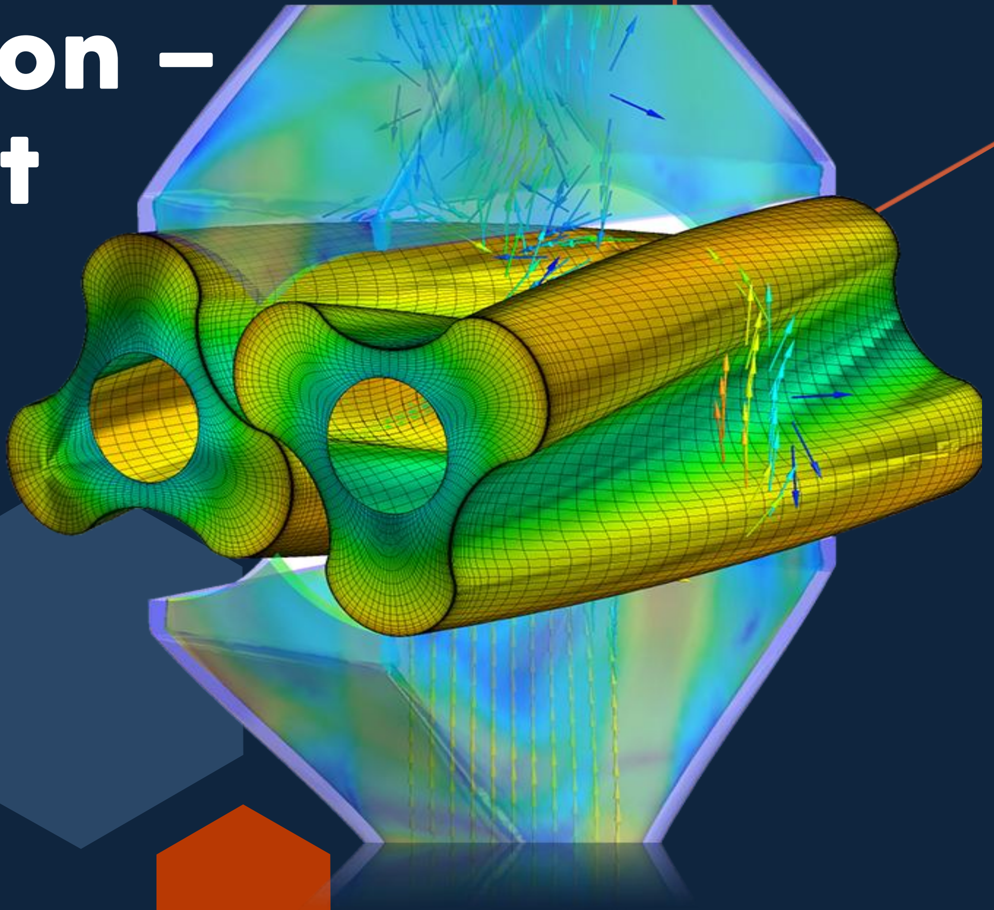
Eagle Rocketry Association – Preliminary Bi-Propellant Feed System Design



California State University, Los Angeles – College of Engineering, Computer Science, and Technology

Eagle Rocketry Collaborative Effort

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Introduction – Feed Systems Team

Main Objective: Develop Cal State LA's first bi-propellant liquid rocket engine.

Goal: Design, assemble, and successfully test a pressurized Liquid Oxygen–Kerosene feed system for our eagle's rocket engine.

Responsibilities:

- Design and Develop A Bi-Propellant Feed System
- Design Pneumatic Pressurizing Valves
- Research & Source Components
- Manufacture & Assemble Components
- Test Rocket Engine Feed System

Engine Design – Eagle Rocketry Parameters

Initial rocket engine design parameters, oxidizer (liquid oxygen) to fuel (kerosene) mixture ratio, and propellant fluid properties are shown below

Engine Design Parameters		
F_{Thrust}	1000	N
$P_{Chamber}$	2.28E+6	Pa
t_{Burn}	10	s

Propellant Properties		
$O/F_{O2(L)/RP-1}$	2	
$T_{O2(L)/RP-1}$	3252.57	K
$MW_{O2(L)/RP-1}$	20.674	kg/k-mol
$\gamma_{O2(L)/RP-1}$	1.1636	J/kg-K
$R_{O2(L)/RP-1}$	402.17	J/kmol-K

Engine Design – Software Analysis

NASA CEA and RPA software was utilized to optimize the propellant mixture ratios, chamber/nozzle geometric dimensions, and rocket engine performance. The values shown are for the finalized design

Parameter	Elevation	Chamber	Units
Thrust	Sea Level	996.7	N
Specific Impulse	Sea Level	2414.77	Ns/kg
Mass Flow Rate	Total	0.4128	kg/s

Type	Chamber	Units
Oxidizer	0.2752	kg/s
Fuel	0.1376	kg/s

Engine Design – Propellant Properties

The following fluid properties for the fuel and oxidizer propellants are listed and utilized for the analytical pressure drop P&ID calculations along the rocket engine feed system

Kerosene ‘RP-1’		
T_{RP-1}	298.1	K
P_{RP-1}	101325	Pa
ρ_{RP-1}	790	Kg/m^3
μ_{RP-1}	0.001078	Pa-s
Mass Weight	1.46	kg

Liquid Oxygen ‘O2(L)’		
$T_{O2(L)}$	90.2	K
$P_{O2(L)}$	101325	Pa
$\rho_{O2(L)}$	1141.09	Kg/m^3
$\mu_{O2(L)}$	0.000195	Pa-s
Mass Weight	2.92	kg

Pressure Losses – Major Loss

The piping major frictional losses were accounted for downstream of the propellant tanks into the rocket engine injector inlets. Similar methodology was considered upstream of the propellant tanks

Kerosene 'RP-1'		
Dia: ¼ in.	Pipe: Copper (Type K)	
Q_{Fuel}	1.68E-4	m^3/s
Vel_{Fuel}	5.51	m/s
Re_{Fuel}	1.72E+4	
e/D_{Fuel}	0.00024	m
f_{Fuel}	0.0274	
$\Delta P_{Total\ Friction}$	86111.34	Pa

Liquid Oxygen 'O2(L)'		
Dia: ¼ in.	Pipe: Copper (Type K)	
$Q_{Oxidizer}$	2.41E-4	m^3/s
$Vel_{Oxidizer}$	7.93	m/s
$Re_{Oxidizer}$	2.89E+5	
$e/D_{oxidizer}$	0.00024	m
$f_{Oxidizer}$	0.0167	
$\Delta P_{Total\ Friction}$	247821.97	Pa

Pressure Losses – Minor Loss

The piping fitting minor pressure losses were accounted for downstream of the propellant tanks into the rocket engine injector entrance inlets. Similar methodology was considered upstream of the propellant tanks.

Kerosene 'RP-1'		
K_{L1}	0.5	Contraction
K_{L2}	0.9	Tee Branch
K_{L3}	0.05	Manual Valve
.	.	.
.	.	.
K_{L8}	0.08	Union
K_{L9}	1	Expansion
$\triangle P_{K\_L\text{-}Total}$	1.30E+5	Pa

Liquid Oxygen 'O2(L)'		
K_{L1}	0.5	Contraction
K_{L2}	0.9	Tee Branch
K_{L2}	0.05	Manual Valve
.	.	
.	.	.
K_{L8}	0.08	Union
K_{L9}	1	Expansion
$\triangle P_{K\_L\text{-}Total}$	1.30E+5	Pa

Pressure Losses – Hydrostatic Loss

Fluid properties entering the rocket engine are affected by the orifice entrance at the combustion chamber

Fluid properties and pressure is affected due to the height difference in the P&ID

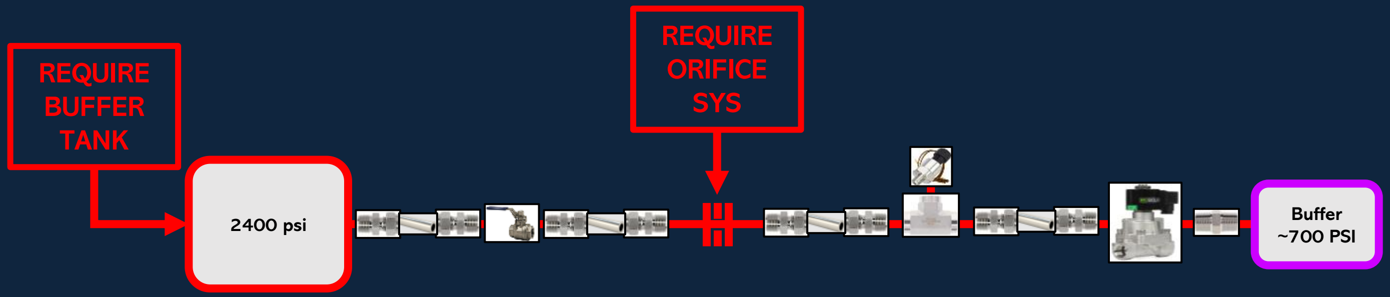
Kerosene 'RP-1'		
Total Height	0.381	m
$\triangle P_{Hydrostatic}$	3068.58	Pa

Liquid Oxygen 'O2(L)'		
Total Height	0.381	m
$\triangle P_{Hydrostatic}$	4264.99	Pa

PI&D – Nitrogen Pressurizing System

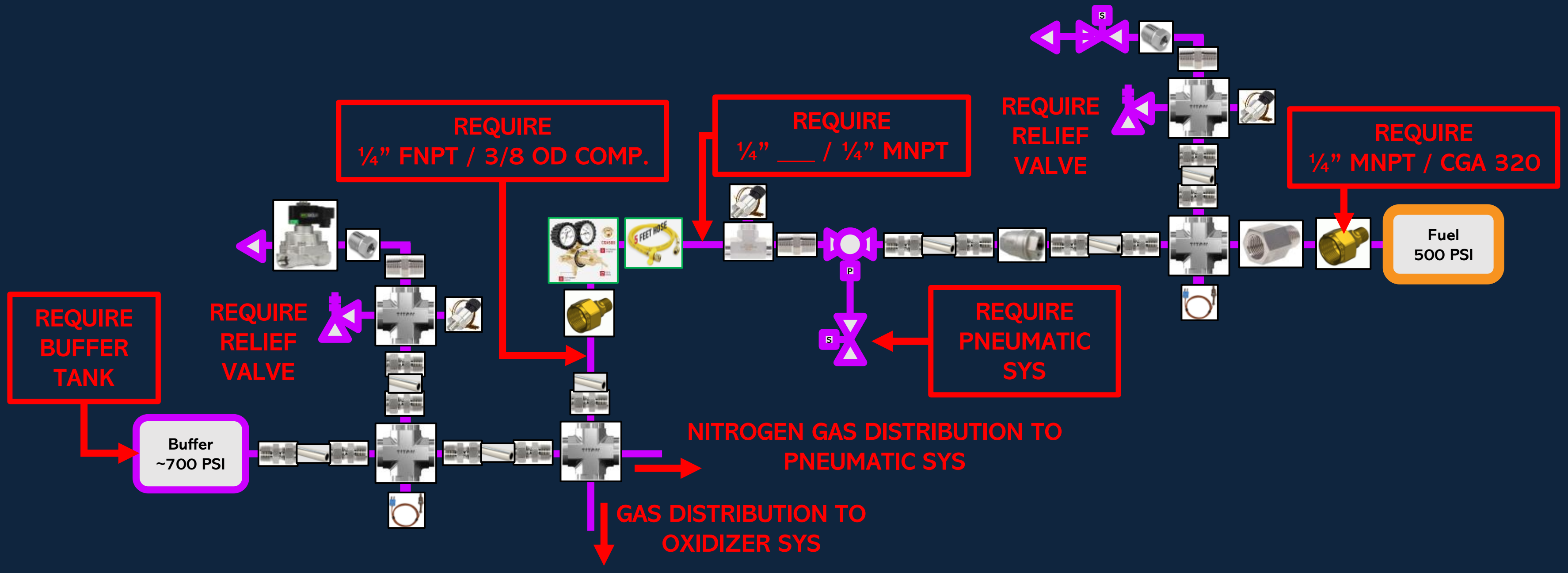
Nitrogen pressurizing system stores large quantities of high-pressure gas and supplies it to feed-lines to maintain constant propellant tank pressures for the liquid rocket engine injectors.

The pressurizing system allows for continuously controlled mass flow rates into the injectors



PI&D – Nitrogen Gas Distribution System

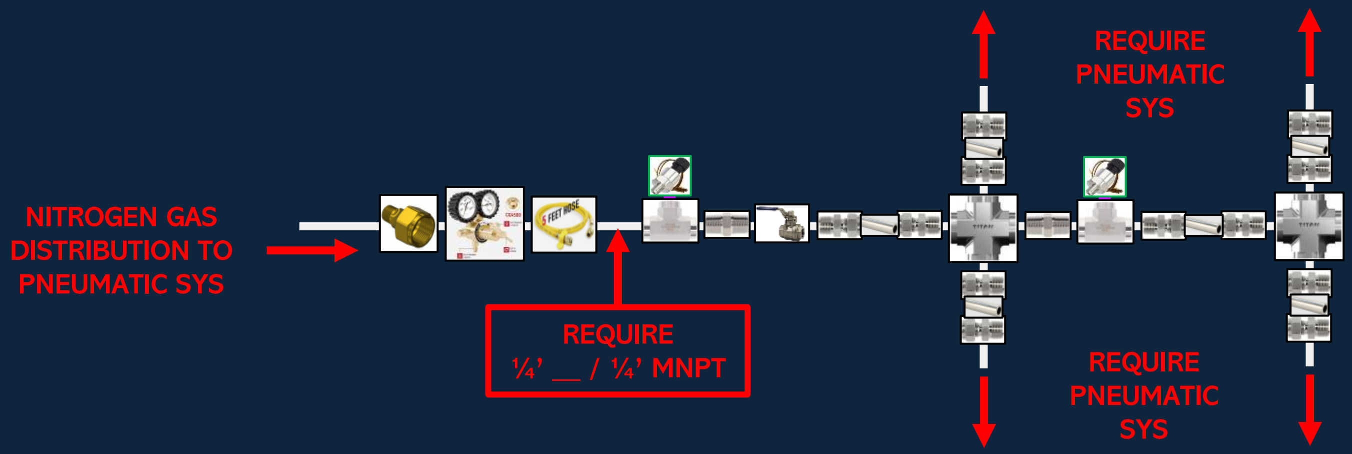
Nitrogen Gas distribution network redirects, regulates, and controls the nitrogen gas utilized for all pneumatic and pressurization tasks.



PI&D – Pneumatic Pressurizing System

The pneumatic pressurizing system utilizes the supplied nitrogen gas to control the flow of the propellant fluids

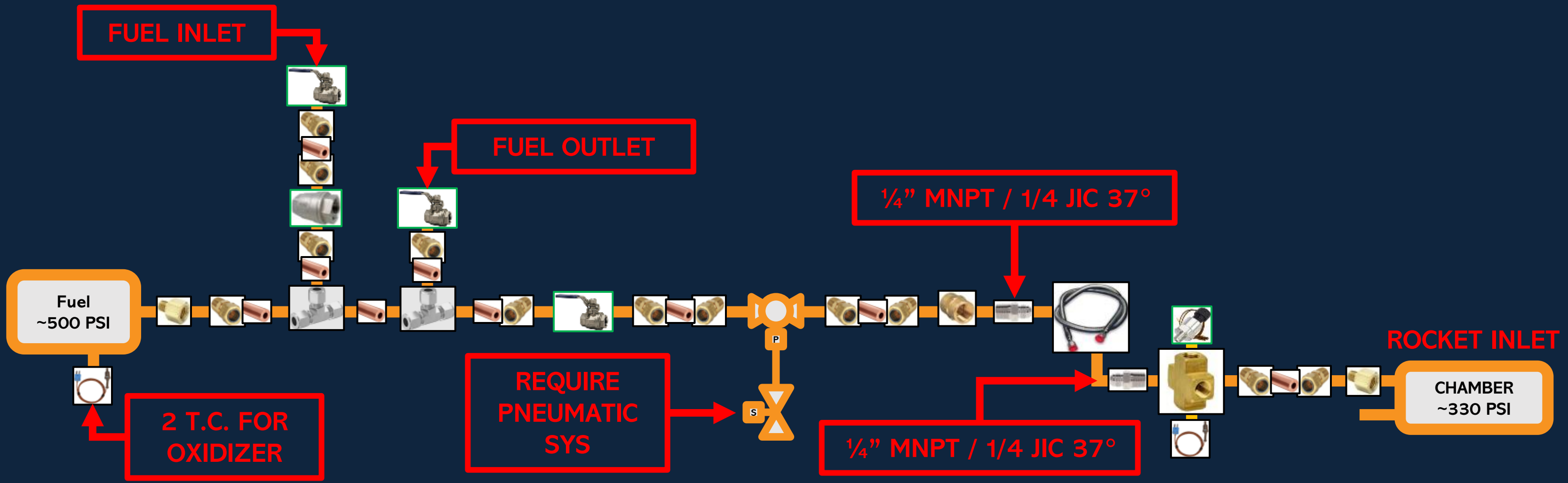
Pneumatic valves carry out safe opening and closing of P&ID main lines with minimal manual operation



PI&D – Fuel / Oxidizer Distribution System

Fuel and oxidizer distribution networks allow for isolation and direct control of specific fluid propellant delivery into the combustion chamber injectors.

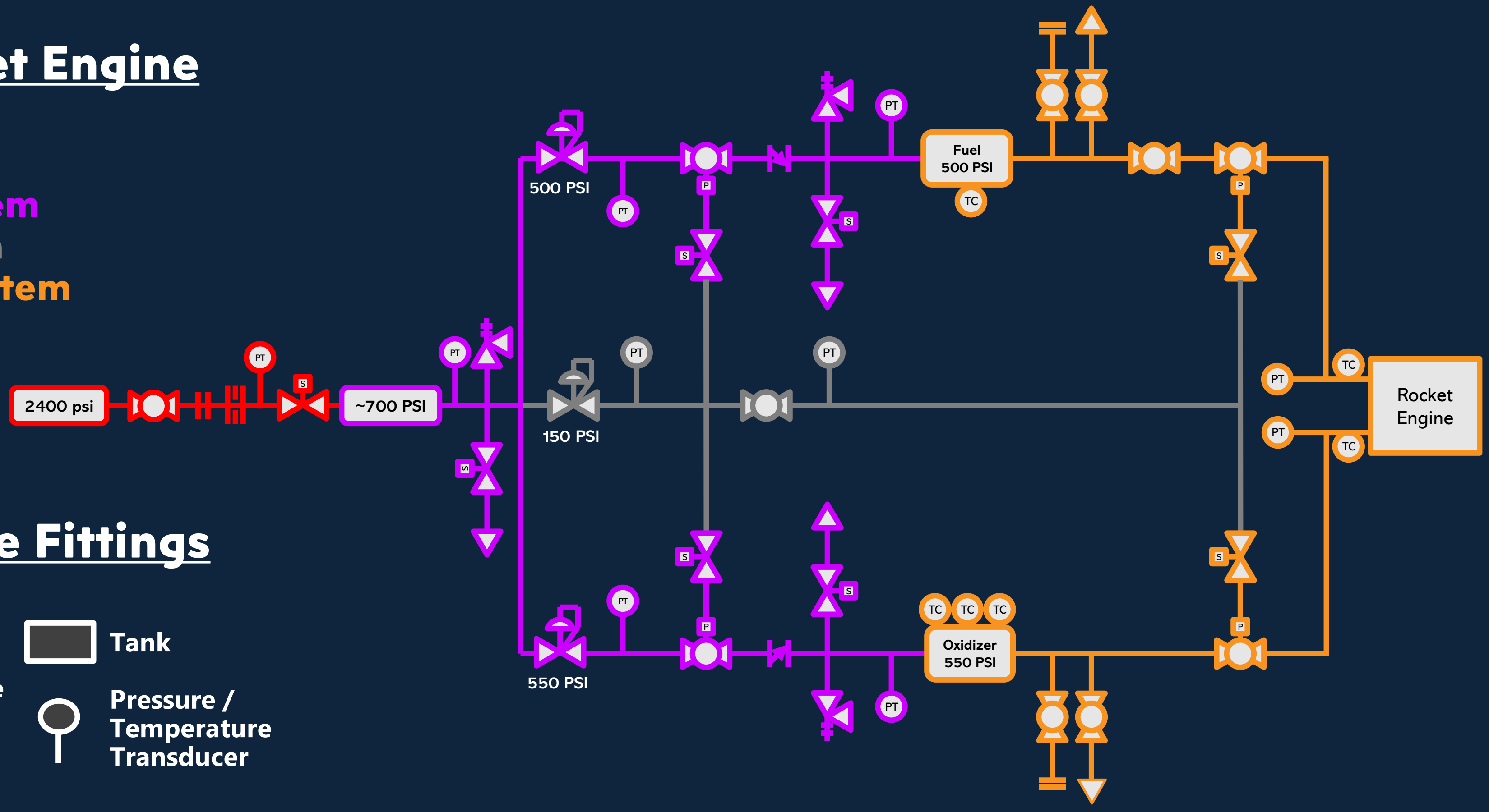
They allow for flexibility in design and analysis of ambient and cryogenic propellants.



PI&D – Eagle Rocketry Feed System

Bi-Propellant Liquid Rocket Engine

- Nitrogen Pressurizing System
- Nitrogen Gas Distribution System
- Pneumatic Pressurizing System
- Fuel / Oxidizer Distribution System



P&ID Component / Pressure Fittings

Manual Ball Valve

Pneumatic Ball Valve

Relief Valve

Pneumatic Ball Valve

Check Valve

Fixed Pressure Regulator

Orifice Plate

Tank

Pressure / Temperature Transducer

Engineering To Order – Engineering Item Specifications Example

Fall 2025: Feed System Components								
Pressure Flow Meter System								
Item	Material	Size Type (In.)	Connection Type	Pressure (PSI)	Temperature (C)	Cost	Notes	Links
Buffer Pressure Regulator	Brass	-	CGA 580	700 (4000,<800)	-	$ 36.78		Link
Pipe Sensors								
Temperature Sensors No.1	SS	1/4	MNPT	3500	-200 to 260	$ 72.90		Link
Tanks								
Nitrogen Tank	SS	-	CGA 580	2640	-			Link
Relief Valves								
Buffer Relief Valve	SS	1/4	MNPT / FNPT	350 < 700 < 750		$ 180.60	Viton / EPDM / NBR	Link
Fuel Relief Valve	SS	1/4	MNPT / FNPT	350 < 500 < 750		$ 180.60	Viton / EPDM / NBR	Link
Oxidizer Relief Valve	Brass	1/4	MNPT	576 < 550 < 710	-195 to 73			Link
Piping & Cryogenic Hoses								
Piping No.1	Copper	3/8	3/8" O.D / 0.245" I.D.	Rockwell F90	-	$ 45.12	6ft. Length	Link
Piping No.2	SS	3/8	3/8" O.D / 0.245" I.D.	5400	-195 to 815	$ 46.40	6ft. Length	Link
Piping No.3	SS	3/4	3/4" O.D / 0.68" I.D.	Rockwell B80	- to 815	$ 37.26	4ft. Length	Link
Flexible Hoses	SS	1/4	MNPT / MNPT	2400	- to 648	$ 64.86	12in. Length	Link
Piping Size Adapters								
Straight Union	SS	1/4	MNPT / MNPT	8000	-	$ 11.48		Link
Straight Union	SS	1/4	FNPT / FNPT	6600	-	$ 15.40		Link
Tank Adapter	Brass	320 to 580	CGA 320 Female to CGA 580 Female	3000	- to 40	$ 29.01	2-9/16" Long	Link
Regulator Adapter	Brass	1/4 to 580	1/4 MNPT to CGA 580 Female	3000		$ 21.96		Link
Straight Reducers	SS	3/4 to 1/4	MNPT / FNPT	11900	-28 to 37	$ 15.50	316 SS	Link
Solenoid Adapter	SS	3/4 to 3/4	MNPT / FNPT	2500 (4500 Com.)		$ 29.80	316 SS	Link
Pressure Fittings (-)								
(-) Straight Connnectors	Brass	3/8 in O.D. x 3/8 in O.D.	Compression	1000	18 to 93	$ 67.83	Pkg. of 10	Link
Straight Adapter	Brass	1/4 in. x 1/4in.	MNPT / MNPT	1000	19 to 93	$ 3.60	Each	Link
(-) Straight Adapters	Brass	3/8 in O.D. x 1/4 in. Pipe	Compression / MNPT	1000	18 to 93	$ 49.59	Pkg. of 10	Link
(-) Elbow Connectors	Brass	3/8 in O.D. x 3/8 in O.D.	Compression	1000	18 to 93	$ 108.10	Pkg. of 10	Link
(-) Elbow Adapters	Brass	3/8 in O.D. x 1/4 in. Pipe	Compression / MNPT	1000	18 to 93	$ 14.84	Each	Link
(-) T Connectors	Copper	3/8 in O.D. x 3/8 in O.D. x 3/8 in O.D.	Compression	1000	-40 to 176	$ 27.32	Each	Link

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