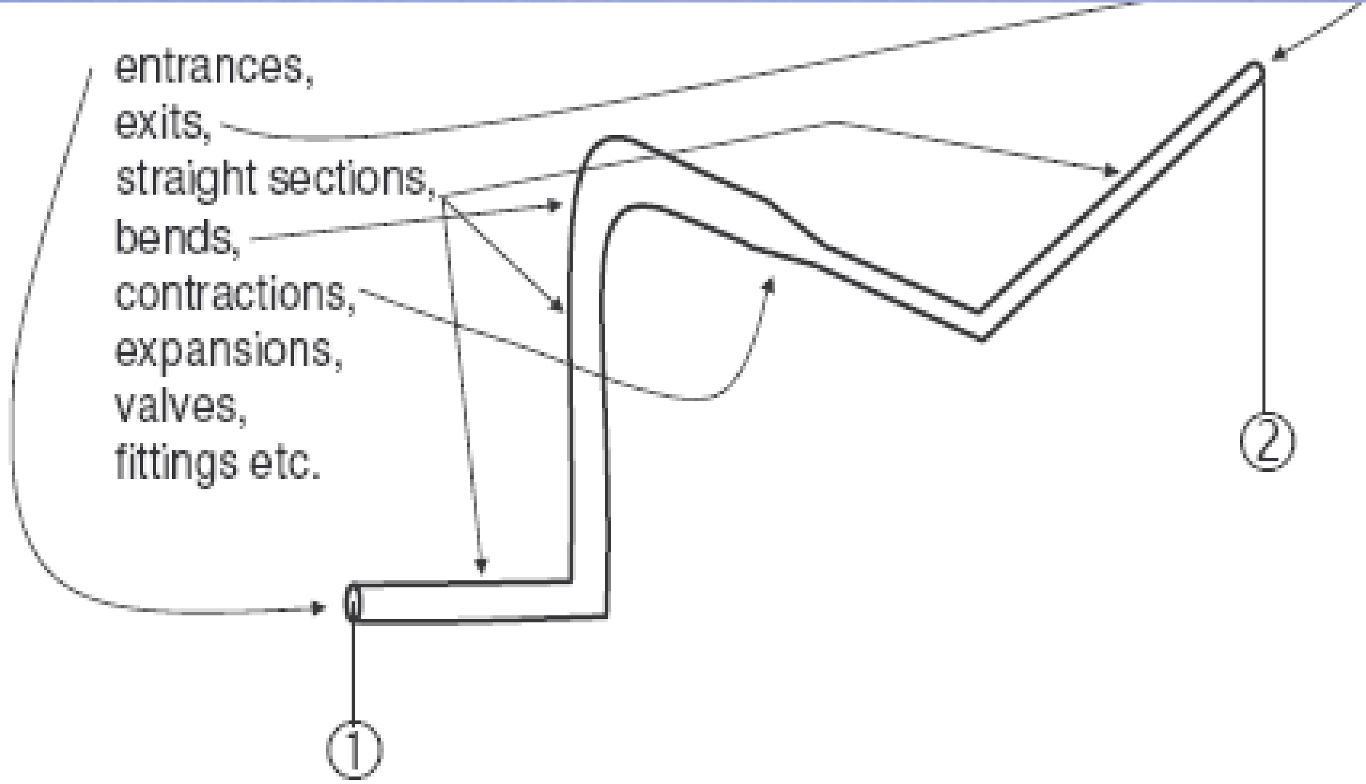
- A static fluid can have **no shearing force** acting on it, and that
- Any force between the fluid and the boundary must be acting at right angles to the boundary.
- Some static forces on a fluid would include: atmospheric pressure, applied forces, gravity

- Wall drag and changes in height lead to pressure drops in pipe fluid flow.

ENERGY LOSSES in FLUID FLOW

- In practice there is no such thing as frictionless flow – and we must normally take frictional losses into account.
- Frictional losses occur because of fluid viscosity and the creation of turbulence because of flow disturbances.

Resistance to Flow and Losses



Changes in fluids cause by temperature, volume, weight

- Gases respond more dramatically to temperature and pressure than do the other three basic types of matter (liquids, solids and plasma)
- E.g., For a small water sample, say, 0.2642 gal (1 l), an increase in pressure from 1-2 atm will decrease the volume of the water by less than 0.01%. A temperature increase from 32° to 212°F (0 to 100°C) will increase its volume by only 2%

Changes in fluids cause by temperature, volume, weight

- For air, an equivalent temperature increase would result in a volume increase of 37%, and an equivalent pressure increase will decrease the volume by a whopping 50%.
- The ideal gas law can be stated as a formula,
  - $pV = nRT$, where p stands for pressure, V for volume, n for number of moles, and T for temperature. R is known as the universal gas constant, a figure equal to 0.0821 atm · liter/mole · K.

Changes in fluids cause by temperature, volume, weight

- What effect does temperature change have on weight of substance?
- Characterize loading operation for high pressure tank

Fluid Power Systems

- Includes hydraulics and pneumatics
- Applied through liquids or gases
- Fluid pumped or compressed to provide force and motion
- Advantages
  - Parts of system can be widely separated
  - Large forces controlled by small forces
  - Motion transmitted without “slack” usually found in mechanical systems
- Disadvantages
  - System losses from moving fluid

Hydraulics

- The engineering science that deals with practical applications where (any) liquid is in motion and transmits energy.

Hydraulic Fundamentals

- "Hydraulics" is used to describe the transmission of fluid power from one location to another

- The fluid can be either liquid or gas.

Hydraulic Fundamentals Definitions

- Incompressibility: Under high pressures the volume of a fluid can decrease in a small proportion, but is considered to be negligible.
- Expansion: Fluids will expand and contract with changes in temperature.
- Pressure transmission: When pressure is applied to a confined body the fluid is transmitted equally in all directions.

Hydraulic Terms

- Area: Measurement of a surface. Knowing the area we can determine the amount of force required to move an object.
- Force: Amount of push or pull on an object
- Unit pressure: Amount of force on an object, usually measured in one square inch.

Hydraulic Terms

- Stroke: Represents the distance of a piston traveling in a cylinder -- usually expressed in inches
- Volume: Expressed in cubic inches, it represents the amount of fluid contained in a reservoir displaced by an actuating cylinder or pump.

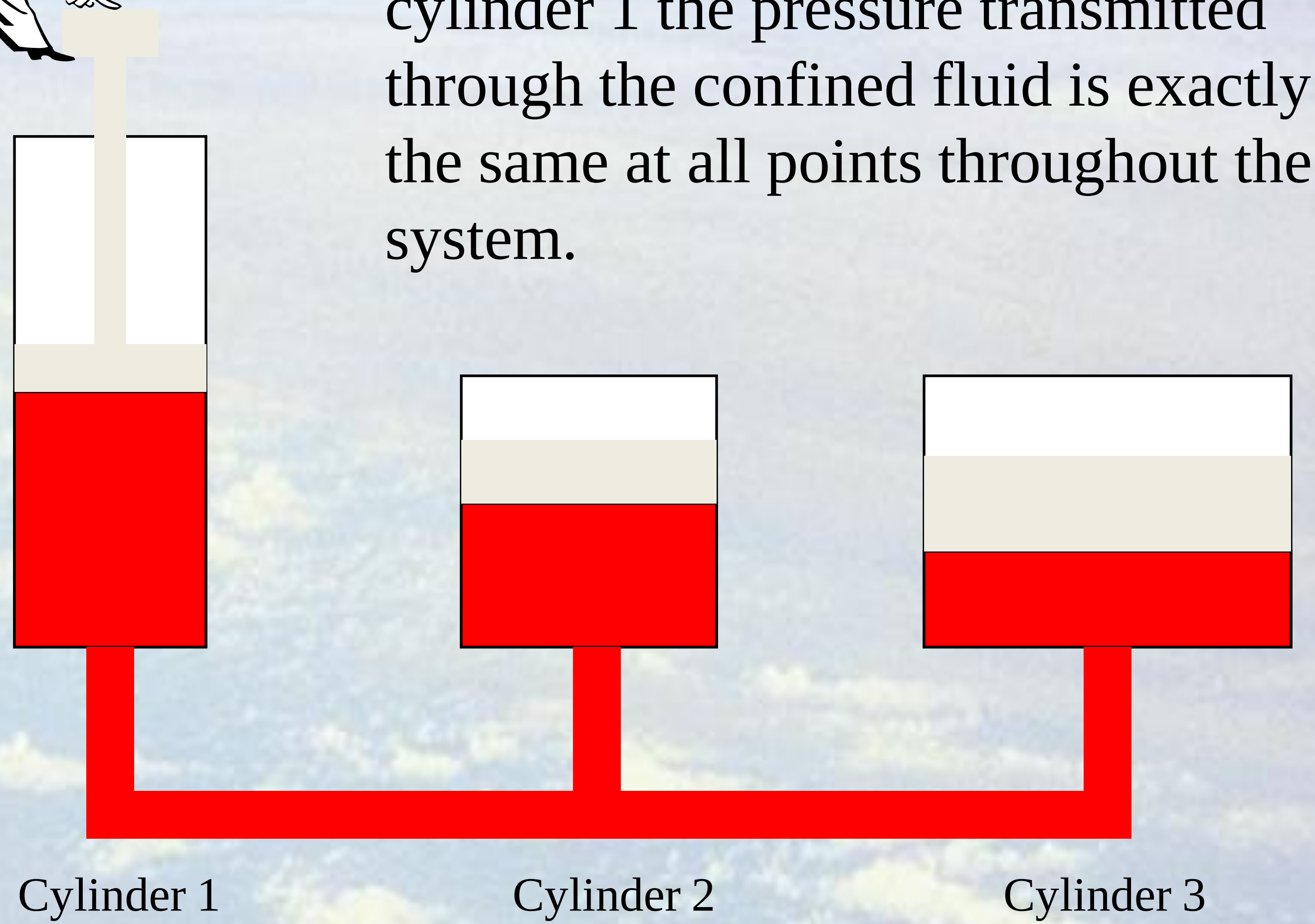
Hydraulic Terms

- Pascal's Law

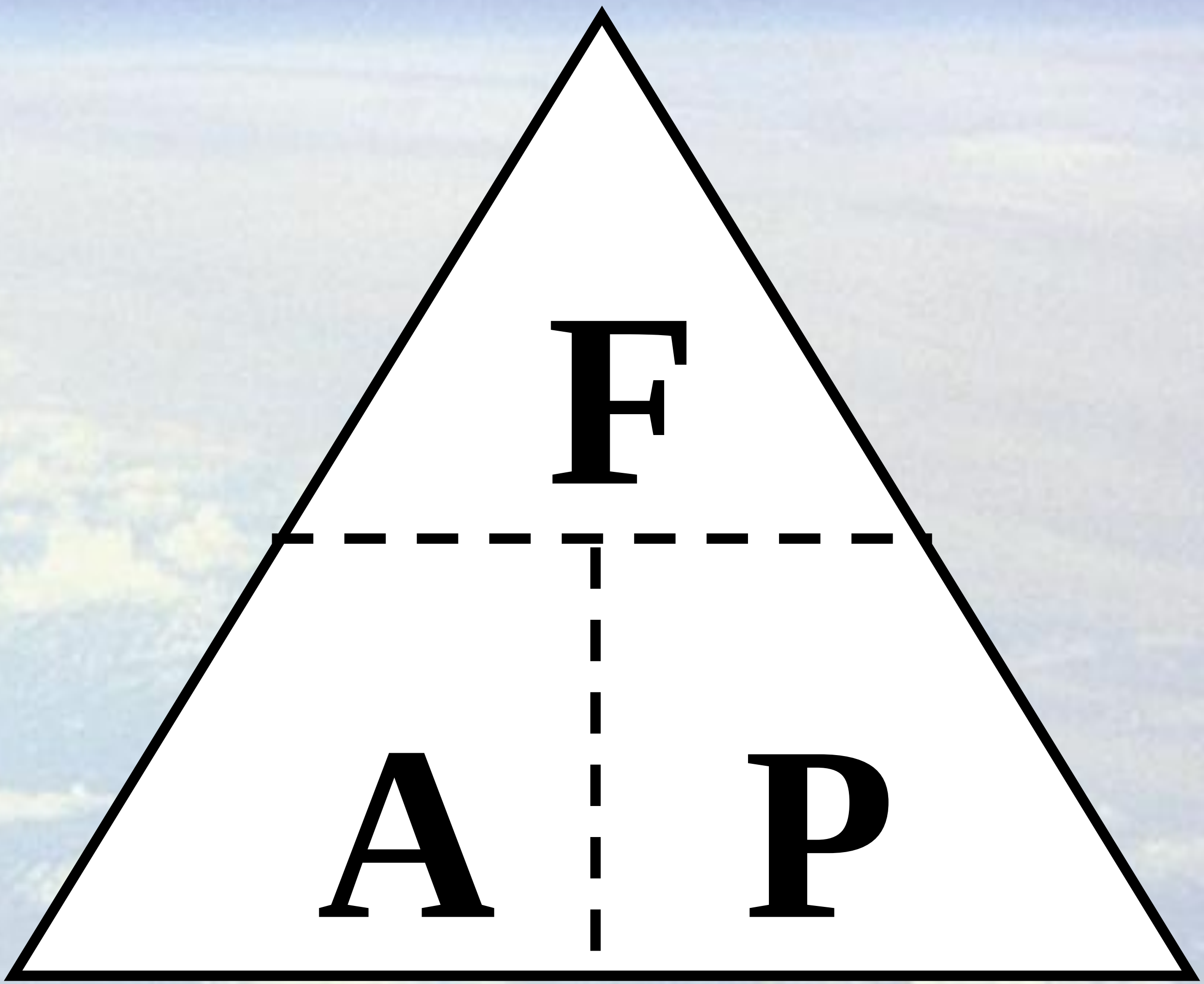
  When a force is exerted on a confined fluid, the pressure is transmitted equally and undiminished in all directions.

Pascal's Law Illustrated

As a force is applied on the piston in cylinder 1 the pressure transmitted through the confined fluid is exactly the same at all points throughout the system.

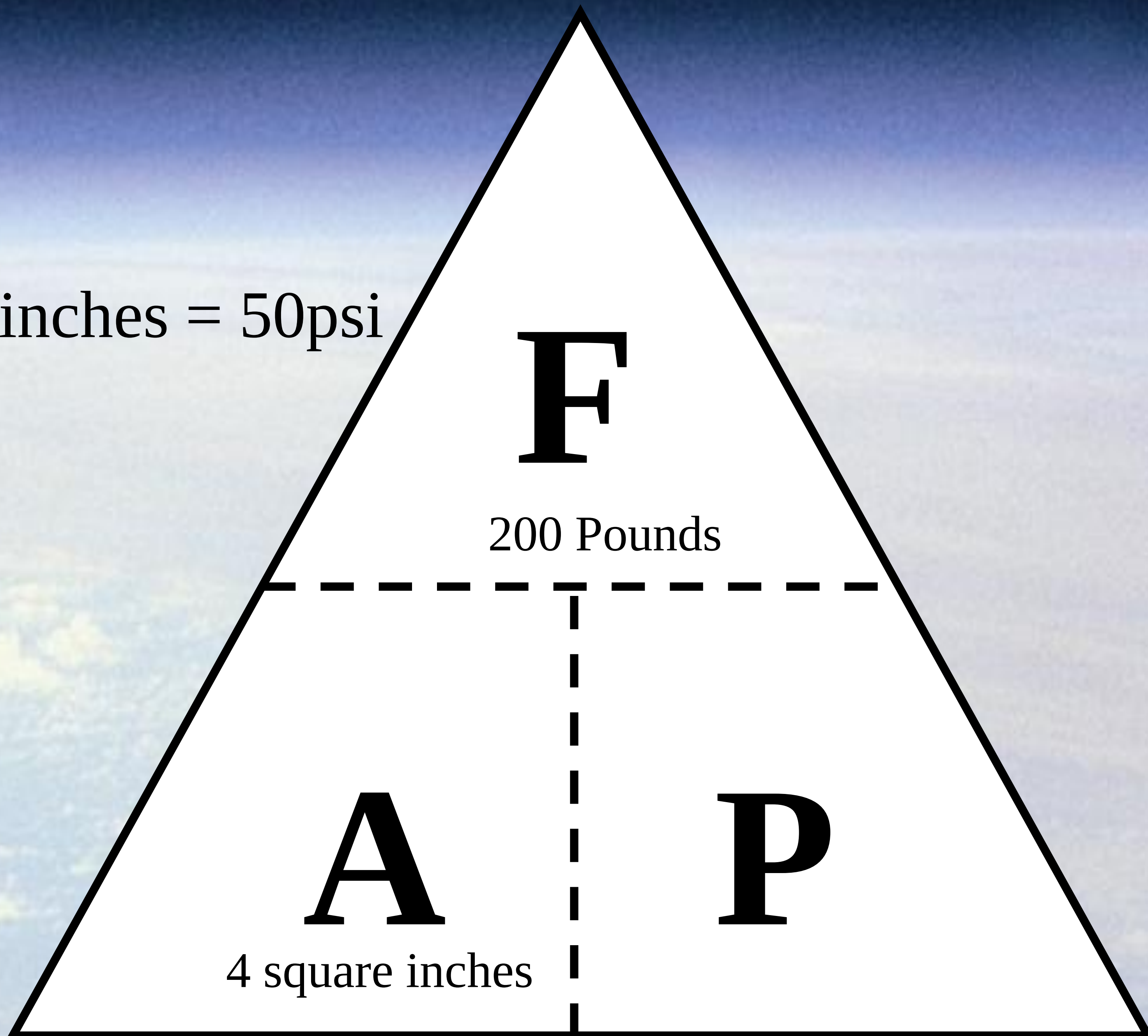


Relationship of Force, Area, and Pressure.



Find P:

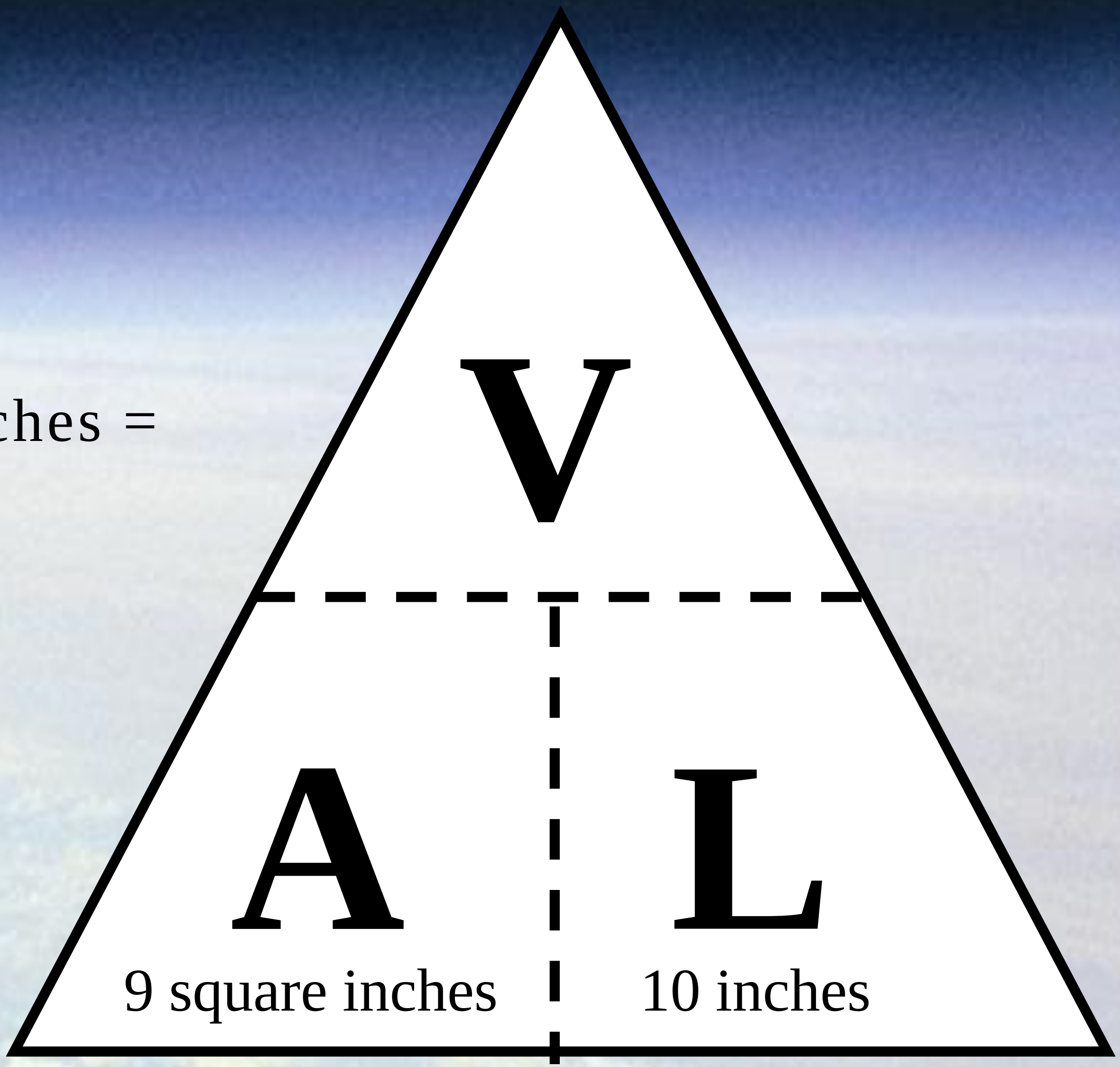
200 lbs/4sq inches = 50psi



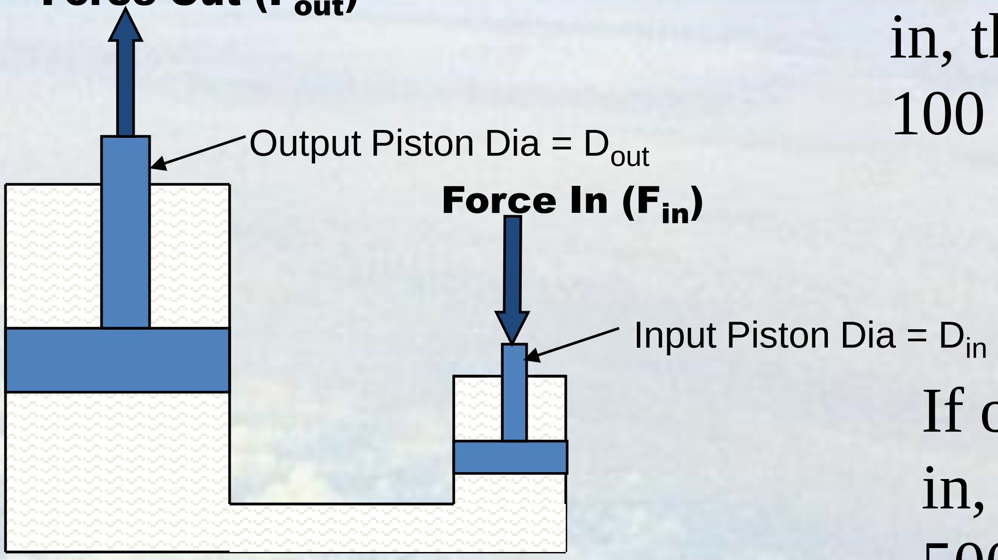
Find V:

9 sq/inches x 10 inches =

90 cubic inches



Hydraulics/Pnuematics Basics



If Force In = 100 lbs and area of in put piston is 1 sq in, then input pressure is 100 psi.

If output piston is 5 sq in, then output force is 500 lbs (maintain 100 psi pressure)

If input piston moves 10 in, then output piston moves 2 in

Cryogenic Systems

- Cryogenics may be defined as low temperature technology or the use of low temperature materials
- Two primary cryogenic propellants used are Hydrogen and oxygen
- Cryogenic inert gases used include Nitrogen and helium which are used as purge hazardous gases and pre-cool propellant systems
- Cryogenics are typically made by the liquefaction of gases

Cryogenic Systems

- **Cryogenics hazards**
  - Flammability
    - Flammable gas such as hydrogen
    - Flammable hazards increase with use of high pressure or concentrated oxygen
  - High pressure gas
    - Cryogenic gas will absorb heat and boil off, creating pressure within storage container. Container must be designed to contain pressure and be equipped with high pressure relief devices which must not be isolated from system or disabled

Cryogenic Systems

- Materials Selection
  - Must be compatible with temperatures encountered, many materials become brittle and lose strength at low temperatures
- Personnel Safety
  - Exposure of personnel to the hazards of fire, high pressure gas, and material failures

Cryogenic Systems

- Personnel Safety (continued)
  - Bodily contact with the extreme low temperatures involved.
    - A very brief contact with fluids or materials at cryogenic temperatures is capable of causing burns similar to thermal burns from high temperature contacts.
    - Prolonged contact with these temperatures will cause embrittlement of the exposed members because of the high water content of the human body. The eyes are especially vulnerable to this type of exposure, so that eye protection is necessary.

Cryogenic Systems

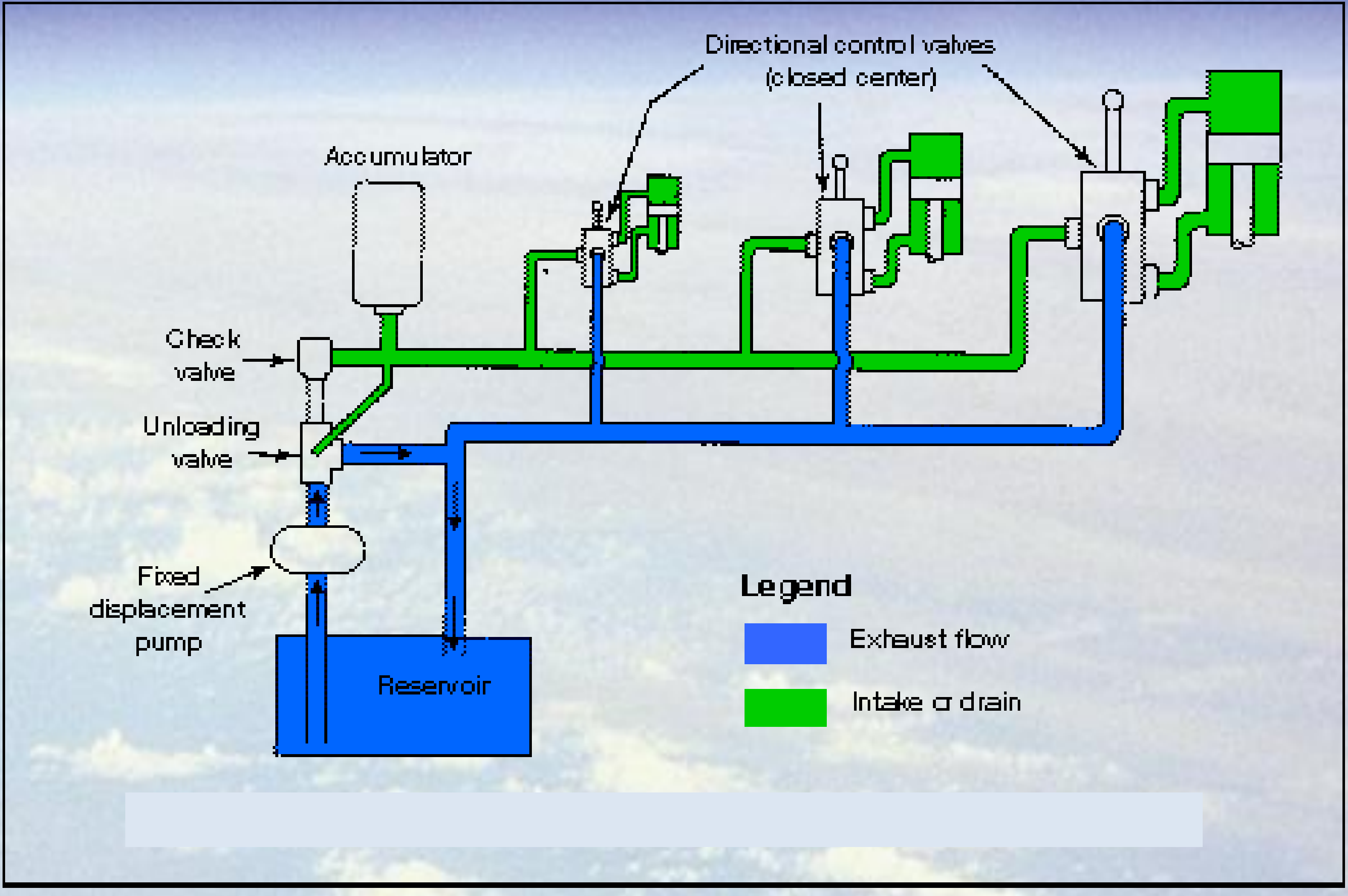
- Personnel Safety (continued)
  - Gases in the cryogenic range may not be toxic, but they are all capable of causing asphyxiation by displacing the air necessary for the support of life. Even oxygen may have harmful physiological effects if prolonged breathing of pure oxygen takes place.

- **Some typical Personal Protective Equipment (PPE) requirements** – safety glasses, face shield, insulating gloves or gauntlets, leather aprons, loose non-absorbent clothing covering arms, trousers, safety shoes which are non-absorbent

Hydraulic Systems

- Basic components
  - Reservoir
  - Pump
  - Valves
  - Actuators

Simple Hydraulic System with Accumulator



Simple Hydraulic System with Accumulator

- In this system, a pump of small but constant volume charges an accumulator.
- When an accumulator is charged to full pressure, an unloading valve diverts the pump flow back to a reservoir. A check valve traps the pressured oil in the circuit.
- When a control valve is operated, an accumulator discharges its oil and actuates a cylinder.
- As pressure begins to drop, an unloading valve directs the pump flow to an accumulator to recharge the flow.
- This system, using a small capacity pump, is effective when operating oil is needed only for a short time.

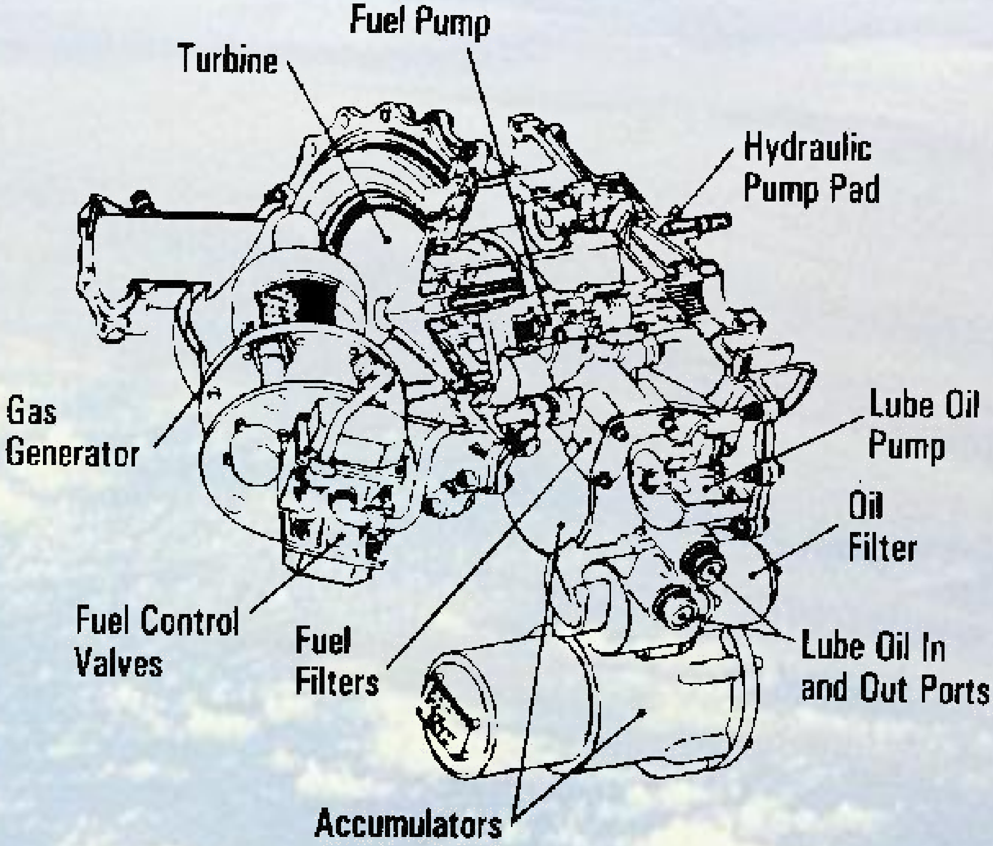
Accumulators

- A hydraulic accumulator stores potential power (liquid under pressure), for future conversion into useful work.
- This work can include operating cylinders and fluid motors, maintaining the required system pressure in case of pump or power failure, and compensating for pressure loss due to leakage.
- Accumulators can be employed as fluid dispensers and fluid barriers and can provide a shock-absorbing (cushioning) action.

Hydraulics on Space Launch Vehicles

- Accumulators frequently precharged with pressurized gas
- Large capacity pump to operate system
  - Variable displacement pumps
  - Fixed displacement pumps
- Power sources usually mechanical (engine or electric motor) or APU
- One principle use is steering (gimbling engines)

Space Shuttle
Auxiliary Power Units and Hydraulic Systems



Hydraulic Fluids

- Fluid types include synthetic compounds, mineral oil, water, and water-based mixtures
- Base stock may be any of: castor oil, glycol, esters, ethers, mineral oil, organophosphate ester, polyalphaolefin, propylene glycol, or silicone.
- Should provide good lubrication, sealing qualities and viscosity that does not create additional flow resistance

Hydraulic Fluids

- Space Shuttle
  - The quantity in each reservoir is 8 gallons.
  - The hydraulic fluid specification is MIL-H-83282, which is a synthetic hydrocarbon (to reduce fire hazards).
    - dyed red so it can be distinguished from incompatible fluids
    - Contains additives to provide the required viscosity and antiwear characteristics, which inhibit oxidation and corrosion
    - used in hydraulic systems having a temperature range of—40°F to +275°T.

Hydraulic Fluid Safety

- Hydraulic systems must store fluid under high pressure.
- Three kinds of hazards exist: burns from the hot, high pressure spray of fluid; bruises, cuts or abrasions from flailing hydraulic lines; and injection of fluid into the skin.
- Proper coupling of high and low pressure hydraulic components and pressure relief valves are important safety measures.

Hydraulic Fluid Safety

- Flash point is the lowest temperature at which a liquid produces sufficient vapors to form an ignitable mixture in air near the surface of the liquid.
- Desire flashpoints provide low degree of evaporation and good resistance to combustion

Petroleum-based mineral oil

- MSDS Hazards
  - **Eye Contact** This product can cause transient mild eye irritation with short-term contact with liquid sprays or mists
  - **Skin Contact** This material can cause mild skin irritation from prolonged or repeated skin contact. Injection under the skin can cause inflammation, swelling and mild central nervous system depression. Injection of pressurized hydrocarbons can cause severe, permanent tissue damage. Initial symptoms may be minor. Injection of petroleum hydrocarbons requires immediate medical attention.
  - **Inhalation** At elevated temperatures or in enclosed spaces, product mist or vapors may irritate the mucous membranes of the nose, the throat, bronchi, and lungs

Petroleum-based mineral oil

- MSDS Hazards (continued)
  - **Ingestion** If swallowed, large volumes of material can cause generalized depression, headache, drowsiness, nausea, vomiting and diarrhea. Smaller doses can cause a laxative effect. If aspirated into the lungs, liquid can cause lung damage.
  - **Chronic Health Effects Summary**
    - Prolonged or repeated skin contact can cause mild irritation and inflammation characterized by drying, cracking, (dermatitis) or oil acne. Repeated or prolonged inhalation of petroleum-based mineral oil mists at concentrations above applicable workplace exposure levels can cause respiratory irritation or other pulmonary effects.

Hydraulic Fluid Contamination

- Hydraulic fluid contamination and deterioration are normal consequences for most hydraulic systems.
- The most common hydraulic fluid contaminants are entrapped air and water, along with particles of metal, seals (rubber) or dirt.
- Fluid deterioration might more appropriately be called "additive deterioration." Additives give the oil its particular characteristics—and be cause these additives are most susceptible to chemical and physical change, their deterioration is what leads to fluid breakdown
- Fluid deterioration is often caused by operation at high temperatures

Water Content

- Water is highly undesirable in hydraulic systems. It can cause emulsions to form, and it can lead to corrosion

Air is an Contaminant

- Extremely Detrimental
  - Premature Wear - Lubricating film compromised by percentage of air, film strength and lubrication properties diminished
  - Noise – Air bubbles traveling in system, bubbles implode (or explode) causing excessive noise, can damage metal components
  - System sponginess – affects fluid density
  - Excessive heat –
  - Caviation

Air Infiltration

- Bad maintenance
- Loose fittings
- Deteriorating or missing seals (O- rings)
  - Gas pressurized accumulators
  - Leaky pump shaft seal
  - Actuator piston rod seals
- Low reservoir fluid level

Oxidation

- As hydraulic fluid deteriorates over time, it oxidizes (union of oil and oxygen), and produces deposits that may cause servovalves to stick. Signs of this natural process include changes in fluid color, odor, or acidity level. Sludge, gum or varnish in the system are further evidence that oxidation has taken place
- Presents of organic acids can lead to oxidation

Abrasives and Friction

- Friction causes hydraulic oil becomes contaminated as result of Hot Spots
- Abrasive contaminates include: rust, sludge, sand

Hydraulic Fluid Sampling

- *Fluid sampling and analysis is the best way to determine whether the fluid and filters* should be changed.
  - will provide an accurate viscosity reading while detecting specific contaminants such as water or foreign particles.
  - used to check the chemical makeup of the fluid to identify whether the additive package is still able to perform as it was originally designed
- Sampling of systems can be through specific sampling ports or places such as pipe drains

Compatibility issues with seals, hose materials, etc.

- Elastomer compatibility and safety.
  - An **elastomer** is a polymer with the property of elasticity. The term, which is derived from *elastic polymer*, is often used interchangeably with the term rubber,
  - Hydraulic equipment such as seals, hoses and accumulator bladders are made up of elastomer materials, which must be compatible with the fluid through the range of system temperatures and as the fluid ages

Compatibility issues with seals, hose materials, etc

- Hydraulic fluid must not react with seal materials and cause breakdown
- Environmental Issues

Sealing and Packing Materials

- These include tetrafluoroethylene (TFE), commonly called Teflon; synthetic rubber (elastomers); cork; leather; metal; and asbestos
  - Petroleum-based fluids are not compatible with natural rubber
- Sealing can be required between: moving and stationary parts, two stationary parts, and two moving parts
- Type of sealing material required is based on motions involved

Sealing and Packing Materials

- Cork makes a good seal or gasket since it compressible

Cleaning Fluid Systems

- Flushing and Drying
- Approved cleaning agents
  - Dry Cleaning solvent for hydraulic systems
  - Cleaning of LOX systems to remove hydrocarbons
- Flushing with Compatible fluid (or base fluid)
  - Sampling during flush (particles)
- Drying with nitrogen
- Pickling (acid) is to remove acid soluble oxides, free iron, etc

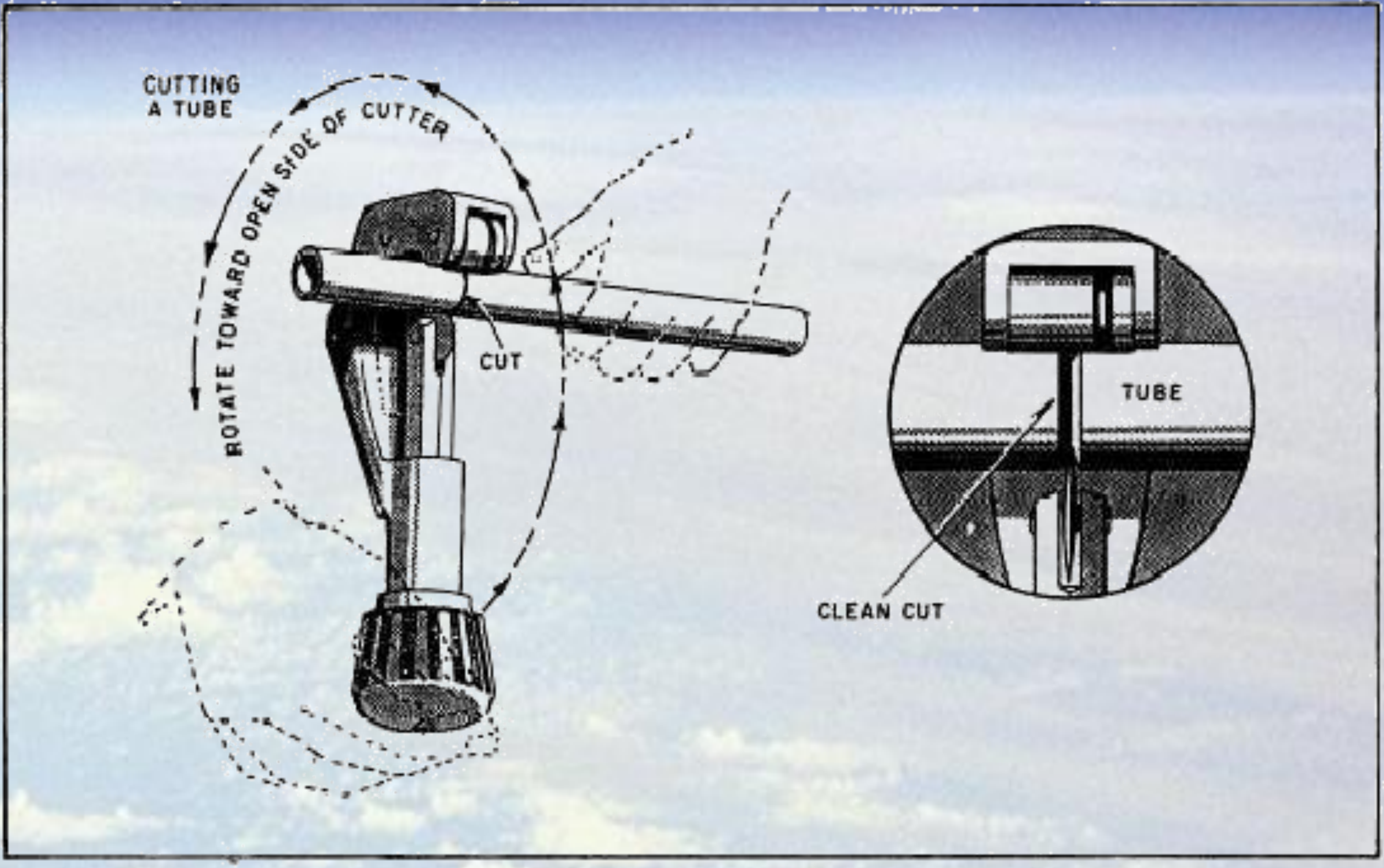
Hydrostatic testing

- What is the advantage of pressure (proof) testing a system with hydrostatic testing vs. pneumatic testing?

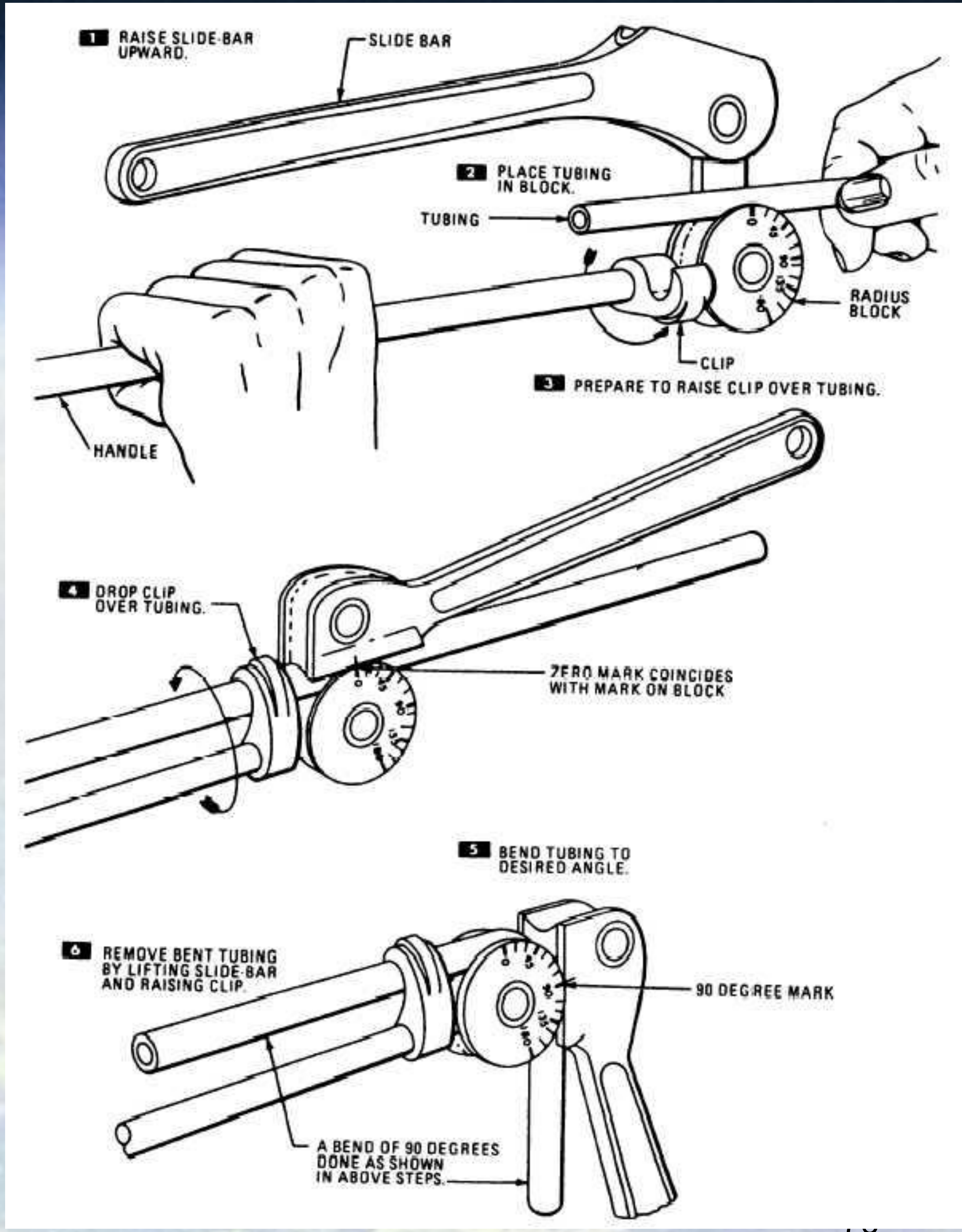
Fluid Lines

- Must be of sufficient size to deliver flow
  - ID
- Strength to withstand pressure
  - Wall thickness
- Inside surfaces that do not create turbulent flow
- Compatible with fluids involved
- Compatible with location to be used
  - Type of material

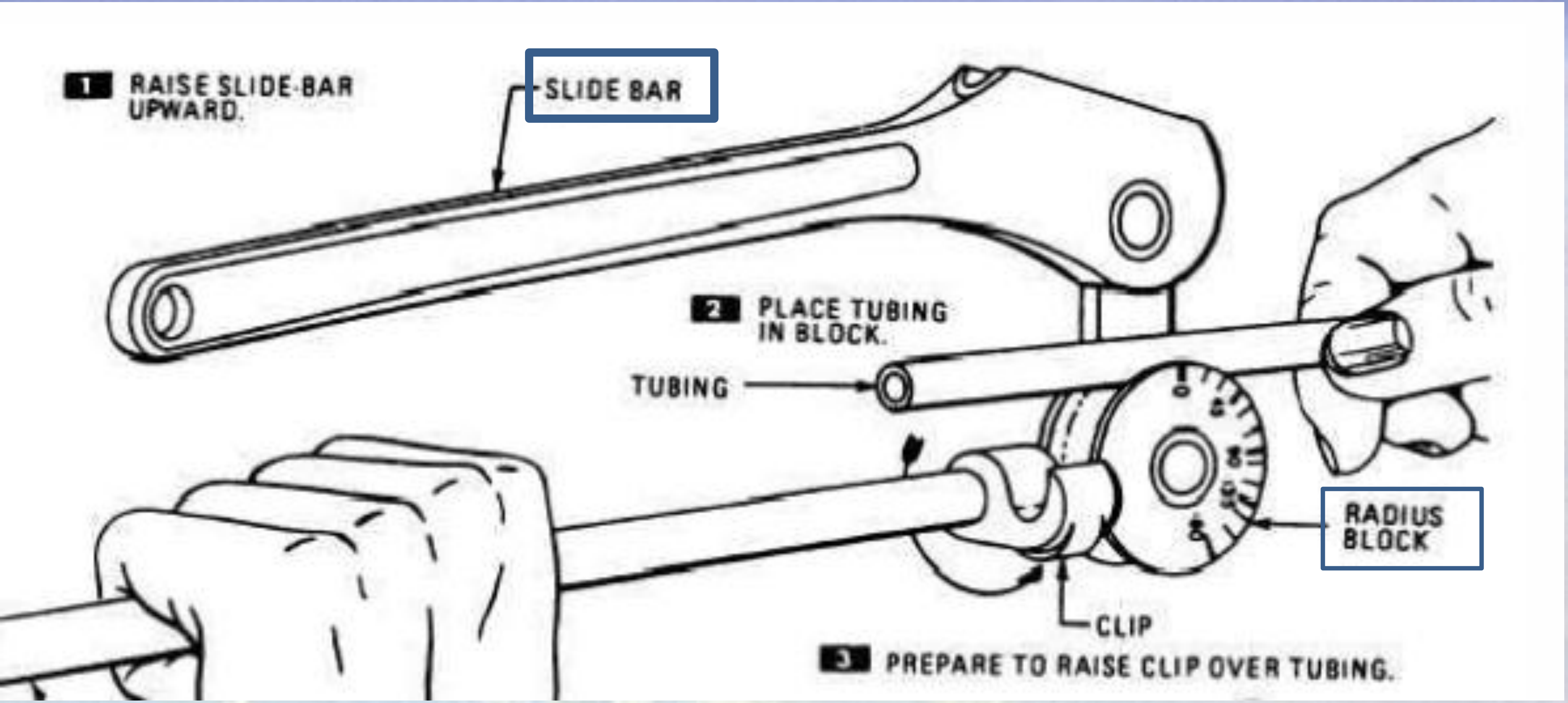
Cutting Tubing



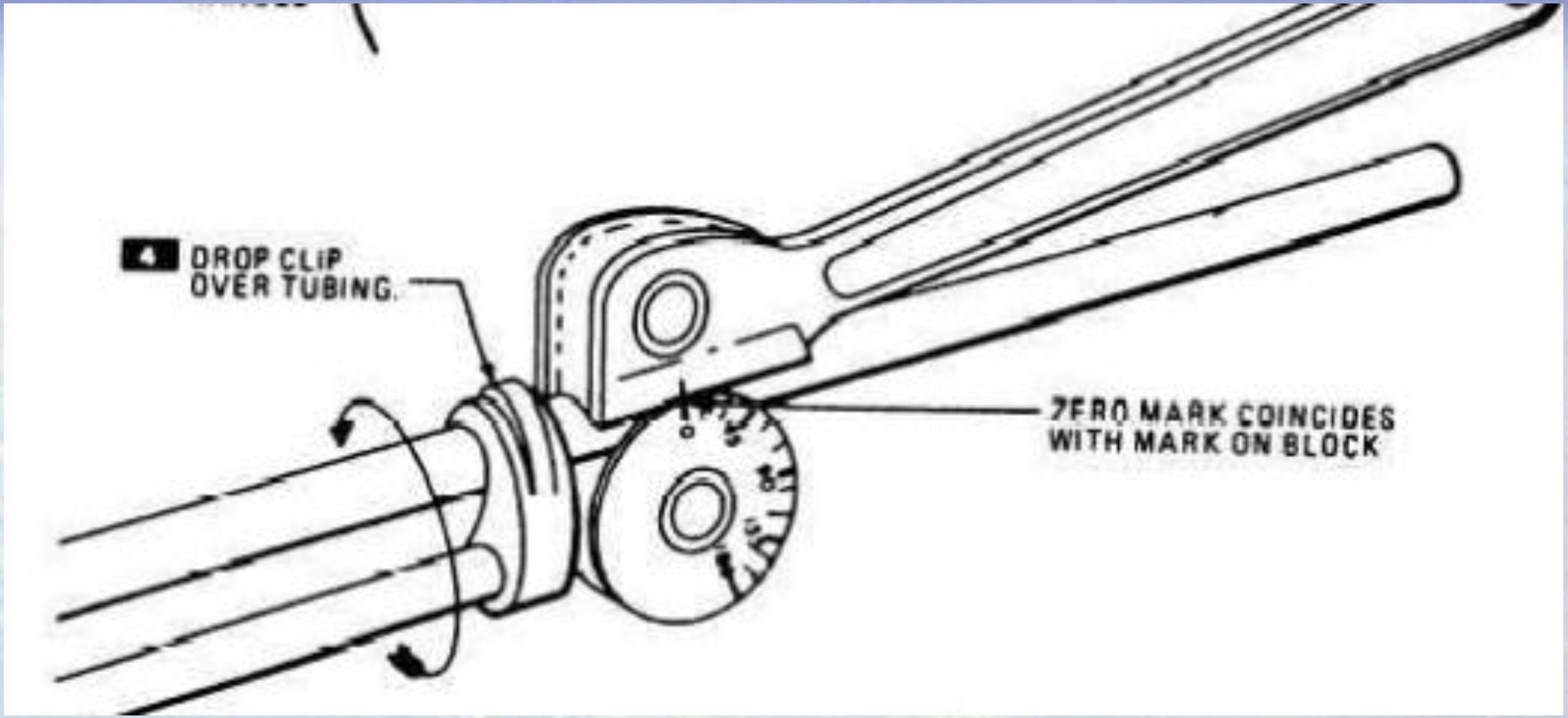
Bending Tubing



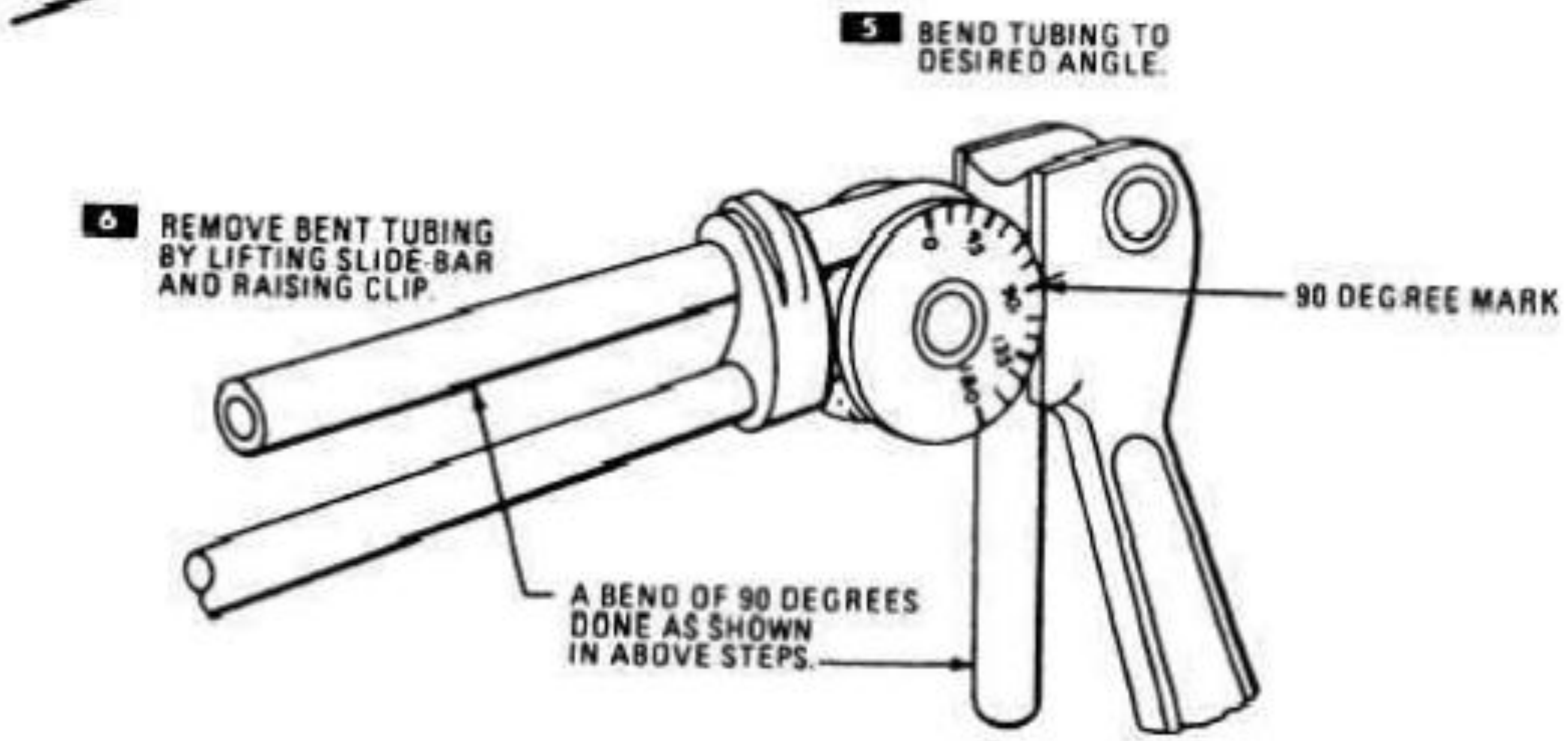
Bending Tubing



Bending Tubing



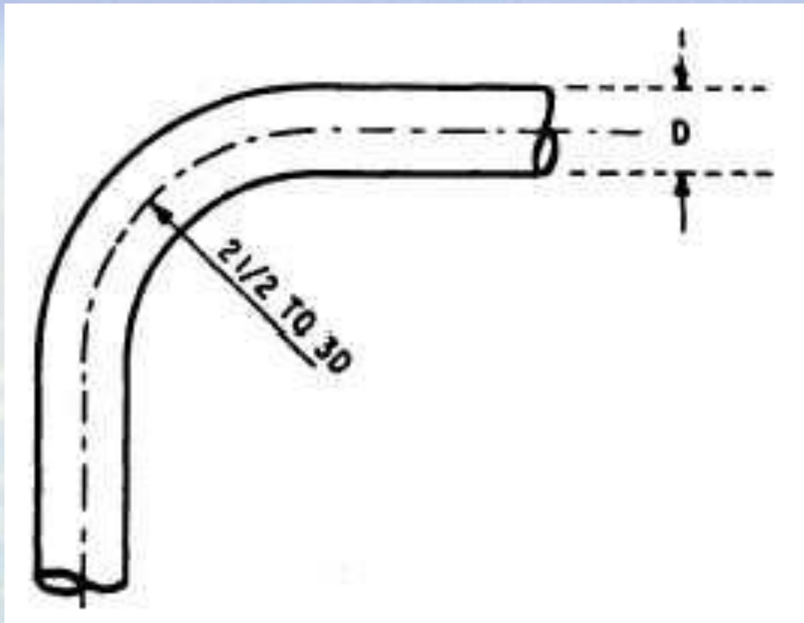
Bending Tubing



Bend Radius

- **Bend radius**, which is measured to the inside curvature, is the minimum radius one can bend a pipe, tube, sheet, cable or hose to without kinking it, damaging it, or shortening its life. The *smaller* the bend radius, the *greater* is the material flexibility (as the radius of curvature *decreases*, the curvature *increases*). The diagram below illustrates a cable with a seven-centimeter bend radius.
- The *minimum bend radius* is the radius below which an object such as a cable should not be bent.

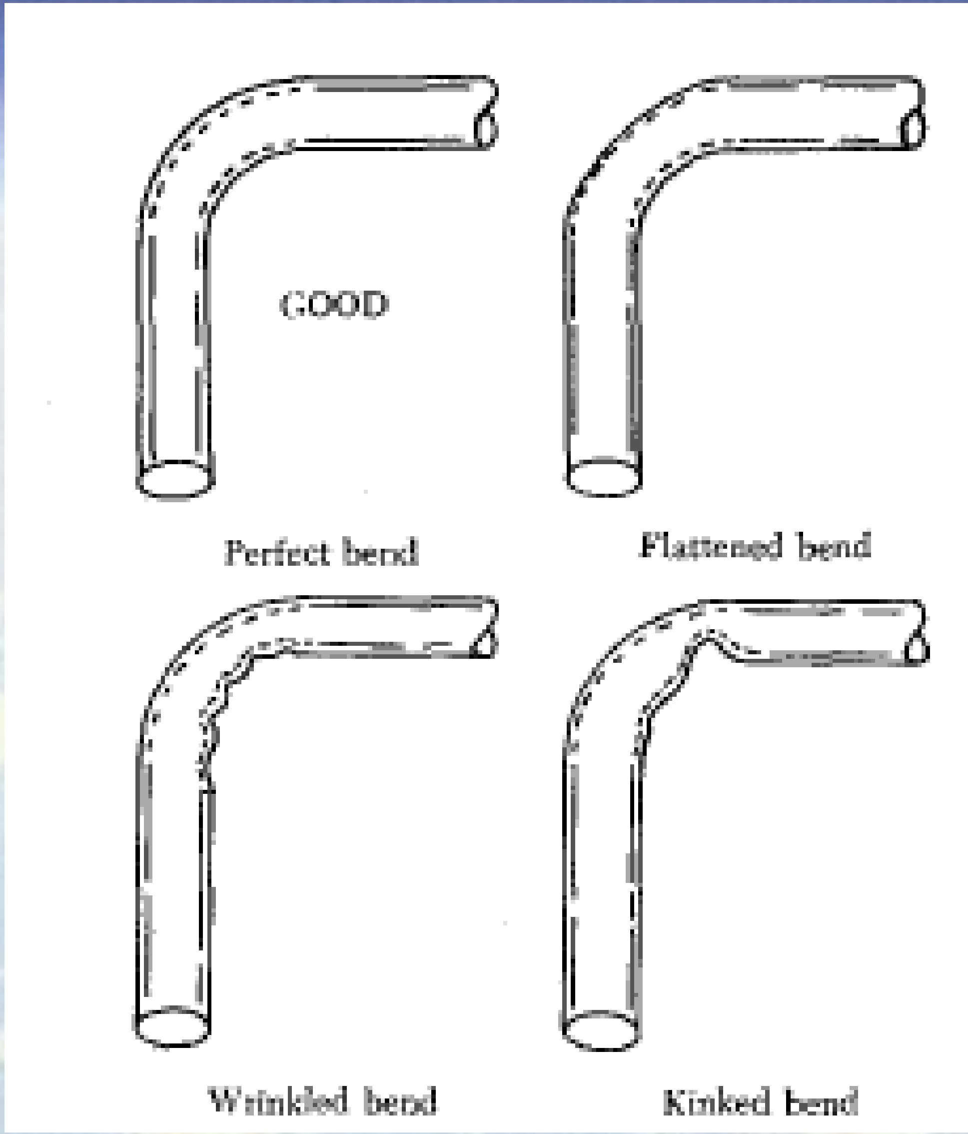
Bend Radius



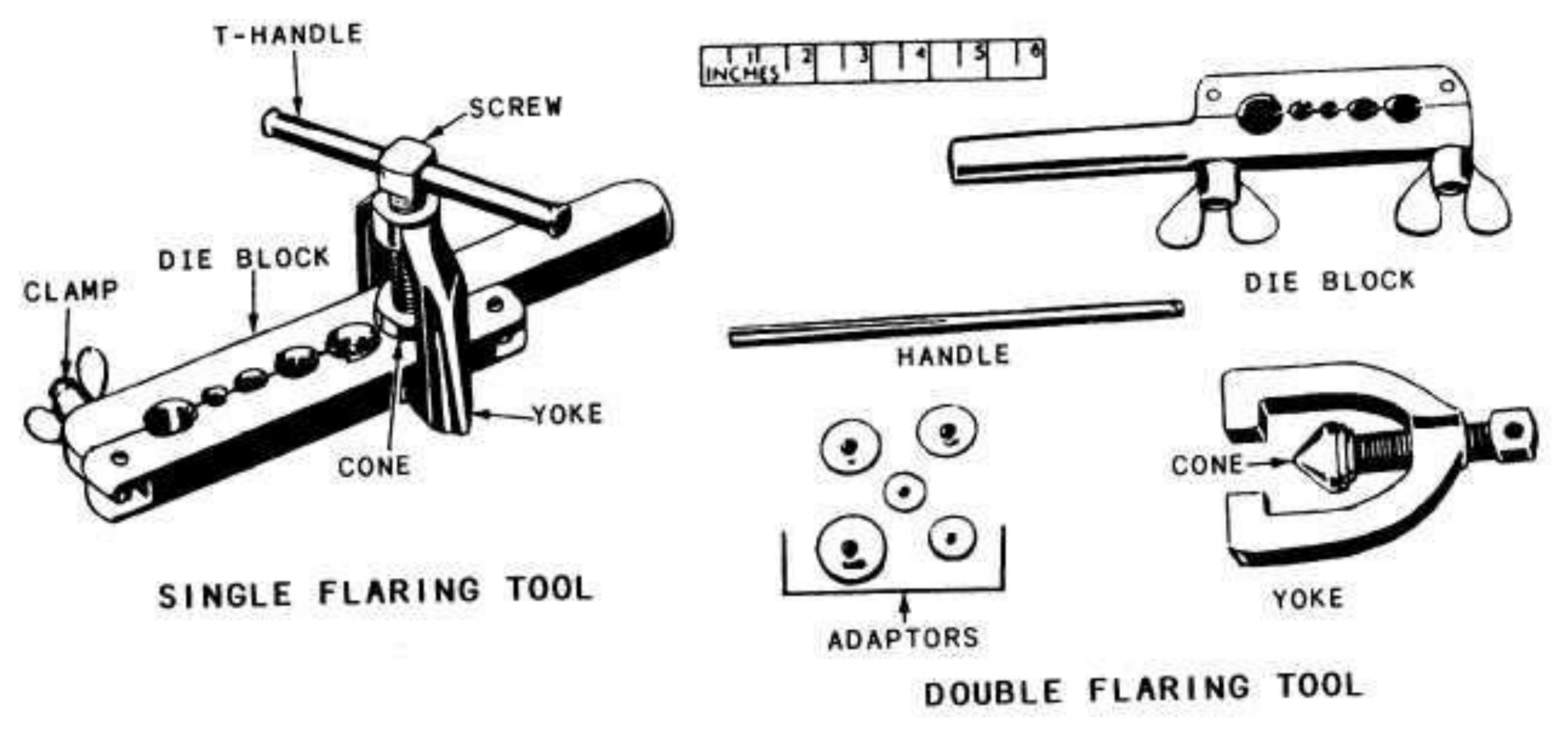
Ideal Bend Radius

Smooth bends are preferred to elbows since they create less losses

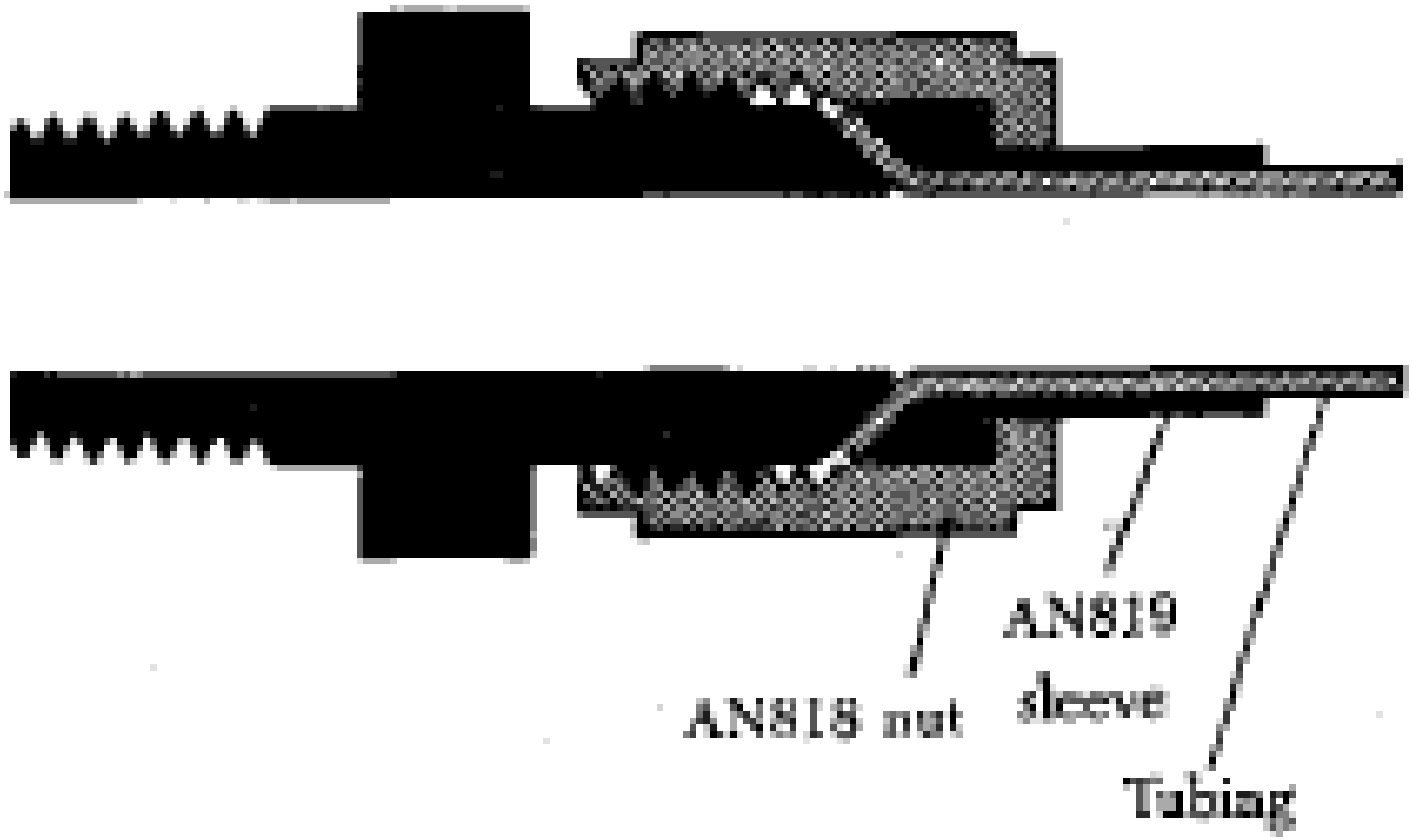
Tube Bending



Flaring Tubing

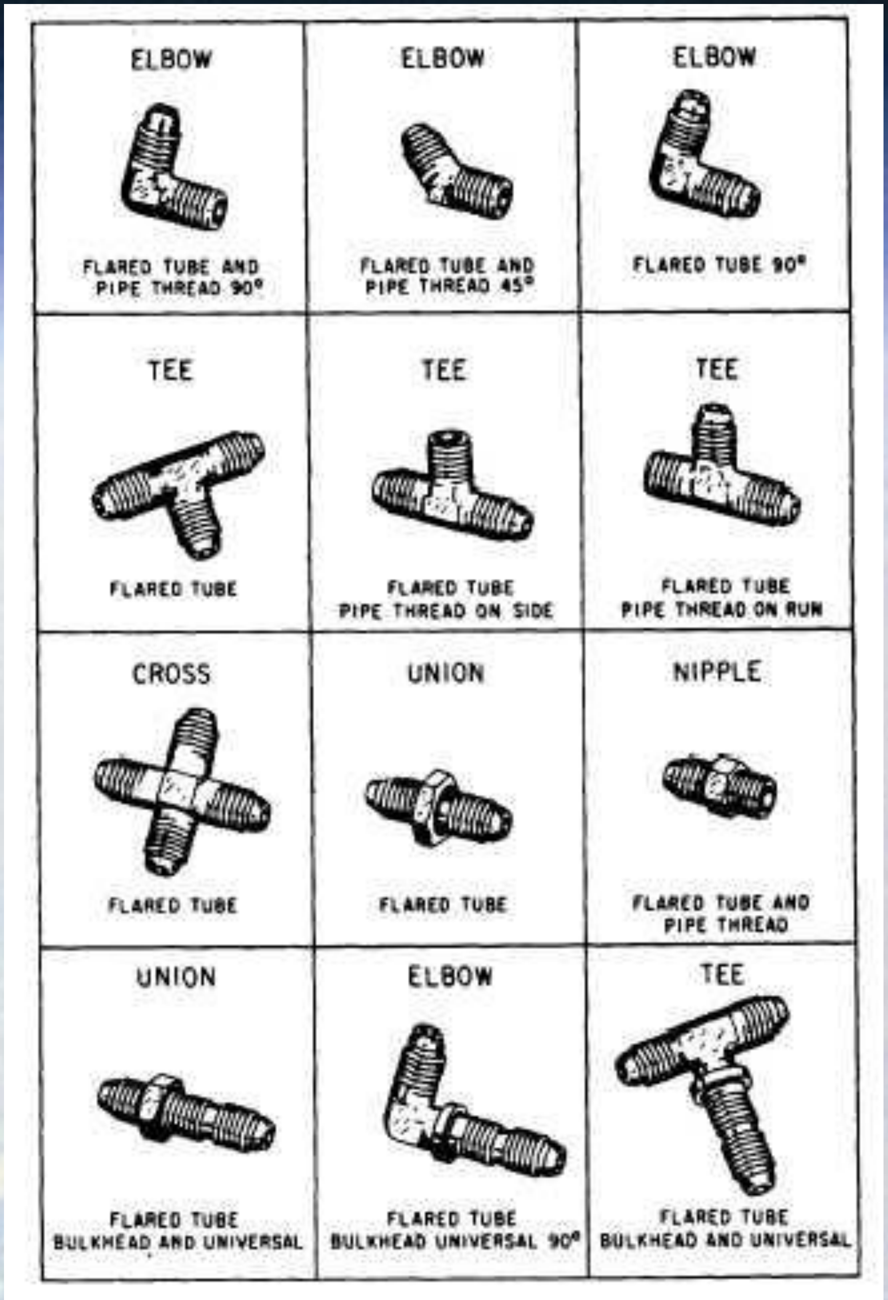


Typical Flared Fitting Joint

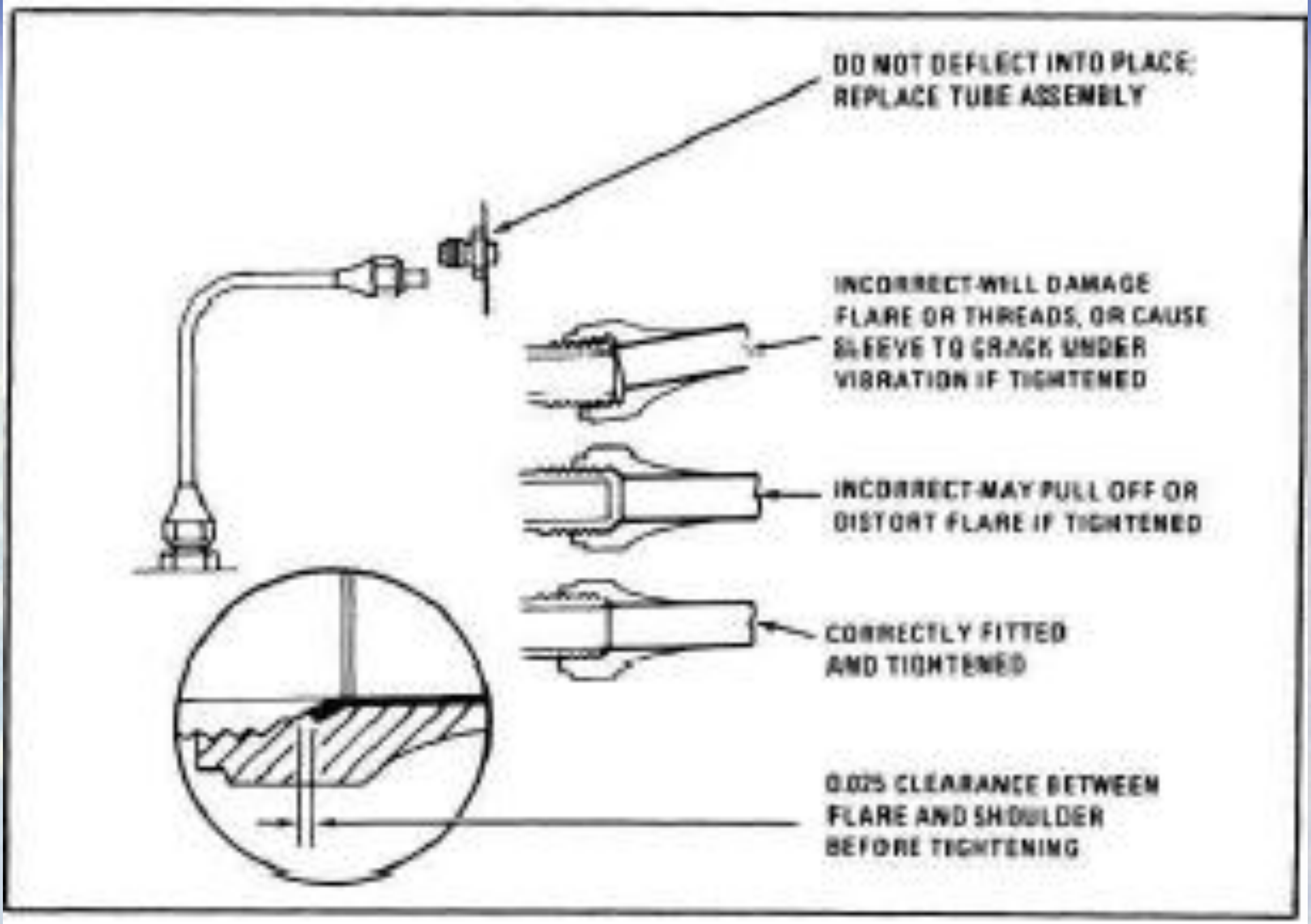


Flared Tubing Fittings

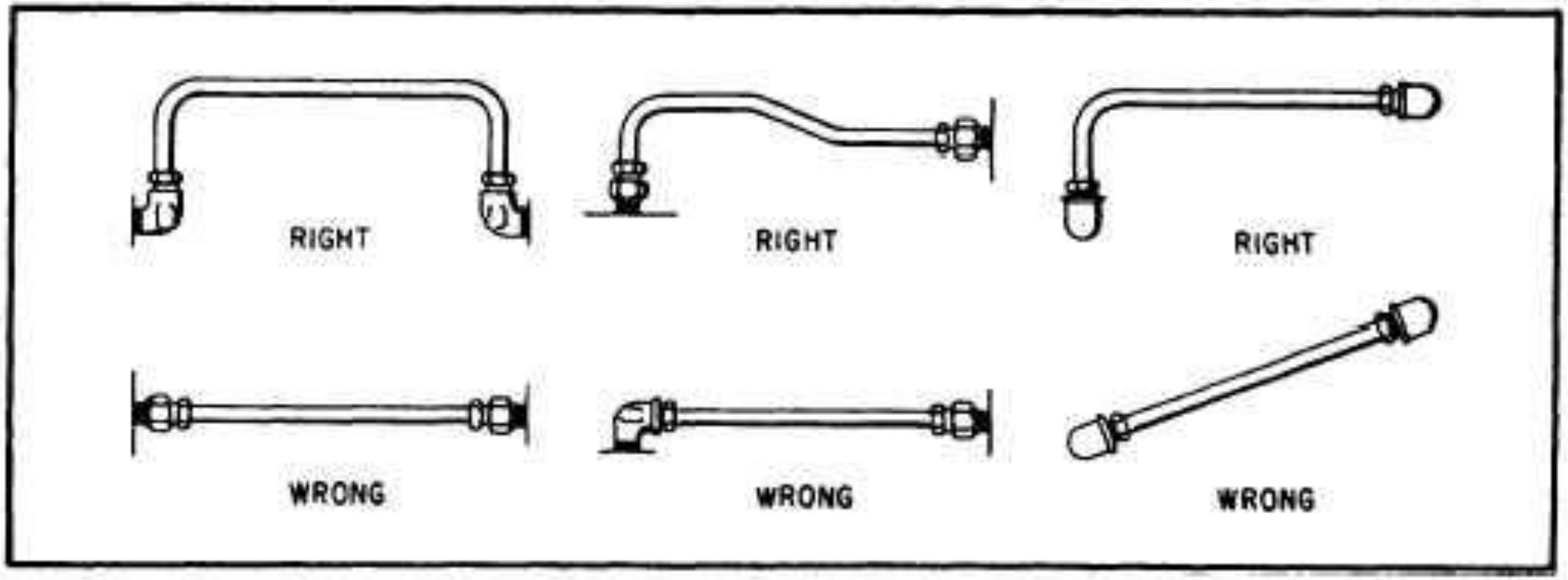
AN fittings are flared at 37^{o}



Flared Fitting Installation



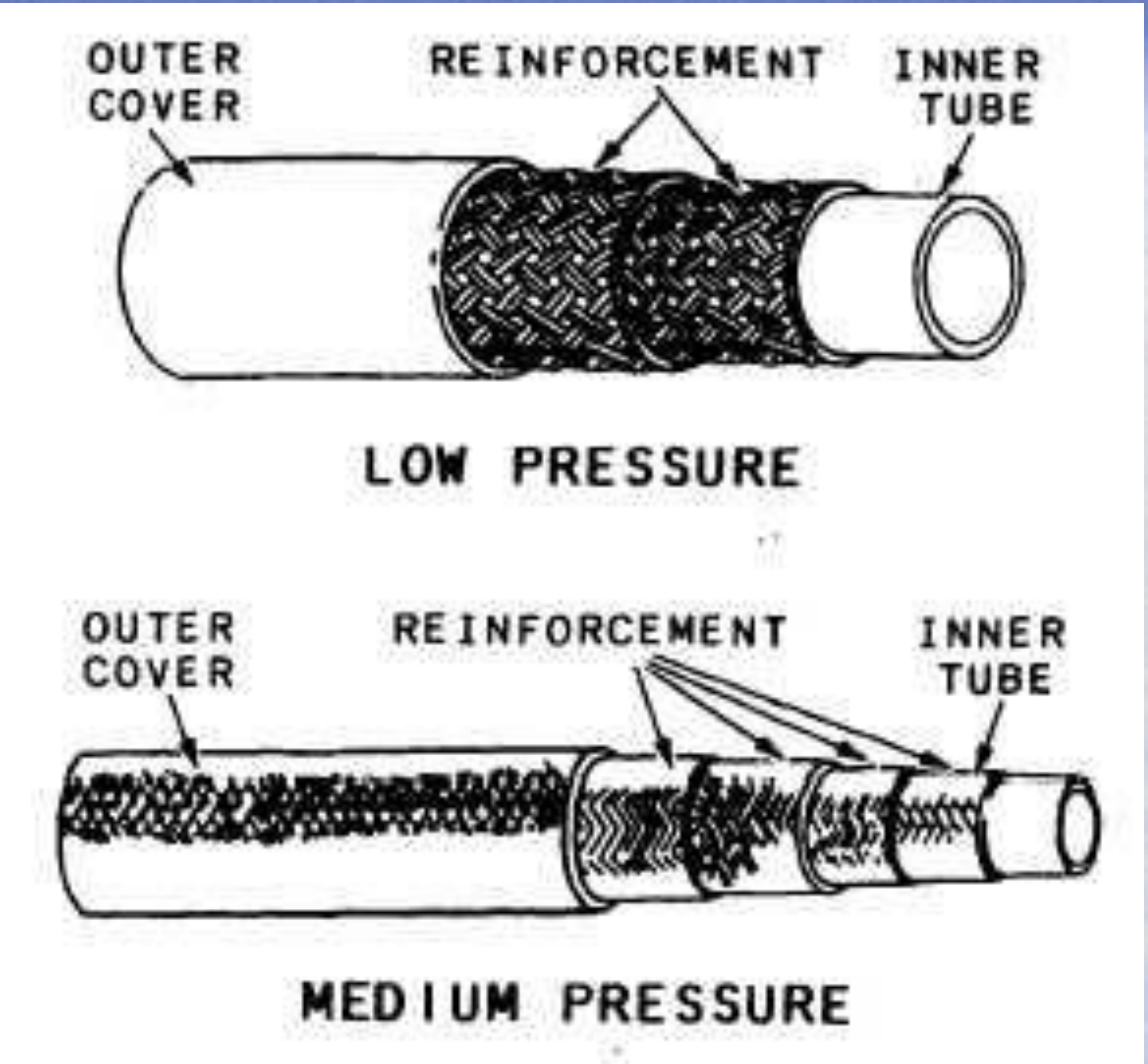
Tubing Installation



Flex Tube

- Used in locations where vibration is an issue
- Size measured by ID in 1/16"

Flex Tube Construction

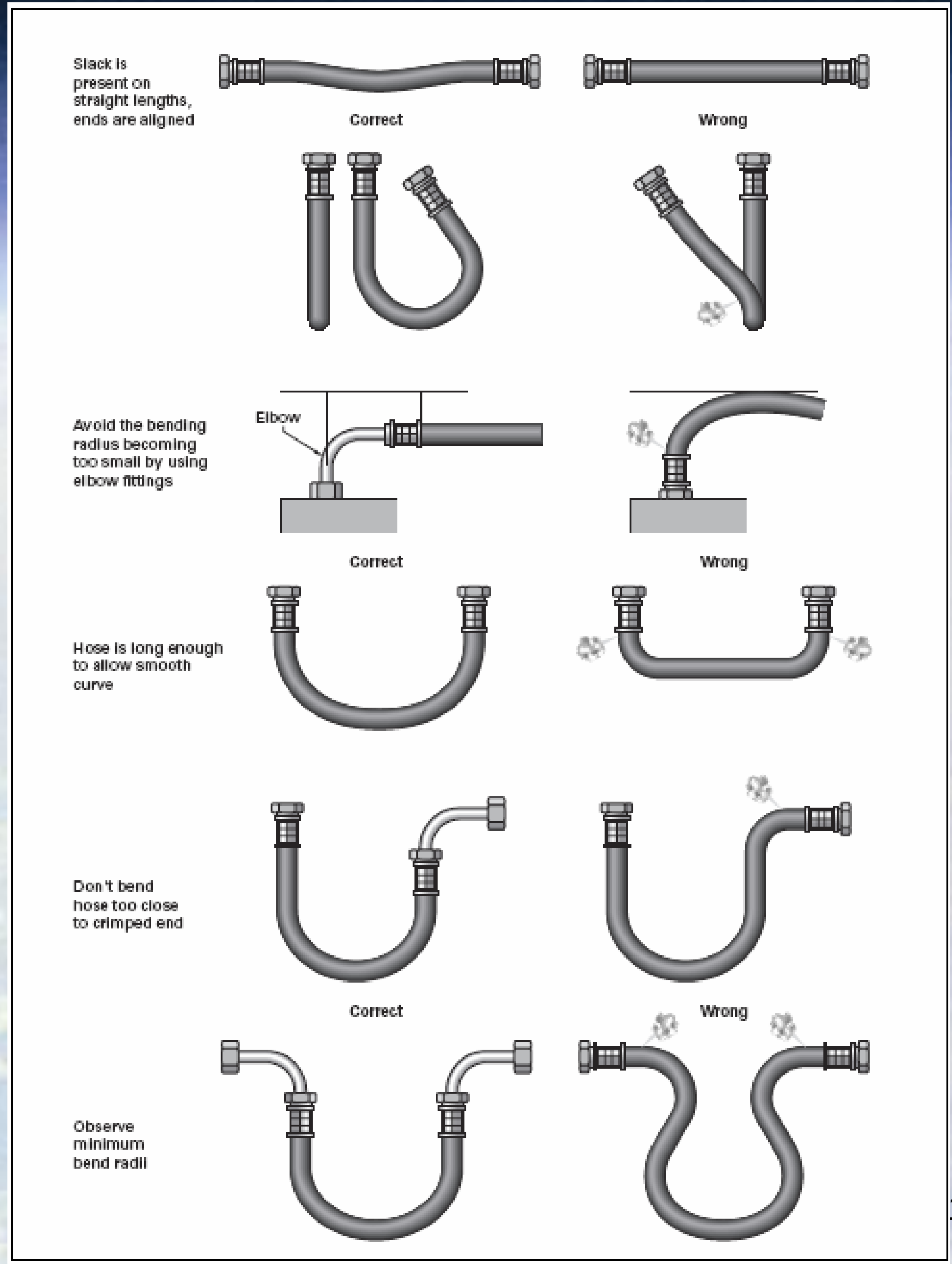


Flex Hose Construction

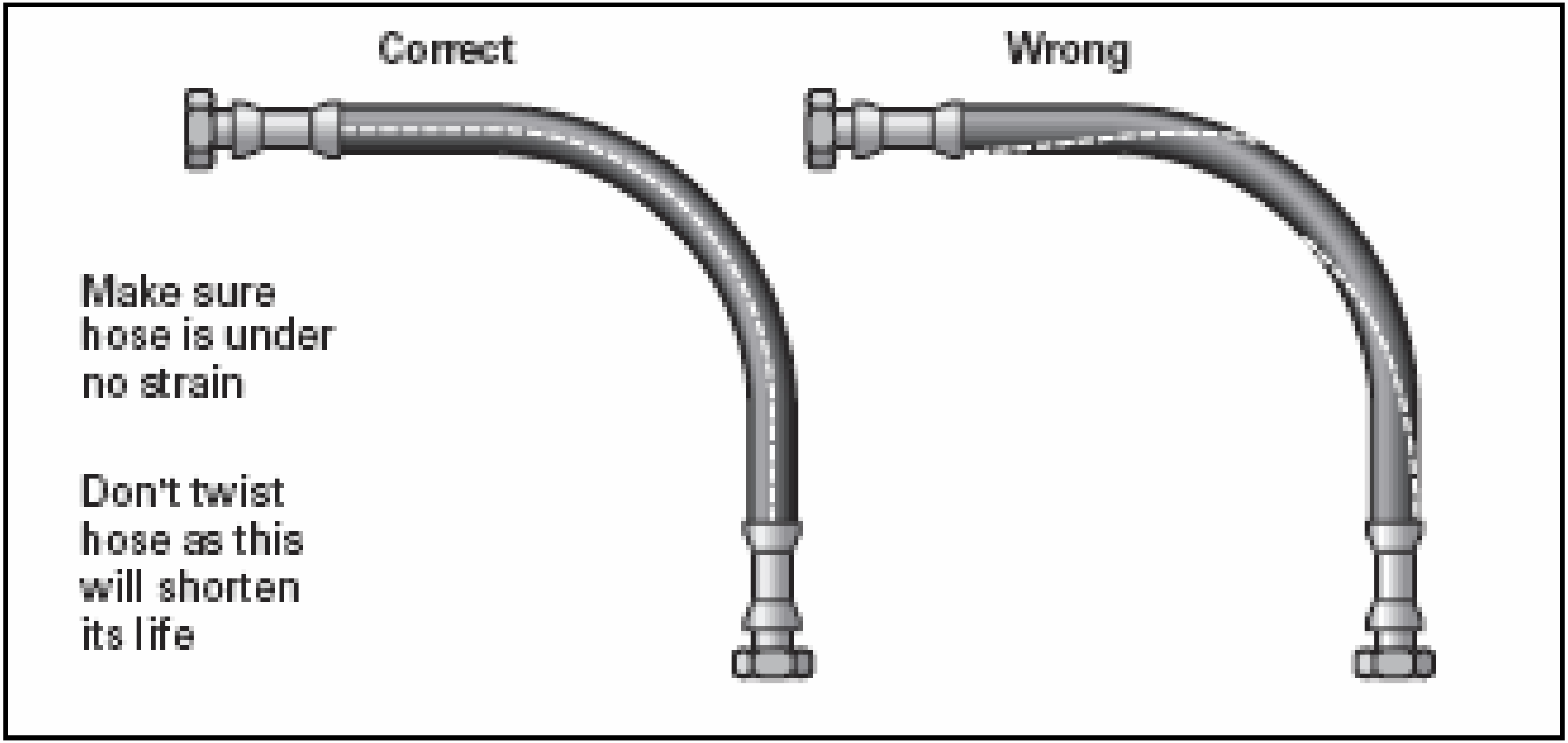
- Ensure that the hose is compatible with system fluid
- Proof test the assembly
- Clean the assembly
  - Flush and dry the hose and cap its ends

Flex Hose Installation

Good and Bad Flex Hose Installation Geometry



Flex Hose Installation



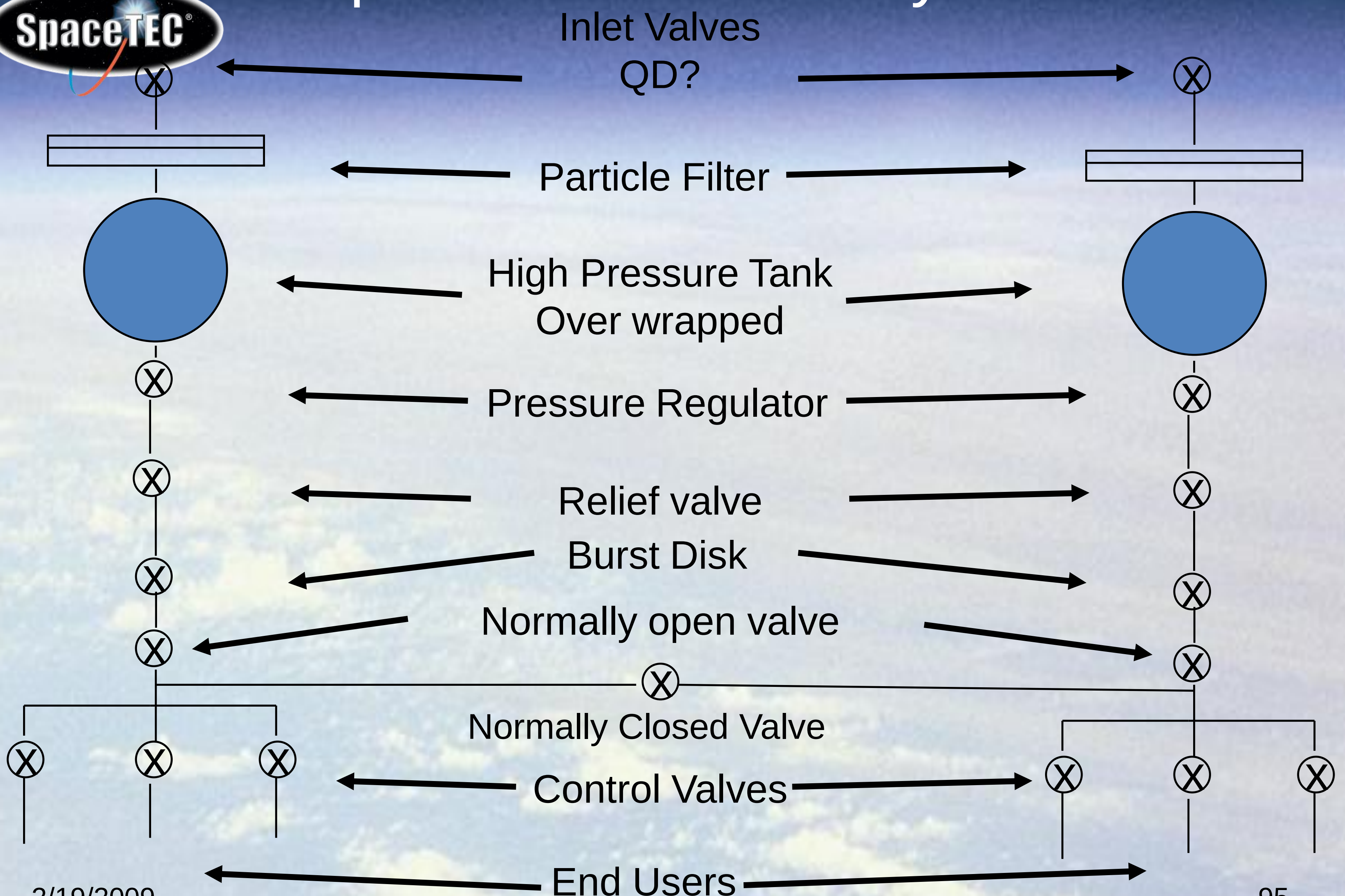
Pressurized Line Installation

- Relieve Stress on fluid or pneumatic lines
  - Bends in lines help take up surges
  - Accumulators also take up surges
  - Flexible pressurized lines
    - **Can Experience 5% to 8% growth**
- Replacement lines should be of same type and dimension
  - Smaller lines could result in fluid heating, turbulent flow, and power losses

Fluid System Components

- All fluid systems (hydraulic, pneumatic, propellant, cryogenic) use similar system components

Simplified Pneumatic System



“Tanks”

- Reservoirs in hydraulic systems
- Receivers in pneumatic power systems
- Vacuum jacketed tanks in cryo systems
  - Vacuum jacketed tanks and lines provide insulation
- Composite overwrapped tanks for high pressure systems
  - Thin metal tank (stainless or titanium) overwrapped with composite material

Pumps

- Provide flow to system
- May be gravity fed from reservoir
- Rated by volume output a given pressure
- Performance cited in terms such as gallons per minute or cubic inches per revolution
- Hydraulic Pump Malfunctions
  - Improper fluid, contaminated fluid, poor maintenance, poor motor selection, improper installation, failures

Connectors

- Quick Disconnects
  - Include shutoff feature, which prevents loss of fluid from the system or entrance of foreign matter into the system when they are disconnected

Connectors

- Welding or Brazing can be preferred joining method for high pressure systems to avoid leaks
  - Low Pressure systems can be joined with threaded connectors
- Manifolds can be used to reduce or eliminate amount of piping required
- Threaded Joints
  - Corrosion can occur even if all threads are covered
    - Pipe joint compound can be used to reduce corrosion
      - Excess compound can get inside lines and cause contamination or compatibility issues

Valves

- Gate Valves
  - opens by lifting a round or rectangular gate/wedge out of the path of the fluid
  - Usually designed to be fully opened or closed and do not work to regulate fluid flow

Valves

- Needle Valve
  - A needle valve has a relatively small orifice with a long, tapered, conical seat.
  - A needle-shaped plunger, on the end of a screw, exactly fits this seat.
  - As the screw is turned and the plunger retracted, flow between the seat and the plunger is possible; however, until the plunger is completely retracted the fluid flow is significantly impeded.
  - Since it takes many turns of the fine-threaded screw to retract the plunger, precise regulation of the flow rate is possible.

Valves

- Drawing nomenclature
  - NC – normally closed
  - NO – normally open

Hydraulic System Valves

- Pilot valve
  - Used to control main valve
  - It closes before main valve and allows pressure to equalize above and below the main piston
- Sliding Spool Valve most often used to directional control applications
  - Poppet can also be used in directional control applications
  - Can be most troublesome of all four way valves

Check Valves

- Usually made of ball and cone configuration
- Orifice check valves can permit free flow in one direction and limited flow in opposite direction

Pressure Relief Devices

- Designed to prevent pressure from rising above a predetermined level
  - E.g., downstream of pressure regulator
- Two types of devices
  - Pressure Relief Valve
  - Burst Disk
    - Releases all fluid
- Output of devices should be routed such as to avoid any personnel hazards

Pressure Relief Devices

- Pressure Relief Valve
  - Once pressure is reduced to determined level valve will cease to vent
  - Relief valves in fluid power systems do not have to be same size
  - Chattering in relief valves caused by rapid opening and closing of the valve as it “hunts" above and below a set pressure
  - Relief valves in a hydraulic or liquid system typically open back to the reservoir and thus control (limit) amount of fluid in system

Relief Valve

Pressure Relief Devices

- Burst Disk
  - Releases all fluid

Filters

Typical Product Range

Material: Wire cloth in a full range of alloys (stainless steel, plain steel, copper and brass) in plain, twill and Dutch weaves.
Synthetics - polyester, nylon 6 and nylon 6,6
screens along with high performance fabrics made of ETFE, ECTFE, PTFE, PVDF and PEEK
Pore sizes: 1 to 12,000 microns
Thickness: 40 microns and up
Weights: 0.5 oz/sq yd and up

Filters

- Intake filters usually first line of defense to protect systems from particle contamination

Regulators

- Usually used to reduce supply tank pressure down to system operating pressure
- Regulator creep is a phenomenon in which delivery pressure rises above a set point.

Fluid Procurement Specs

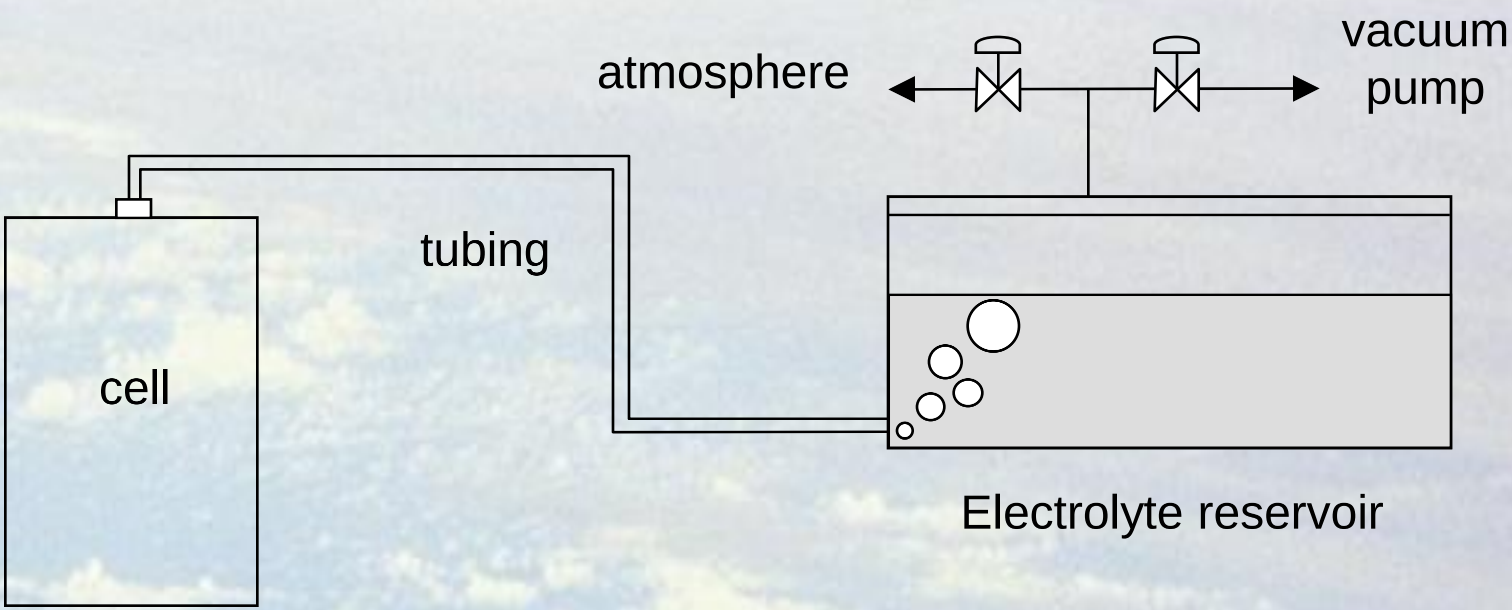
CHARACTERISTIC	PROCURED/ DELIVERED	DELIVERED	PROCURED/ DELIVERED
SPECIFICATION:	MIL-PRF-27401D, Type I and II	SE-S-0073, Table 6.3-5	MIL-PRF-27401D, Type I and II
	Grade B		Grade C (see NOTE)
Purity	99.99% by vol. (min.) Indirect method	99.99% by vol. (min.) Indirect method -or- 95.00% by vol. (min.) Direct method	99.995% by vol. (min.) Indirect method
Total impurities	100 ppm by vol. (max.)	100 ppm by vol. (max.)	50 ppm by vol. (max.)
O_2	50 ppm by vol. (max.)	50 ppm by vol. (max.)	20 ppm by vol. (max.)
Total hydrocarbon content (as methane)	5.0 ppm by vol. (max.)	5.0 ppm by vol. (max.)	5.0 ppm by vol. (max.)
Moisture content	11.5 ppm by vol. (max.)	11.5 ppm by vol. (max.)	5.7 ppm by vol. (max.)
Hydrogen	N/A	N/A	0.5 ppm by vol. (max.)
=" Particulate*	1.0 mg/liter	N/A	1.0 mg/liter

Loading Systems

- Pressure
- Pump
- Vacuum

Vacuum Activation Of Battery

- Vacuum Activation
- Electrolyte Redistribution



1. Evacuate cell through reservoir
2. Force electrolyte into cell
   with atmospheric pressure

References

- **FAA Advisory Circular** AC 65-9A
  - [Large AC] Airframe and Powerplant Mechanics General Handbook
- Moog
  - Hydraulics - http://www.moog.com/media/1/hydmanif.pdf
  - Spacecraft Fluid Controls
    - http://www.moog.com/media/1/SpacecraftFluidControlsCatalog06.pdf
- *BRSIA*
  - *Flexible Hose Code of Practice for Service Installers*
    - *www.hfs.scot.nhs.uk/publications/cop11-2002.pdf*
- Pneumatic Applications and Reference Handbook
  - http://www.allair.com/pdf/mead_pneumatic_handbook.pdf
- **Space systems — Fluid characteristics, sampling and test**
- **methods — Part 7:** Hydrazine propellant
  - http://standards.gsfc.nasa.gov/reviews/iso-dis-15859/iso-dis-15859-7.pdf