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Introduction into Propellant Feed Systems

LPL Crash Course Lecture Series

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What is a Propellant Feed System?

"A propellant feed system is a major component of a liquid rocket engine that is responsible for delivering the propellants from the tanks into the engine's combustion chamber." ~ NASA

Specifically:

Deliver at a required **mass flow rate** and **pressure condition**

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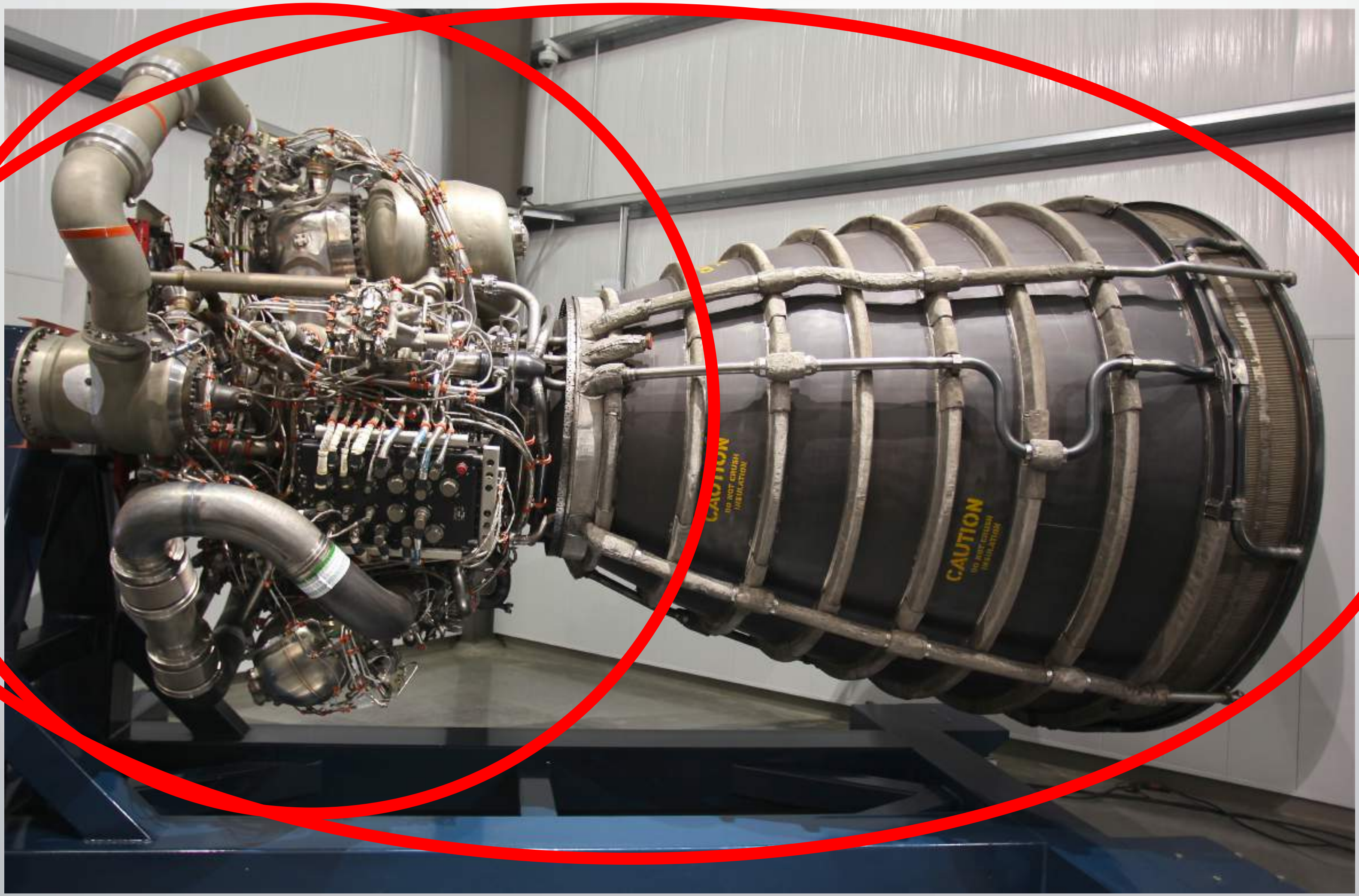
Space Shuttle Main Engine (SSME)



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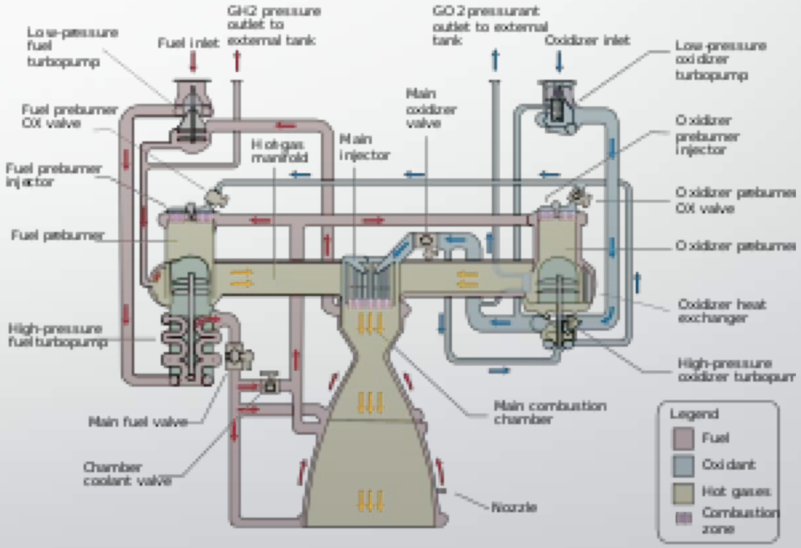
Components Found in Various Feed Systems

- Tanks (pressurant or propellant)
- Feed Lines (tubing or piping)
- Valves (Relief, Control, etc.)
- Turbopumps (Pump, Turbine)
- Small Combustion Chambers
- Sensors (placement for monitoring)



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Two Main Types of Feed Systems

Pressure-Fed

Typically seen with In-Space Propulsion (Orbit maneuvers, attitude control, etc.)

- Fairly cost effective and simple system
- BUT performance is lost due to required weight

Pump-Fed

Typically seen on Launch Vehicles where a large change in velocity is need

- High Performance (no need for heavy tanks)
- BUT costly and quite complex

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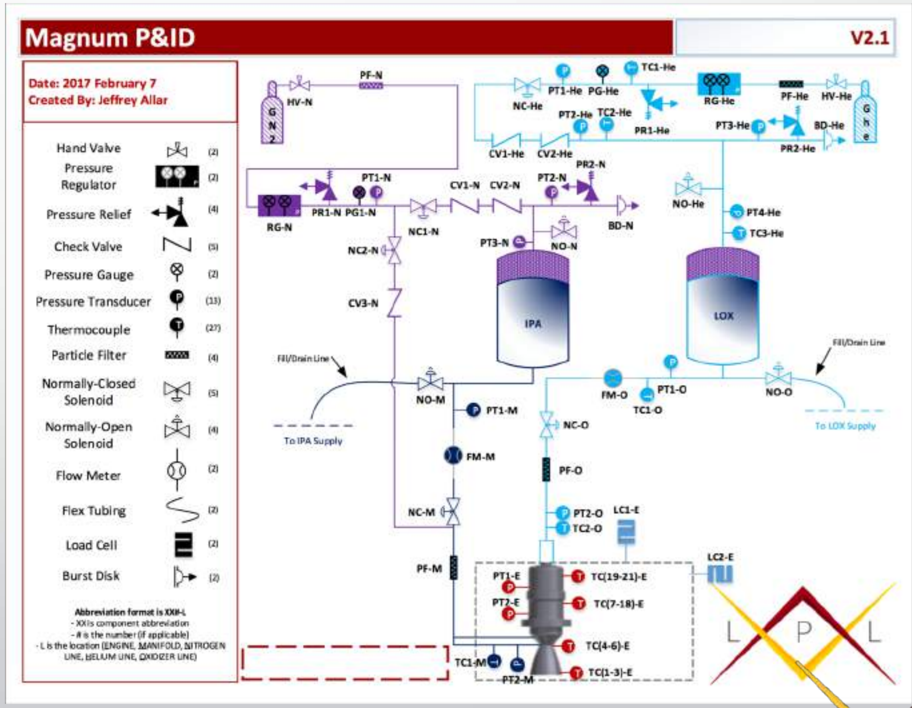
Plumbing & Instrumentation Diagram (P&ID)

Top level overview of a feed system and all its respected components that are used to monitor the performance and health of the rocket engine

- The schematic does not attempt to represent where each component and circuit is to be placed onto system, only the layout of components within each circuit and relative to one another.



Component Functions

Valves

Use of valves is a primary way of regulating flow throughout the system.

They are given their name by either location within the plumbing system, construction of the orifice, or how operation is induced (opening and closing of the orifice)

Valve classifications commonly used in engine plumbing:

- Bleed (Vent) Valve: Placed in such a way that it allows fluid to bleed from the system on command. The opening of a bleed valve is usually for the purpose of relieving pressure in the system and is therefore commonly placed in a circuit with a pressure relief. It is also used to safely drain propellants from the lines.
- Isolation (iso) Valve: Isolates fluid and prevents it from reaching a specific location in the plumbing system.
- Ball Valve: A spherical shape seals the orifice
- Needle Valve: Orifice is needle-shaped to significantly slow down and allow for fine control of the flow rate (e.g. kitchen faucet)
- Check Valve: Limits the flow of a fluid to just one direction; prevents backflow. Every check valve has an arrow indicated flow direction. Be careful to install check valves with the arrow pointing downstream.
- Actuated Valve: A motor operates the valve. Used when precise valve control is necessary (e.g. a 30° orifice opening within 4 seconds vs just having an immediate open or close). Can also be used in binary (on/off) operation.
- Throttle Valve: A specific type of actuated valve which is located just upstream of the engine. It's used to control flow of propellant to the engine which will result in different levels of thrust.
- Solenoid Valve: Will open or close when energized by an electric current. Normally-open solenoid valves close when energized and normally-closed solenoids open when energized. In the event of a system failure (e.g. a max pressure limit is reached), power is killed and each valve goes into the default state. This is used as a mitigation technique to avoid damage to the system as well as injury.
- Hand Valve: Refers to a manually operated valve. The handle always points in the direction of flow when the valve is open; it is perpendicular when the valve is closed.

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Pressure Monitoring & Control Components

- **Pressure Relief:** This is a specialized valve used to relieve pressure from the system. It is a mechanical component where an inner spring is released once a maximum pressure is reached, thus allowing pressure to be reduced
- **Pressure Transducer**: Monitors pressure throughout the system by using a set of resistors, similar to the working principal of a strain gauge.
- **Pressure Gauge:** General term for a pressure reading device, usually analog
- **Pressure Regulator:** Used to regulate the downstream pressure

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Additional Components

- Thermocouples- Used to measure the temperature in the system
  - Come in probe or weld-on styles
- Turbine Flow Meter- Used to measure the mass flow rate using a magnetic
- Load Cell- Used to measure the force (Thrust) of the engine
- Particulate Filter- Used to filter out containments in system

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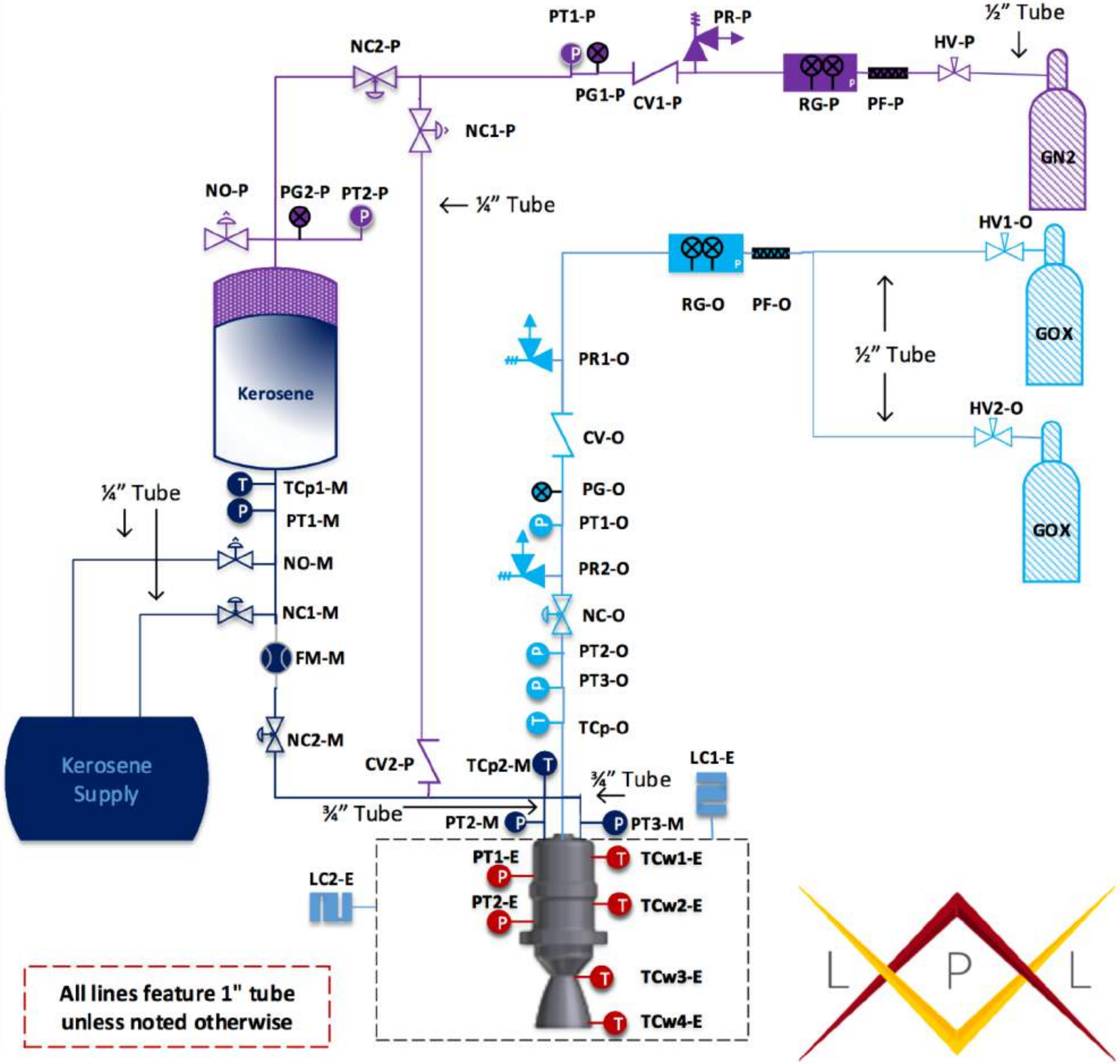
Blue Steel P&ID

V2.2

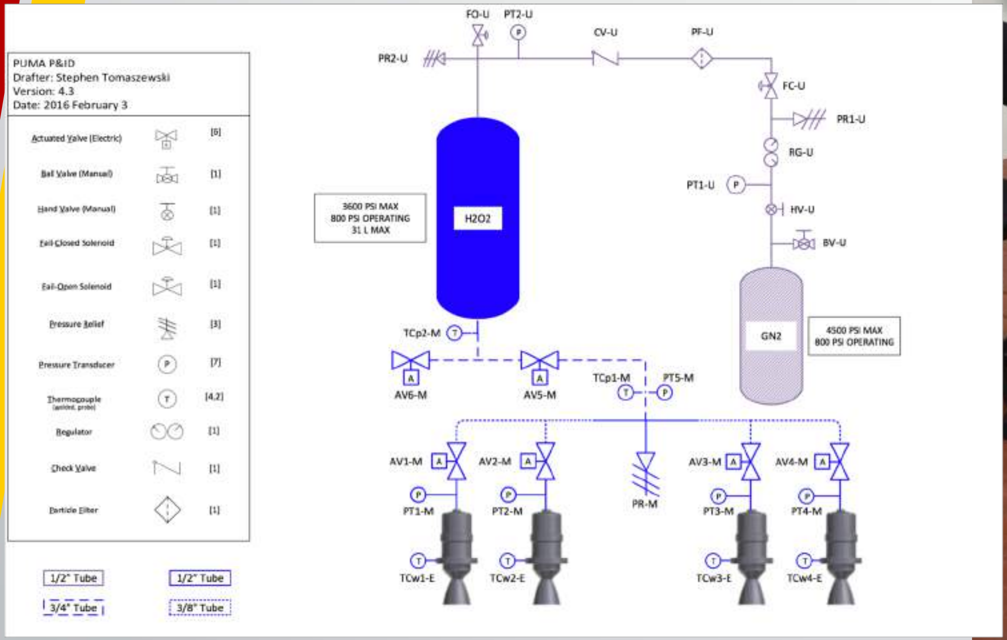
Date: 2017 February 6
Created By: John Targonski

Hand Valve	(3)
Pressure Regulator	(2)
Pressure Relief	(3)
Check Valve	(3)
Pressure Gauge	(3)
Pressure Transducer	(10)
Thermocouple	(p3, w4)
Particle Filter	(2)
Normally-Closed Solenoid	(4)
Normally-Open Solenoid	(2)
Flow Meter	(1)
Load Cell	(2)

Abbreviation format is XX#-L
- XX is component abbreviation
- # is the number (if applicable)
- L is the location (ENGINE, MANIFOLD, PRESSURANT LINE, OXIDIZER LINE)



Example



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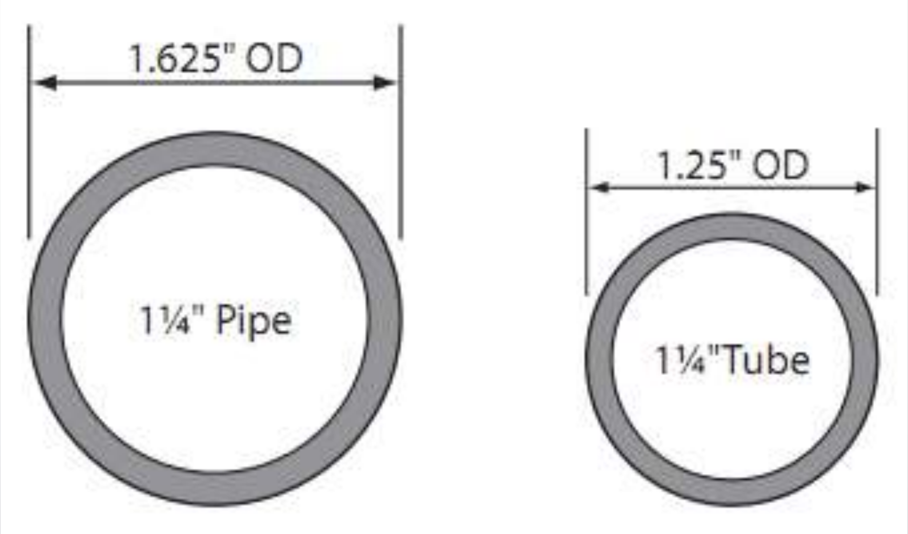
What is the difference between Piping & Tubing?

- **Piping** refers to the **INNER** Diameter
- **Tubing** refers to the **OUTTER** Diameter



Fittings Used in Industry

- NPT (National Pipe Threading)

Standard that is seen on majority of components

- Swagelok (What we use ☺)

Used to connect tubing

- AN (Army Navy)

Used to connect tubing

Why is it important to (L)OX Clean?

- **Oxygen is a Hazard!**
  - Hazard is that oxygen promotes combustion
  - Can Start a **Fire**
- **Three** elements to promote a fire ~ oxidizer, fuel, ignition
  - *Oxidizer*- GOX or LOX
  - *Fuel*- Valve, Regs, Plumbing, Fittings, orifices, seals, etc
  - *Ignition* - Energy from within the system that initiates a "Kindling Chain"
    - Kindling Chain – ability of a fire to propagate and burn through components
    - Kindling Chain results in something called **RUD** in the propulsion world
      - RUD- Rapid Unscheduled Disassembly (Everything blows the f*** up)

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Examples of the Kindling Chain

- **Mechanical Impact** – When one object strikes another heat is produced
  - *Eg. Component in feed system breaks off and strikes your pressurized oxidizer*
- **Particle Impact** – When a particle strikes a surface in a system heat is produced
  - *Eg. Dirt/Sand gets in our oxidizer line and strikes an elbow fitting*
- **Friction** – When two solid materials rub together heat is produced
  - *Eg. Valve is assembled incorrectly and grinds when in operation*
- **Compression Heating-** When a gas is obstructed its temperature spikes and heat is produced
  - *Eg. Initially opening a valve, the GOX gets chocked at the valve's small orifice from high to low pressure*

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How Can We Prevent this Hazard?

From reading standards (ASTM)!

- Training – **ASTM G128** (Summary of what I just went over)
- Material Selection – **ASTM G63** (Nonmetals) **ASTM G94** (Metals)
- OX Clean- **ASTM G93**
  - Wire Brush or Grinding Cleaning
  - Ultrasonic Cleaning **(ASTM G131)**

Note: All of these standards are on the drive in pdf form
Known to cure the disorder of insomnia

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Oxygen Service Compatible Organic Materials

Material	Typical Ignition Temp °C	Typical Ignition Temp °F
PTFE (Teflon Tape) and PCTFE/PTFCE/Neoflon	468	875
70% Bronze-filled PTFE	468	875
Fluoroelastomer **(Flurocarbon FKM)**	316	600
Nylon	210	410
Polyethylene	182	360
Chroloprene & **Nitrile**	149	300

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Metals Selection for Oxygen Service

Resistance to Ignition in Oxygen

Materials are listed in order from hardest to ignite to easiest to ignite.

- Copper, copper alloys, and nickel-copper alloys --most resistant
- Stainless steel (300 series)
- Carbon steel
- Aluminum--least resistant

Rate of Reaction

Materials are listed in order from slowest rate of combustion to most rapid rate of combustion.

- Copper, copper alloys, and nickel-copper alloys --do not normally propagate combustion
- Carbon steel
- Stainless steel (300 series)
- Aluminum--burns very rapidly

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Industry Suggested Guidelines

- All regulators and control valves should be degreased and processed for oxygen service
- All metals in contact with oxygen in the main flow stream should be of appropriate materials suitable for the given oxygen service.
- All diaphragms in contact with oxygen gas should be made of fluoroelastomer.
- All O-rings in contact with oxygen gas should be made of fluoroelastomer or a similar fluorocarbon elastomer.
- Organic materials should be avoided for use in valve seats or other parts exposed to the flow stream.
- Filters should be placed upstream of all valves and regulators. Only non-ferrous, inorganic filter elements should be used. Filters must have regular maintenance and cleaning.
- Plated parts should not be used in the main flow stream because of their potential contributions to foreign particle impingement.

LOX Cleaning Example Procedure

Wire Brush or Grinding Cleaning

Document Title:	Standard LOX Cleaning Procedure	**Component:**	
Document Number:		**Serial Number:**	
Revision Number:		**Date:**	
Release Date:		**Technician 1:**	
Purpose:	Reduce contaminants that may cause rapid H2O2 decomposition	**Technician 2:**	
Supplies Needed:	Three stainless steel trays, Simple Green All-Purpose Cleaner, powder-free gloves, nylon brush, Class 100 clean room polyethylene bags, labels, N2 gas cylinder, rubber bands		

	Step	Instruction	Tech 1:
1	Pre-cleaning	Cover hands with clean gloves and use eye protection	
2		Inspect components for damages or cracks	
3	Prepare Solutions	Prepare a 5% by volume Simple Green aqueous solution (e.g. 50 mL Simple Green to 1 L warm tap water) in stainless steel tray for cleaning stage	
4		Fill second stainless steel tray with warm tap water for rinsing stage	
5		Fill third stainless steel tray with DI or distilled water for final rinse stage	
6	Clean	Immerse components in 5% Simple Green solution and thoroughly scrub with nylon brush	
7	Rinse	Place components in warm tap water container and rinse until suds are not longer visible, approximately 30 seconds	
8		Immerse components in filtered (DI or distilled) water for final rinse	
9	Drying	Blow dry components with N2 gas supply	
10	Inspecting	Visually inspect for contaminants. If ANY particulate is visable, repeat steps 8-11.	
11	Packaging	Double bag item or assembly in clean room plastic bag	
12		Label each outer bag with item name	
13	Clean Up	Dispose of cleaning and rinse solution down drain. Dispose of used gloves in regular trash	

Pass Criterion:	Parts are visibly clean

PASS	FAIL
Tech 2:	

Notes:	Tech 1 indicates each step has been completed with check mark. Tech 2 records whether components have passed visual inspection by placing check mark under PASS or FAIL and initials next to Tech 2. Any remaining Simple Green Concentrate should be given to another work unit or disposed of through Penn State chemical waste disposal program
References:	Safety Standard for Oxygen and Oxygen Systems Cleaning Equipment for Oxygen Service

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Companies to Start Your Procurement Search

- Swagelok, Mcmaster-Carr (everything)
- ASCO, Emerson, Peter Paul, Moog, Marotta, Park (valves)
- Omega (sensors)

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Question?