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# AA284B Team A

# Critical Design Review

March 11, 2020

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# Agenda

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Project Goals

Updated System Parameters

Changes Since PDR

Safety Factors

Budget & Fabrication

Revised Plans and Schedule

Engineering Drawings



# Goal

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Startup, shutdown, and restart of LOx-GCH<sub>4</sub> engine

Stretch Goals:

- Stable combustion ( $P_c$  oscillation <5% mean)
- Measure C\* efficiency
- Image engine startup and reignition



# System Parameters

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Oxidizer	Liquid Oxygen
Fuel	Gaseous Methane
Chamber Pressure	10 bar (~150 psia)
Thrust	640 N (~144 lbf)
Throat Diameter	25.4 mm (1 in)
O/F Ratio	2.5
Ox Mass Flow Rate	0.1986 kg/s
Fuel Mass Flow Rate	0.0795 kg/s
Ox Pressurization	<b>Compressed Helium</b>
Nozzle Expansion Ratio	2.18 (Sea Level Optimal)
Injector	<b>Shear Coaxial: LOx center, Methane annular</b>
Igniter	Gas-Gas Impinging with spark plug ignition
$I_{sp}$	230 sec



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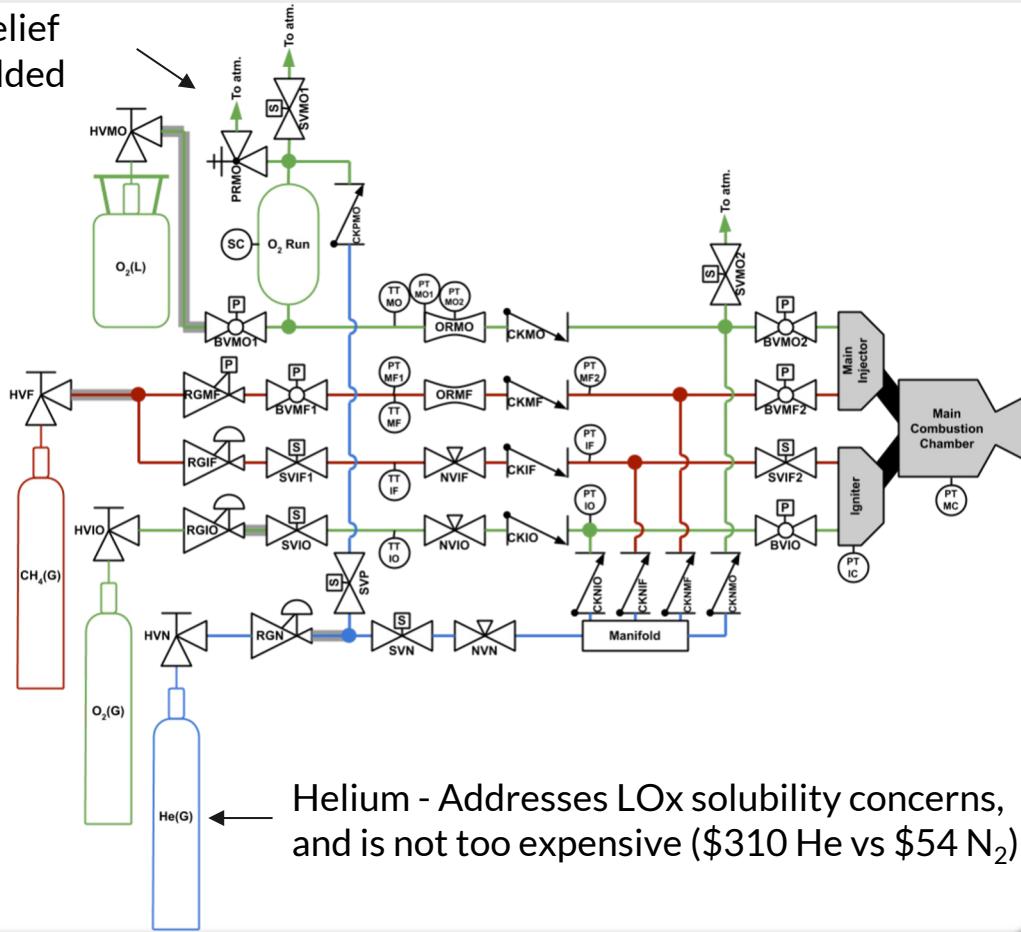
# Changes Since PDR



# P&ID

Flow Controls		
BV	Ball Valve	
CK	Check Valve	
HV	Hand Valve (Tank Valve)	
NV	Needle Valve	
OR	Orifice/Venturi	
PR	Pressure Relief Valve	
RG	Pressure Regulator	
SV	Solenoid Valve	
Instruments		
TT	Temperature Transducer	
PT	Pressure Transducer	
SC	Scale	
Fluid Media		
MO	Main Injector (Liquid) Oxygen	
MF	Main Injector Fuel (CH <sub>4</sub> )	
IO	Igniter Oxygen (Gaseous)	
IF	Igniter Fuel (CH <sub>4</sub> )	
N, P	Helium (N-Purge, P-Pressurant)	
[Type][Working Medium][Adjacent Medium]		

Relief  
Added



# P&ID Fitting Accounting Spreadsheet

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[https://docs.google.com/spreadsheets/d/1Akb-G0P3gi-R2JlckR0jrPFSVN0DPMDoXRMupv SYY/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Akb-G0P3gi-R2JlckR0jrPFSVN0DPMDoXRMupvSYY/edit?usp=sharing)



# P&ID Fitting Accounting: LOX

P&ID	Desc.	Cryo	O2	CH4	N2	Mfg.	Model No.	MAWP	Body Mat'l	Seal Mat'
BVMO1	Main Ox Fill Valve	✓		✓		<input type="checkbox"/>	Triad Process E TRI-60C-005	2000 psi	CF8M, CF3M CRES	Kel-F (PCTFE)
BVMO2	Main Ox Control Valve	✓		✓		<input type="checkbox"/>	Triad Process E TRI-60C-005	2000 psi	CF8M, CF3M CRES	Kel-F (PCTFE)
CKMO	Main Ox Check	✓		✓		<input type="checkbox"/>	Check-All U3CSSTF1.50SS	1500 psi	316 CRES	PTFE
CKNMO	Main Ox Purge Check	✓		✓		<input checked="" type="checkbox"/>	Check-All U3CSSTF1.50SS	1500 psi	316 CRES	PTFE
CKPMO	Main Ox Press Check	✓		✓		<input checked="" type="checkbox"/>	Check-All U3CSSTF1.50SS	1500 psi	316 CRES	PTFE
ORMO	Main Ox Cavitating Venturi	✓		✓		<input type="checkbox"/>	N/A	N/A	316 CRES or Inconel 718	N/A
PRMO	Main Ox Run Tank Relief	✓		✓		<input type="checkbox"/>	Generant HPRV-250SS-T-1200	3700 psi	Brass or 303 CRES or 316 CRES	PTFE
PTMO1	Main Ox Venturi Upstream PT	✓		✓		<input type="checkbox"/>	GP:50	311	10000 psi	17-4PH CRES
PTMO2	Main Ox Venturi Throat PT	✓		✓		<input type="checkbox"/>	GP:50	311	10000 psi	17-4PH CRES
SVMO1	Main Ox Run Tank Vent	✓		✓		<input type="checkbox"/>	GEMS Sensors D2062-LN2-C204-OC	1000 psi	303 CRES	RULON (PTFE)
SVMO2	Main Ox Feedline Vent	✓		✓		<input type="checkbox"/>	GEMS Sensors D2062-LN2-C204-OC	1000 psi	303 CRES	RULON (PTFE)
TTMO	Main Ox Run Tank TT	✓		✓		<input type="checkbox"/>	Nanmac A8A-21-6	NA	SS 303, SS 304	



# P&ID Fitting Accounting: GOX

P&ID	Desc.	Cryo	O2	CH4	N2	Mfg.	Model No.	MAWP	Body Mat'l	Seal Mat'
BVIO	Igniter Ox Control Valve	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Swagelok	SS-43GS4-31C	2500 psi	316, A276, A479 CRES	PTFE
CKIO	Igniter Ox Check	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Check-All	U3CSSTF1.50SS	1500 psi	316 CRES	PTFE
CKNIO	Igniter Ox Purge Check	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
NVIO	Igniter Ox Metering Valve	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Swagelok	SS-4L-MH	1000 psi	316 CRES	Fluorocarbon FK
PTIO	Igniter Ox PT	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	TE Connectivity	MSP-600-2K5-P-5-D-4	2500 psi	17-4PH CRES	
RGIO	Igniter Ox Pressure Regulator	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Victor Gas Equi	SR4J	3000 psi	Brass	PCTFE
SVIO	Igniter Ox Shutoff Valve	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Parker Skinner	71216SN2FU00	1000 psi	430 CRES	RULON (PTFE)
TTIO	Igniter Ox TT	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Nanmac	A8A-21-6	NA	SS 303, SS 304	



# P&ID Fitting Accounting: GCH4

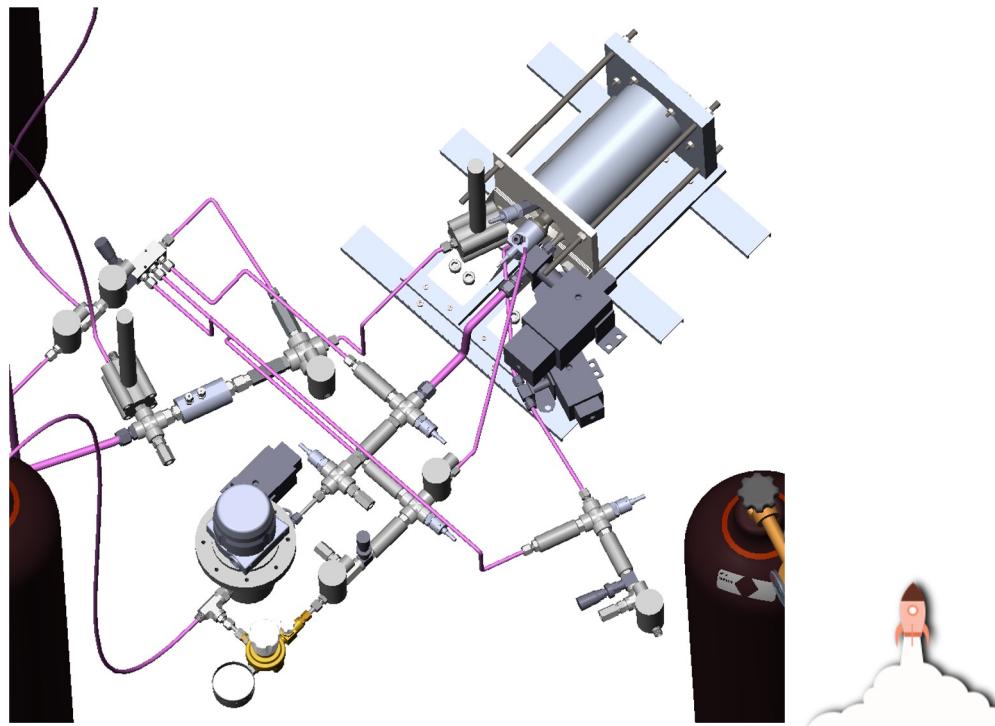
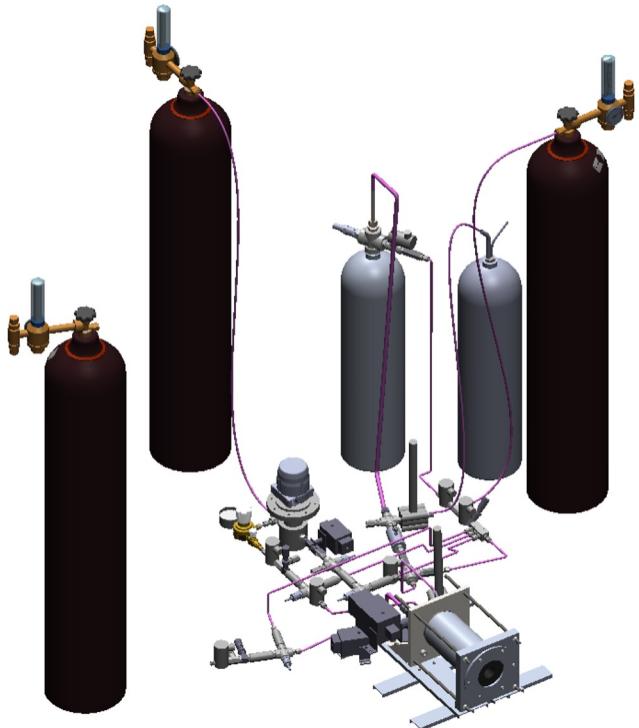
P&ID	Desc.	Cryo	O2	CH4	N2	Mfg.	Model No.	MAWP	Body Mat'l	Seal Mat'	
BVMF1	Main Fuel Shutoff Valve	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Swagelok	SS-43GS4-31C	2500 psi	316, A276, A479 CRES	PTFE
BVMF2	Main Fuel Control Valve	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Swagelok	SS-44S6-33C	1500 psi	316, A276, A479 CRES	PTFE
CKIF	Igniter Fuel Check	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
CKMF	Main Fuel Check	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
CKNIF	Igniter Fuel Purge Check	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
CKNMF	Main Fuel Purge Check	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
NVIF	Igniter Fuel Metering Valve	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Swagelok	SS-4MG-MH	1000 psi	316 CRES	Fluorocarbon FK
ORMF	Main Fuel Flow Rate Orifice	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	McMaster-Carr	2822t15-2822T355	4000 psi	303 CRES	N/A
PTIF	Igniter Fuel PT	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	TE Connectivity	MSP-600-2K5-P-5-D-4	2500 psi	17-4PH CRES	
PTMF1	Main Fuel PT Upstream	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	TE Connectivity	MSP-600-2K5-P-5-D-4	2500 psi	17-4PH CRES	
PTMF2	Main Fuel PT Downstream	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	TE Connectivity	MSP-600-2K5-P-5-D-4	2500 psi	17-4PH CRES	
RGIF	Igniter Fuel Pressure Regulator	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Victor Gas Equi	SR4J	3000 psi	Brass	PCTFE
RGMF	Main Fuel Pressure Regulator	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Tescom	26-2095T69A470AN	15000 psi	316 CRES	Viton
SVIF1	Igniter Fuel Shutoff Valve	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Parker Skinner	71216SN2FU00	1000 psi	430 CRES	RULON (PTFE)
SVIF2	Igniter Fuel Control Valve	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Parker Skinner	71216SN2FU00	1000 psi	430 CRES	RULON (PTFE)
TTIF	Igniter Fuel TT	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Nanmac	A8A-21-6	NA	SS 303, SS 304	
TTMF	Main Fuel TT	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	Nanmac	A8A-21-6	NA	SS 303, SS 304	

# P&ID Fitting Accounting: He

P&ID	Desc.	Cryo	O2	CH4	He	Mfg.	Model No.	MAWP	Body Mat'l	Seal Mat'
CKNIF	Igniter Fuel Purge Check	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
CKNIO	Igniter Ox Purge Check	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
CKNMF	Main Fuel Purge Check	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	McMaster-Carr	1874N13	3000 psi	SS 316	Fluoroelastomer
CKNMO	<b>Main Ox Purge Check</b>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Check-All	U3CSSTF1.50SS	1500 psi	316 CRES	PTFE
CKPMO	<b>Main Ox Press Check</b>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Check-All	U3CSSTF1.50SS	1500 psi	316 CRES	PTFE
RGN	Helium Pressure Regulator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Victor Gas Equi	SR4J	3000 psi	Brass	PCTFE
SVN	Helium Purge Shutoff Valve	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	GEMS Sensors	A2021-LB-C204	1000 psi	303 CRES	Nitrile (Buna-N)
SVP	Main Ox Run Tank Pressurizatio	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	GEMS Sensors	A2021-LB-C204	1000 psi	303 CRES	Nitrile (Buna-N)

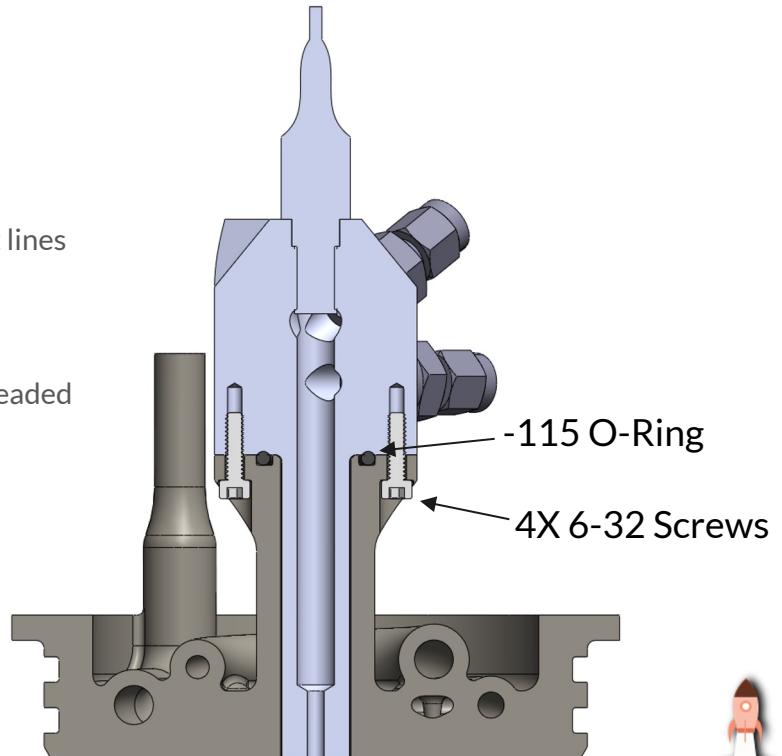


# Overall System Layout (image)



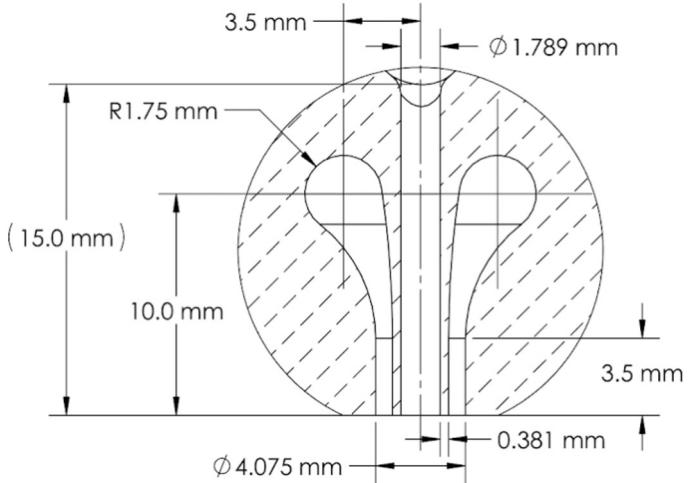
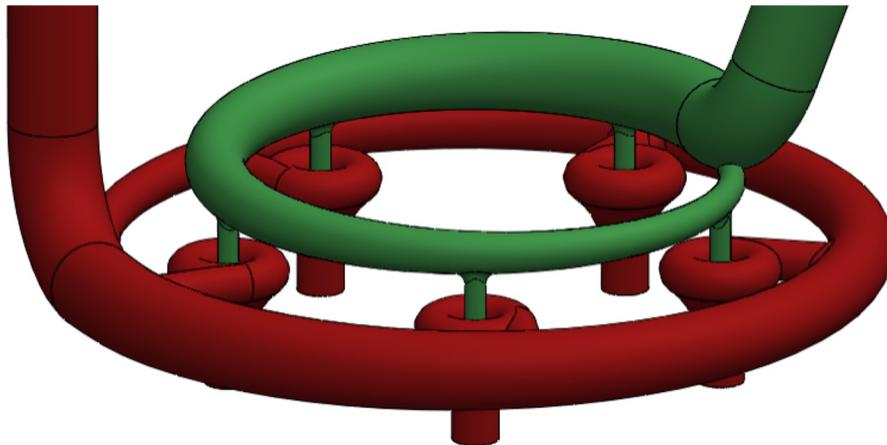
# Injector/Igniter Assembly

- Replaced threaded connection with bolt circle
  - Allows control over igniter clocking relative to injector
  - Prevents fitting interference between igniter & main propellant lines
- Moved interface farther from injector face
  - Easier access to machine O-ring gland and bolt holes
  - Igniter is now “sleeve” inside injector, easier to replace than threaded
  - Can split igniter into “fitting head” and chamber if needed for machinability or material compatibility
- FoS >11 Yield
  - Hand Calculation: Thread shear area = thread minor dia.
  - 0.88" O-Ring gland OD
  - 150 psi
  - 316 CRES,  $F_{TY} = 25$  ksi



# Main Injector

- Annular gap increased to 0.03" for printability
- 10 → 5 Elements to maintain high momentum flux ratio
- Swirl → Shear Coaxial for printability & simplicity
- To Do: CFD to determine actual discharge coefficients

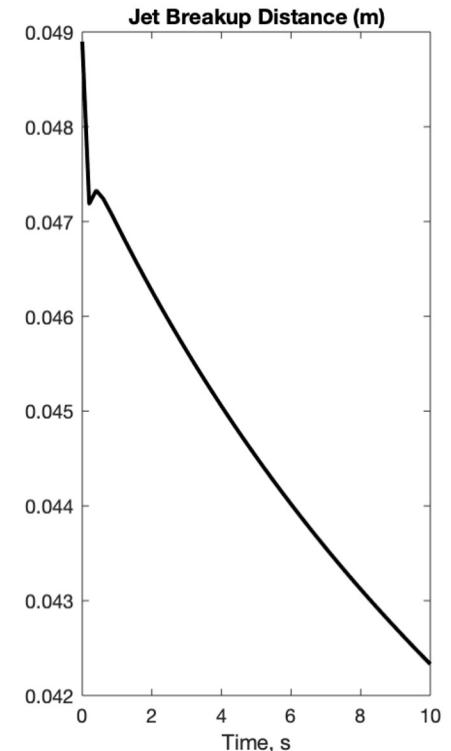
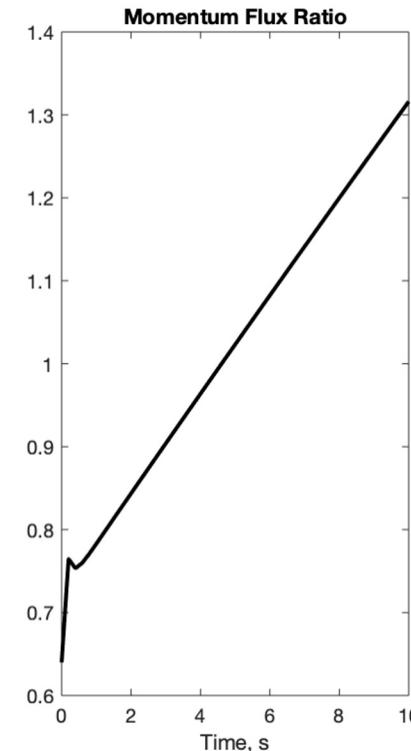
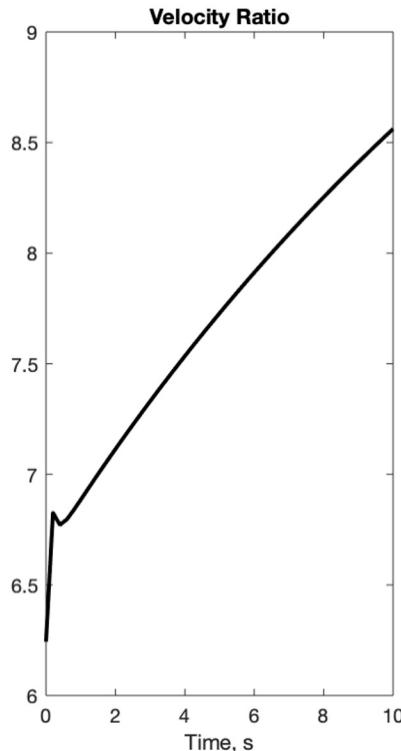


# Main Injector Element Characteristics

Breakup distance  
correlation from this paper:  
<https://doi.org/10.2514/1.26538>

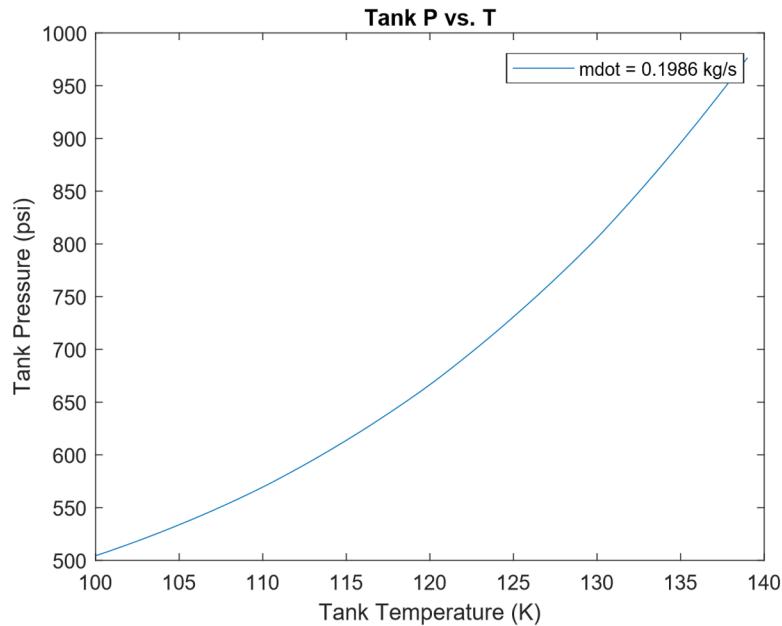
Chamber Length ~0.16 m

Good performance  
expected, but injector  
behavior still needs to be  
characterized



# Venturi Dependence on Inlet Temperature

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# Pneumatic Controls

Bottled N2 now used to power pneumatically actuated valves instead of air compressor (avoids possible power supply issues during test).

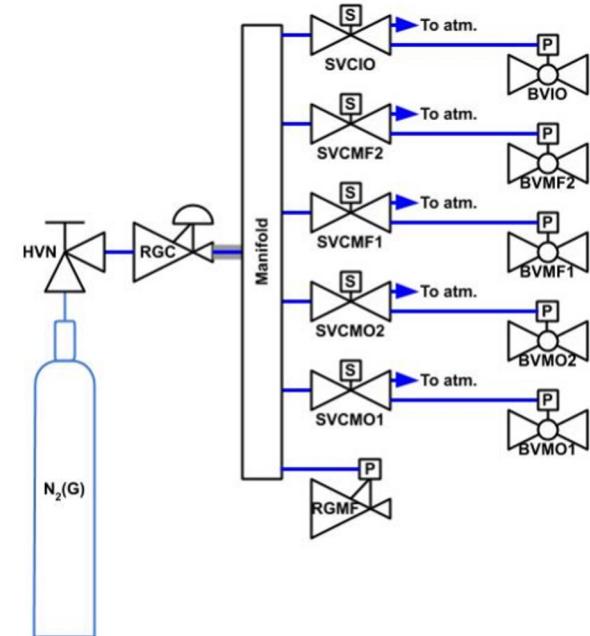
Pressure regulated down to 100 psi and controlled using 2 position, 3 way solenoid valves.

Swagelok Actuator Model #	Air Displacement [in <sup>3</sup> ]	Number of actuators	Volume of 100 Actuations [in <sup>3</sup> ]
131	1.5	3	150
133	4.9	2	490
135	15.5	1	1550

**Volume for actuation = 2980 in<sup>3</sup> or 1.724 ft<sup>3</sup>**

Pressure [PSI]	Density [lbm/ft <sup>3</sup> ]	Volume [ft <sup>3</sup> ]	Mass [lbm]
235	1.23464	228	281.4
145	0.78882	1.724	1.3589

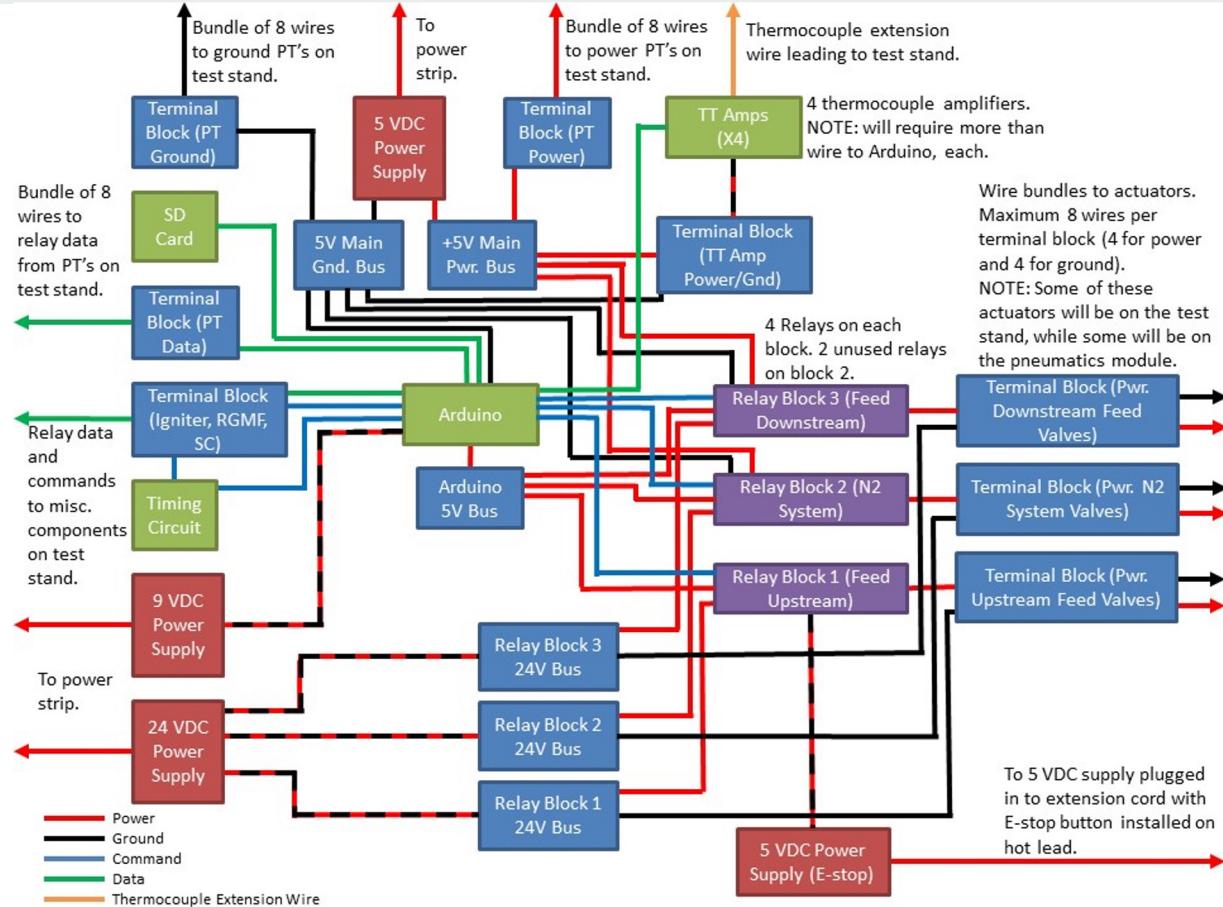
**N2 for Actuation = 0.4827%**



# Electronics

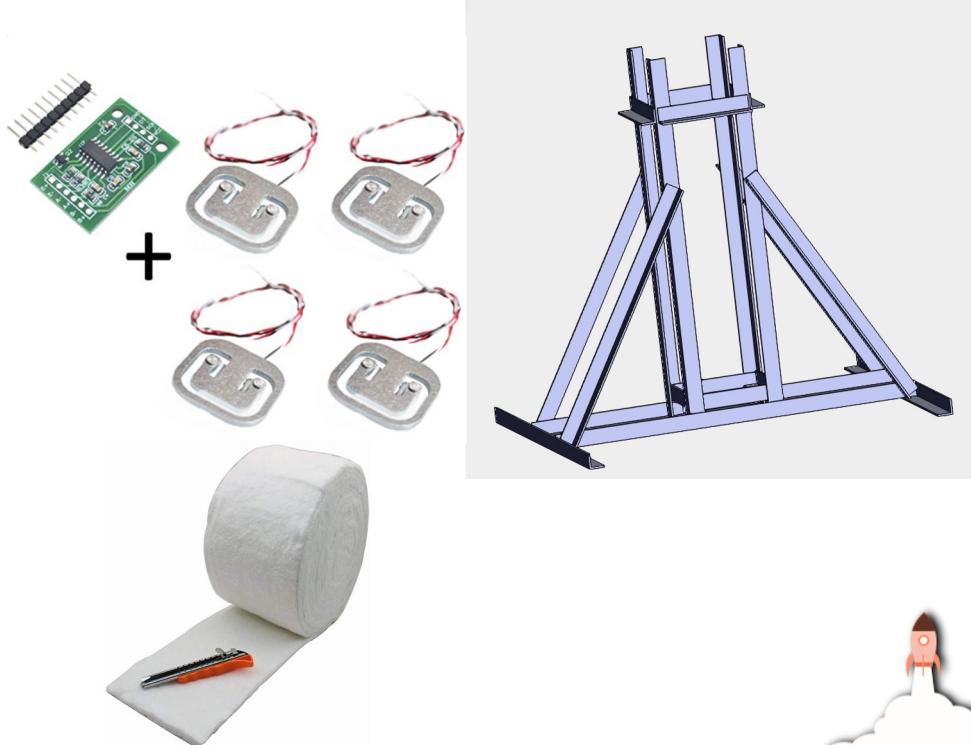
Most of the electrical system will be mounted on a single board with terminal blocks or connectors to interface with the test stand.

The wiring will look like this except some of these lines are bundles of wires, not a single wire.



# LOx Tank Mount & Insulation

- 4 load cells for monitoring run tank weight in real time
- Load cells will be placed at the base of the tank support structure
- Insulation using 0.4 inch thick ceramic fiber blanket & aluminum foil, held in place via cable ties & aluminum foil lined tape



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# Factors of Safety



# Summary of Safety Factors

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Component	Safety Factor
Igniter	>15
Igniter Screws	>11
Injector	2
Tie Rods	25
Nozzle Retainer Bolts	2.6
Chamber Wall	16
Nozzle End Flange	2.8
Test Stand Support Plate	10
$\frac{1}{4}$ -0.035" 316 Tube	2.6 (@2000psi)
$\frac{3}{8}$ -0.035" 316 Tube	3.4 (@1000psi)
$\frac{1}{2}$ -0.035" 316 Tube	2.5 (@1000psi)



# Injector/Igniter FEA

## Injector

### Pressures

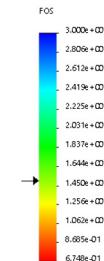
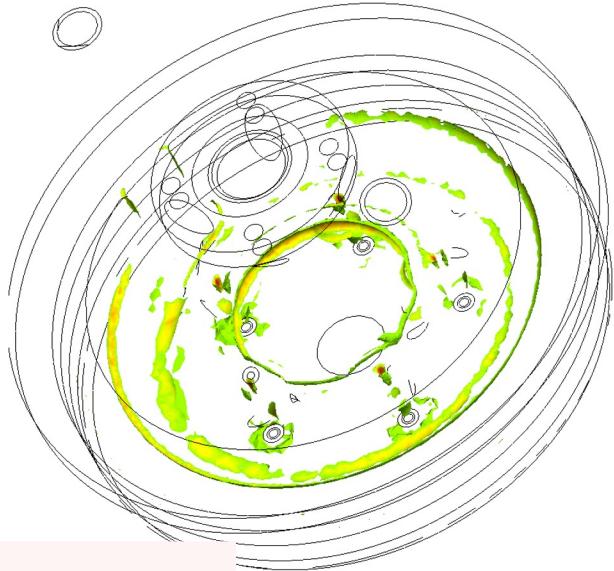
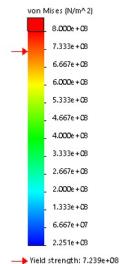
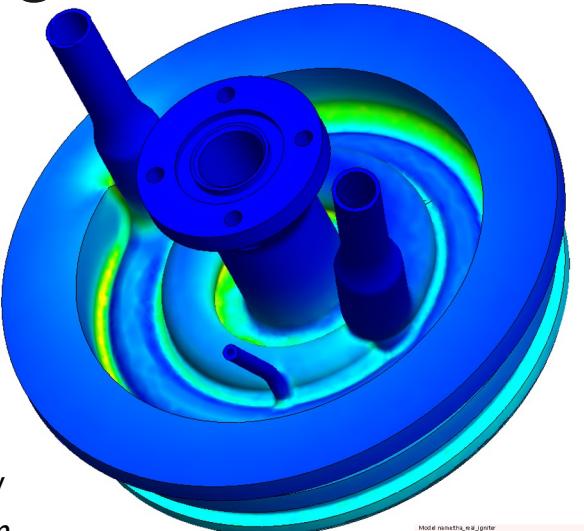
150 psi on face

217 psi in manifold

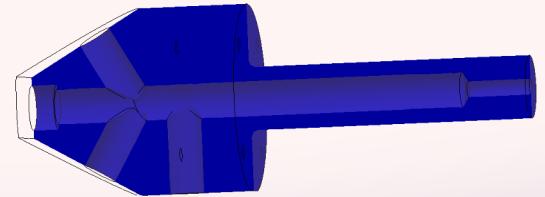
### Temperatures

500 K on face

*Localized areas of low FS around LOx stream due to thermal stress, but large FS in bulk - May revisit before printing*

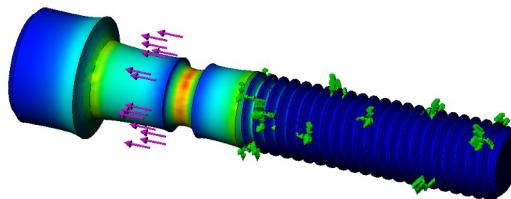


Igniter  
Pressure  
200 psi  
FS > 15

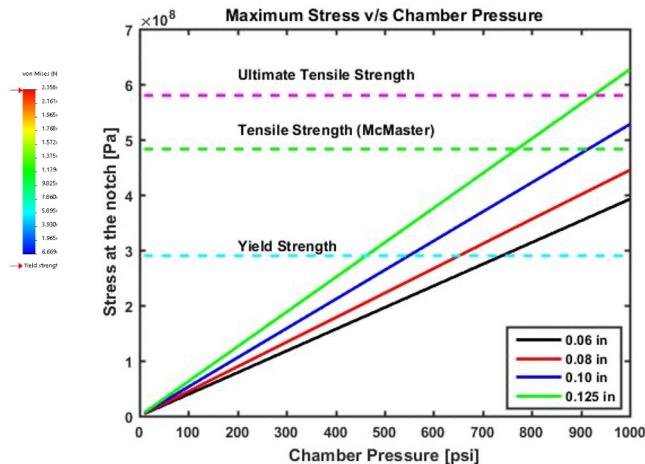


# Combustion Chamber Overpressure Relief

- FEA simulations confirmed with hand calculations



FEA

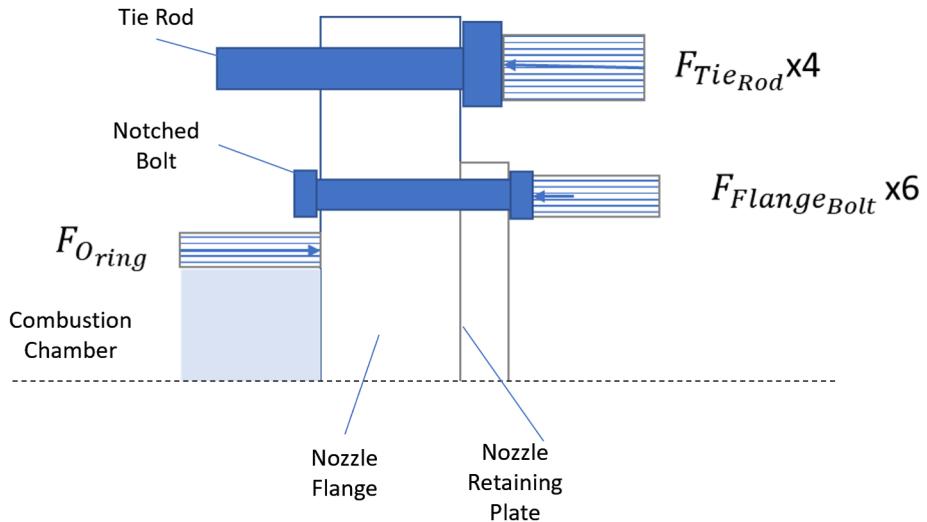


- 0.06 in notch depth will lead to failure at 800 psi

Hand  
Calculation

# Factor of Safety

- Hand calculations confirmed the current setup can withstand the operating chamber pressure of 150 PSI.
- Assumptions:
  - Pressure distributions modelled as point loads on a cantilever beam.



$$P_{TR} = 800 \text{ PSI}$$

$$\sigma_{max\ TR} = 20000 \text{ PSI}$$

$$FS_{TR} = 25$$

$$P_{FB} = 300 \text{ PSI}$$

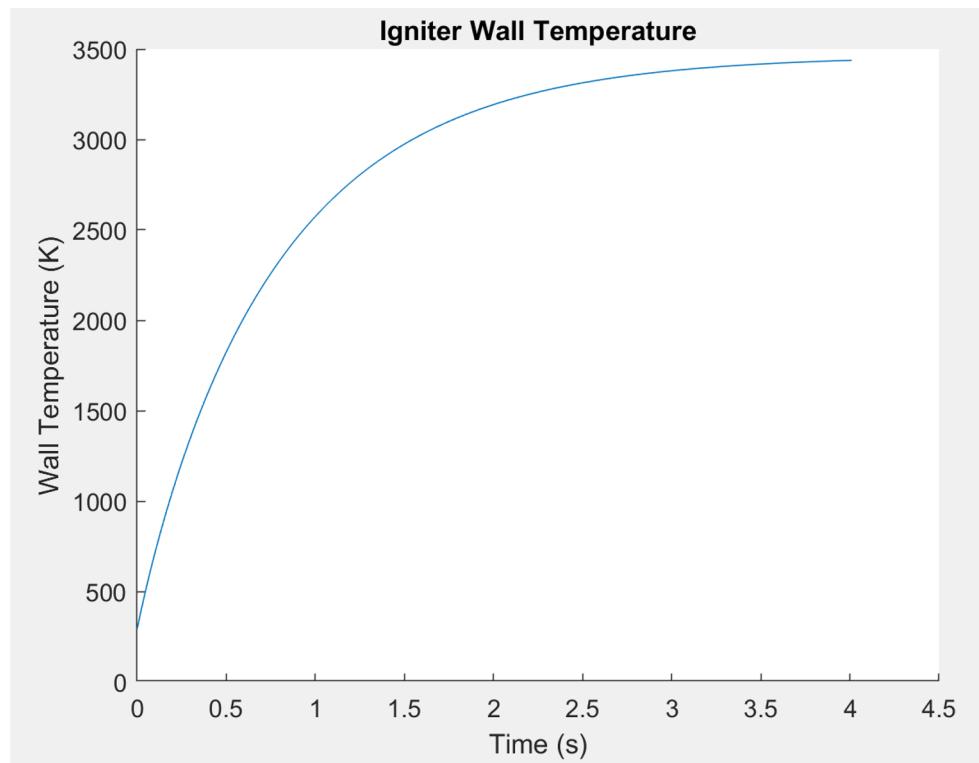
$$\sigma_{max\ FB} = 800 \text{ PSI}$$

$$FS_{FB} = 2.6$$



# Igniter Heat Transfer Estimate

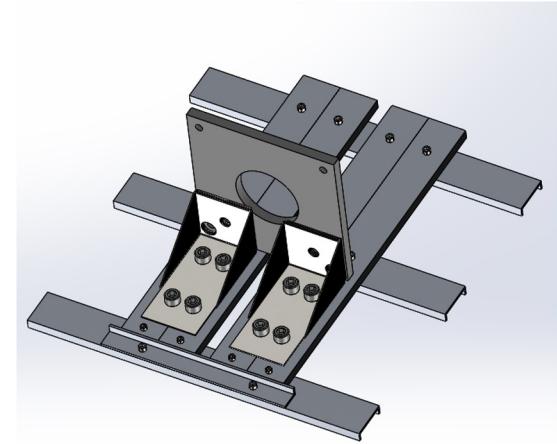
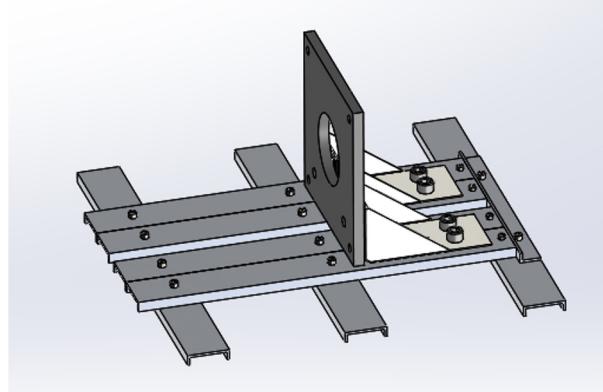
- Treated igniter chamber as a simple tube, with the following flow characteristics
  - Internal forced convection from flow at 3464 K from CEA
  - Weighted average  $C_p$  and viscosity of flow from CEA
  - External natural convection
  - Ignore conduction resistance
- Forced Convection
  - Sieder and Tate Relation due to high  $dT$
- Natural Convection
  - Empirical horizontal pipe
- Energy difference results in  $dT$  of wall



# Test Stand

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- Changes from PDR:
  - No welds
  - Corner brackets are rated for 500 lbs each, FoS = 10
  - Removed backplate of combustion chamber assembly to reduce weight and cost
  - Cost: \$277.92
  - Materials: HomeDepot and MetalsDepot (2 day delivery time)
  - Manufacturing: Drilling holes, CNC back plate -> lead time: 1 week



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# Budget & Fabrication



# Budget

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<https://docs.google.com/spreadsheets/d/1Akb-G0P3gi-R2JlickR0jrPFSVN0DPMDoXRMupvSYY/edit#gid=67673>

## Running Total

Budgeted	Purchased	Remaining
6694.78	424.65	2880.57

## Subsystem Breakdown

Subsystem	Budgeted	Purchased
Avionics	1063.92	148.06
Igniter/Injector	2.61	235.84
Nozzle/Chamber	800.91	40.75
Feed	4532.8	0
Test	294.54	0

## Component Breakdown

Component	Budgeted	Purchased
Adhesives/Sealants	51.2	0
Fasteners	59.92	40.75
Flow Control	2219.12	0
Instruments	445.93	51.23
Machined Parts	595.68	0
Metal Stock	399.49	72
Propellant/Gas	547.64	0
Seal Elements	26.36	0
Services	0	0
Tanks	184.95	0
Tubing/Pipe Fittings	1379.24	52.92
Tubing/Pipes	218.89	0



# Fabrication

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Custom Part	Fabrication Method	Supplier/Shop	Cost
Injector	DMP & Post-Machined	Protolabs	Sponsored
Igniter	Machined	PRL	Materials
Cavitating Venturi	Machined	PRL	Materials
Combustion Chamber	Machined	Pending	Pending
Nozzle Retaining (Notched) Bolts	Machined	PRL	Materials
Nozzle	Machined	Electro Tech Machining	~\$198 ea. for 3
Nozzle End Flange	Machined	Pending	Pending
Nozzle Retaining Plate	Waterjet	PRL	Materials
Test Stand Support Plate	Waterjet	PRL	Materials



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# Revised Test Plan & Schedule



# Test Plan

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## Subsystem tests

- Igniter test (needs to re-ignite for this mission)
  - Test igniter under operating conditions
    - Determine ignition timing, test control software, size of igniter throat
    - Determine igniter jet-penetration distance for the chosen operating pressure
  - Series of tests
    - Ignite the igniter propellant in open air
    - Measure pressure rise in combustion chamber with no oxidizer flow
- Hydro testing of pressure vessels
  - Manufacture components tested to 1.5 MAWP, holding pressure for 10 min
  - Fill test component with water
  - Procedure
    - Seal off pressure vessel except for a single entry port (Designs for the Aluminium plug for the combustor ready)
    - Fill the vessel with deionized water
    - Orient the chamber to eliminate the presence of trapped air
    - Use a hydraulic pump cart to bring it up to a pre-determined test pressure
    - Hold pressure for an amount of time and visually inspect for leaks



# Test Plan

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## Subsystem tests

- Cold flow test
  - Confirm that oxidizer mass rate matches the design objective
  - Load rocket with oxidizer and vent, no igniter installed
  - Adjust tank pressure to tune oxidizer mass flow rate
  - Procedure
    - Setup air feed supply
- Avionics startup, data acquisition, shutdown

## Full system test

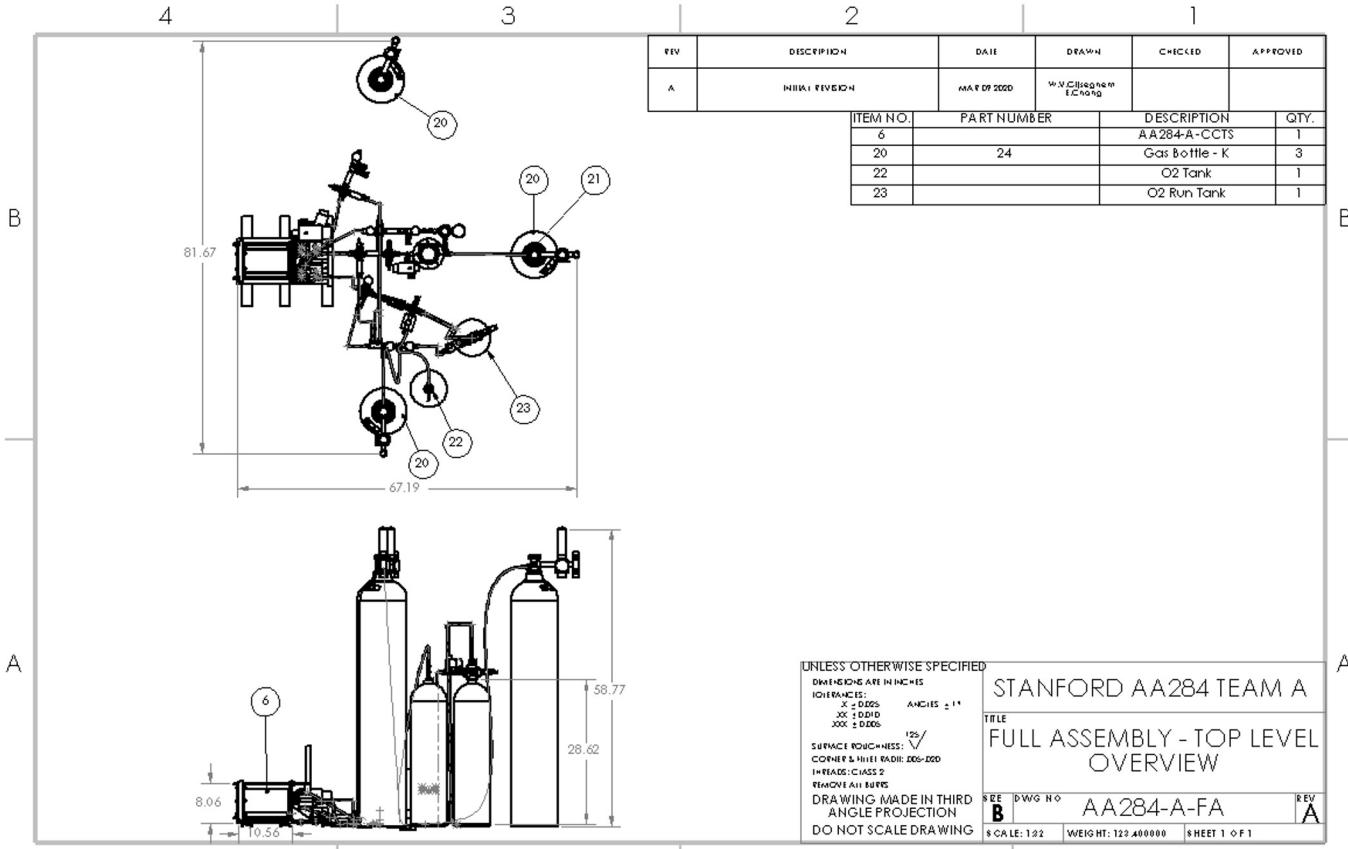
- Single (5 second) burn
- 2 burns back-to-back
- Three burns back-to-back



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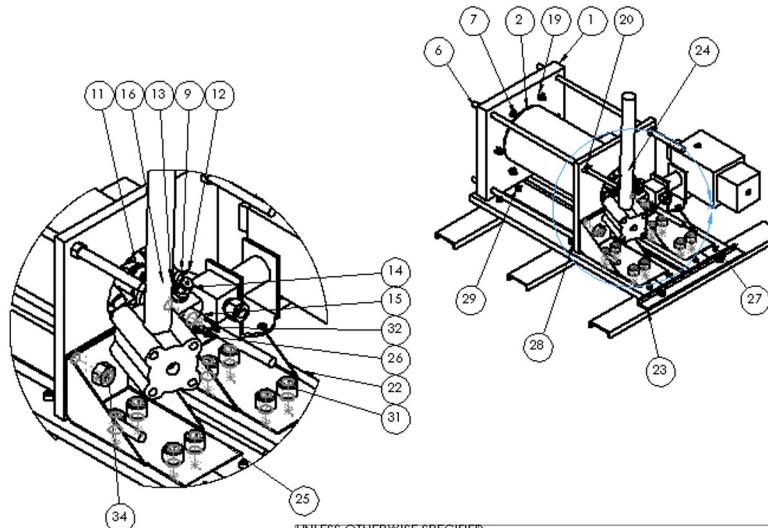
# Assembly Drawings





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	105	AA-284-A-NRP	1
2	99	AA284-A-CCT	1
3	100	AA284-A-CPL	1
4	97	AA284A-A-NZL	1
5	104	AA284-A-NEF	1
6	108	Tie rod	4
7	102	AA284-A-NRN	6
8	78	342 Size O-Ring	1
9	Main Injector Assembly	AA-284-A-MI	1
10		115 Size O-Ring	1
12	A1	Ball valve	1
13	Igniter Assembly	AA-284-A-IG	1
15	77	Spark plug	1
16	52	MSP-300 Pressure Transducer	1
17	181	6-32, super corrosion resistant, 1/2" Long	4
18	80	240 Size O-Ring	2
19	98	Hext nut, 1/4-20	8
20	164	1/2"-20, 1-1/4" long	8
21	109	244 Size O-Ring	1
22	71	C-Channel bar 2 in. x 36 in. Plain Steel C-Channel Bar with 1/8 in. Thick	7
23	73	1-1/2 in. x 48 in. Plain Steel Angle with 1/8 in. Thick	1
24	74	A284-A-TSSP	1
25	165	Corner bracket	1
26	165	Corner bracket mirror	1
29	75	1/4"-20, 9 1/8" long	16
31	163	Socket head, 1/2"-20, 3/4" long	8
32	162	Hex Nut, 1/2"-20	10
36	9	Triad 1/4" Ball valve	1

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	Initial Revision	MAR 09 2020	E.Cheng		



UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES

DEVIANCES:

X = ±0.025

XX = ±0.050

XXX = ±0.000

125/V

CONVERSE HOLE RADIUS: 0.05-0.060

HEADS: CLASS 2

REMOVED ALL BURRS

DRAWING MADE IN THIRD

ANGLE PROJECTION

DO NOT SCALE DRAWING

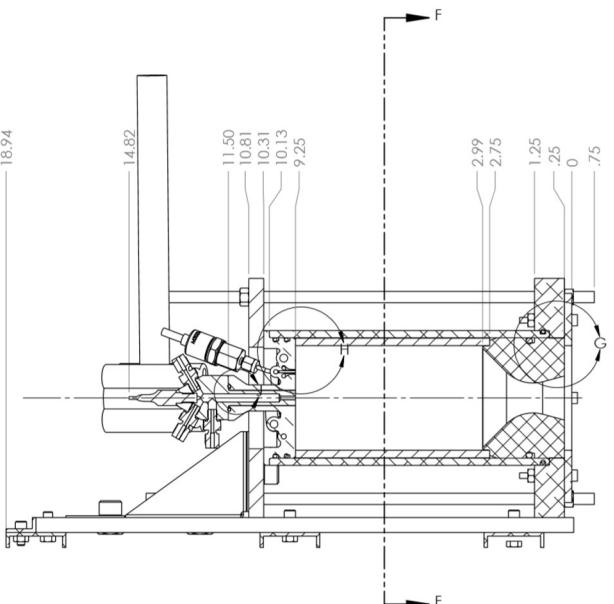
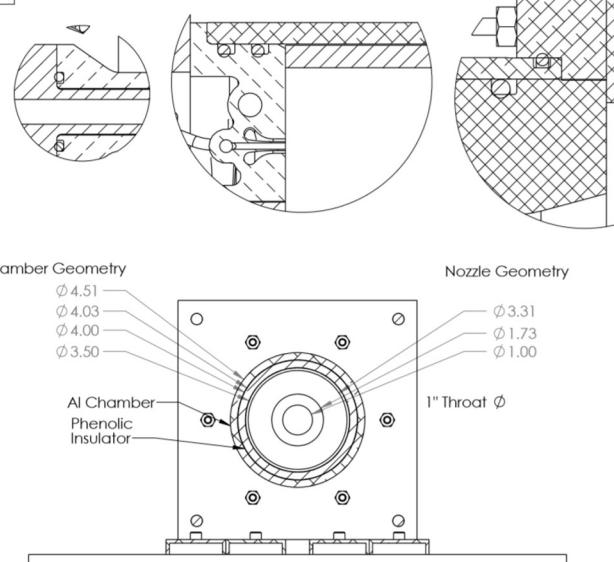
STANFORD AA284 TEAM A

COMBUSTION CHAMBER  
TEST STAND ASSEMBLY

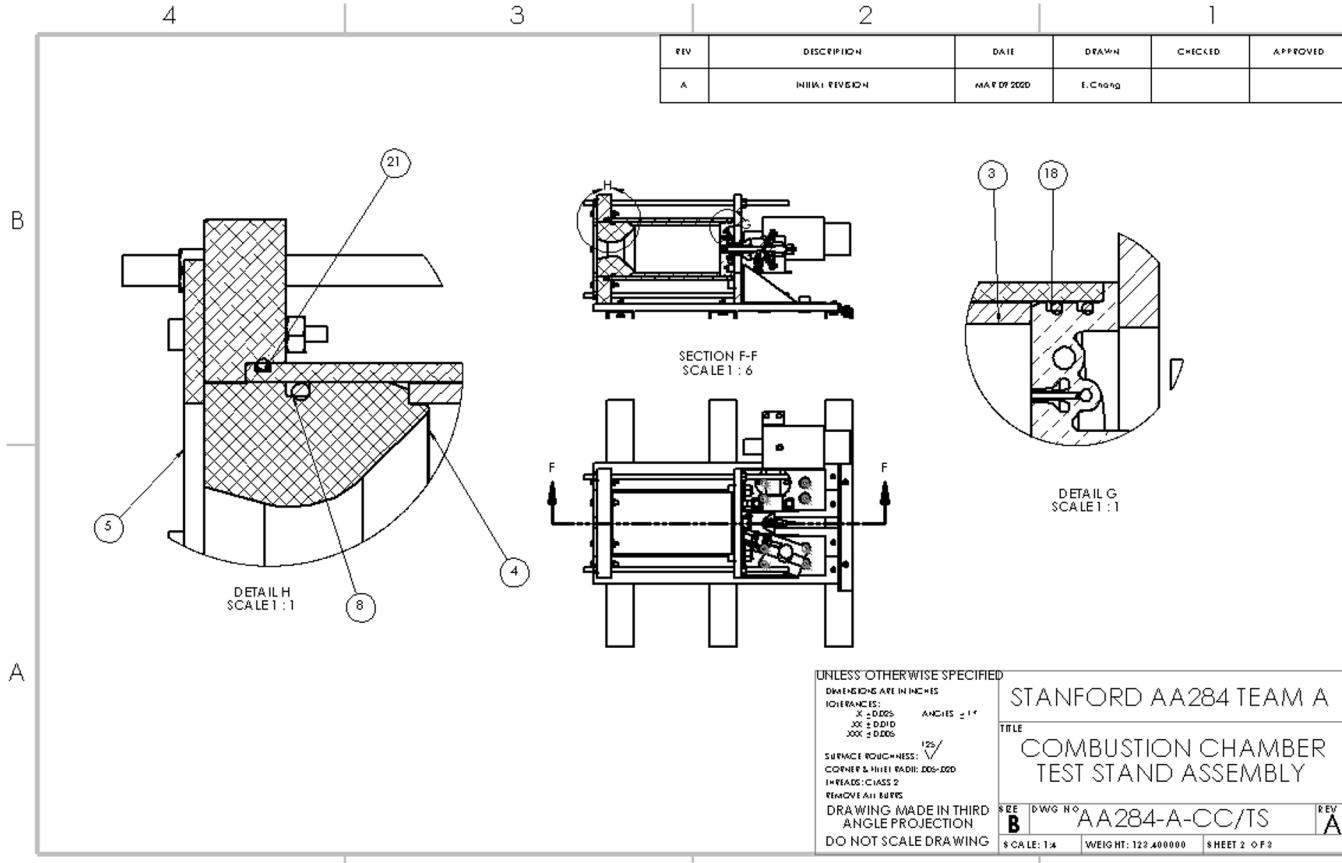
SEE DWG NO B AA284-A-CC/TS REV A

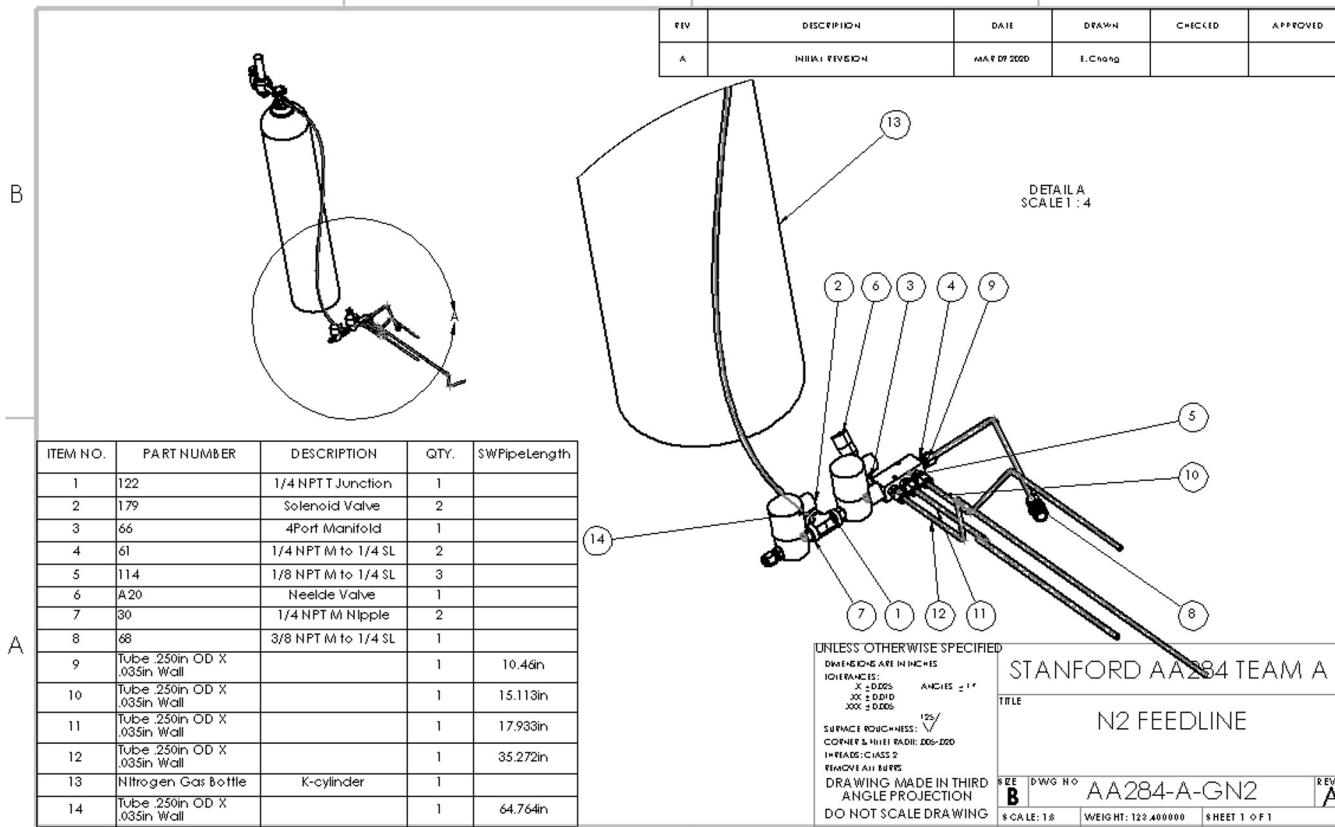
SCALE: 1:4 WEIGHT: 123.400000 SHEET 1 OF 1



REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 09 2020	A. Taraborelli		
<hr/>					
					
<p>SECTION D-D SCALE 1 : 3</p> <p>SECTION F-F SCALE 1 : 3</p> <p>DETAIL J SCALE 1 : 1</p> <p>DETAIL H SCALE 1 : 1</p> <p>DETAIL G SCALE 1 : 1</p>					
 <p>Chamber Geometry</p> <p>Nozzle Geometry</p> <p>SECTION F-F SCALE 1 : 3</p>					
<p>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: <math>.X \pm 0.025</math> <math>.XX \pm 0.010</math> <math>.XXX \pm 0.005</math></p> <p>ANGLES <math>\pm 1^\circ</math></p> <p>SURFACE ROUGHNESS: <math>125\sqrt{\text{ }}</math> CORNERS &amp; FILLET RADII: .005-.020 THREADS: CLASS 2 REMOVE ALL BURRS</p> <p>DRAWING MADE IN THIRD ANGLE PROJECTION DO NOT SCALE DRAWING</p> <p>SIZE DWG NO. AA284-A-CCT/TS REV A SCALE: 1:8 WEIGHT: 123.40000 SHEET 1 OF 1</p>					

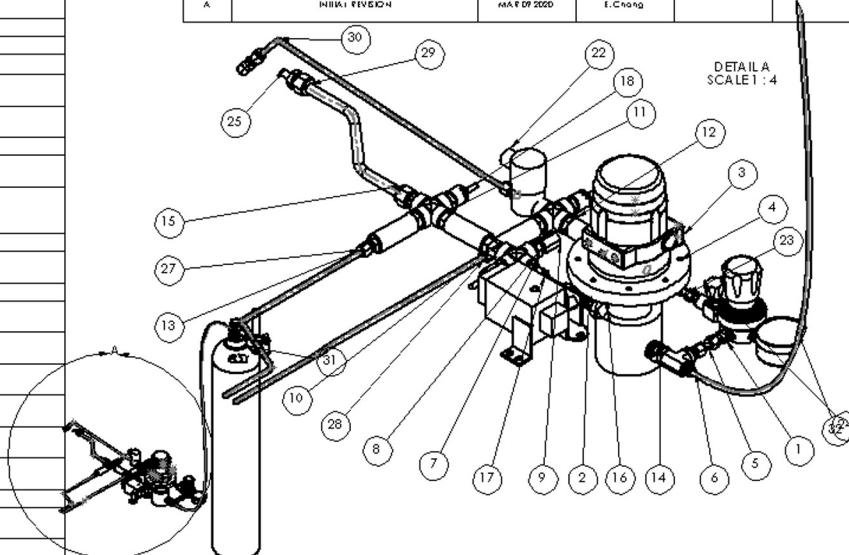






ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	SW Pipe Length
1	61	1/4 NPT M to 1/4 SL	5	
2	A13	Ball Valve	1	
3	A6	ER-3000	1	
4	A6	Tescom Regulator	1	
5	60	1/4" OD, 0.035" in Wall tube	1	
6	31	1/4 NPT M to 1/4 NPT F	2	
7	41	1/4 NPT+ Junction	3	
8	92	1/4 NPT M to 1/8 NPT F	2	
9	14	Thero Couple and 1/8 NT M to RTD adapter	2	
10	113	Orifice	1	
11	47	1/4 NPT M to 3/8 NPT M	5	
12	46	Check Valve	4	
13	47	1/4 SL to 3/8 NPT M	2	
14	23	1/2 NPT to 1/2 NPT M	1	
15	96	1/4 NPT M to 3/8 SL tube stub	1	
16	116	1/2 NPT to 1/4 SL stub	1	
17	60	1/4" OD, 0.035" in Wall tube	1	
18	52	MSP-300 Pressure Transducer	3	
19	A22	Needle valve	1	
20	123	1/4 NPT F to 3/8 NPT M	1	
21	A31	Flex Hose Adapter	1	
22	A1	Solenoid Valve	2	
23	60	1/4" OD, 0.035" in Wall tube	1	
24	A8	Pressure Regulator	1	
27	Tube 250in OD X .035in Wall		1	14.325in
28	Tube 250in OD X .035in Wall		1	17.146in
29	Tube .500in OD X .035in Wall		1	8.758in
30	Tube 250in OD X .035in Wall		1	14.54in
31	Gas Bottle		1	
32	Tube 250in OD X .035in Wall		1	59.30in

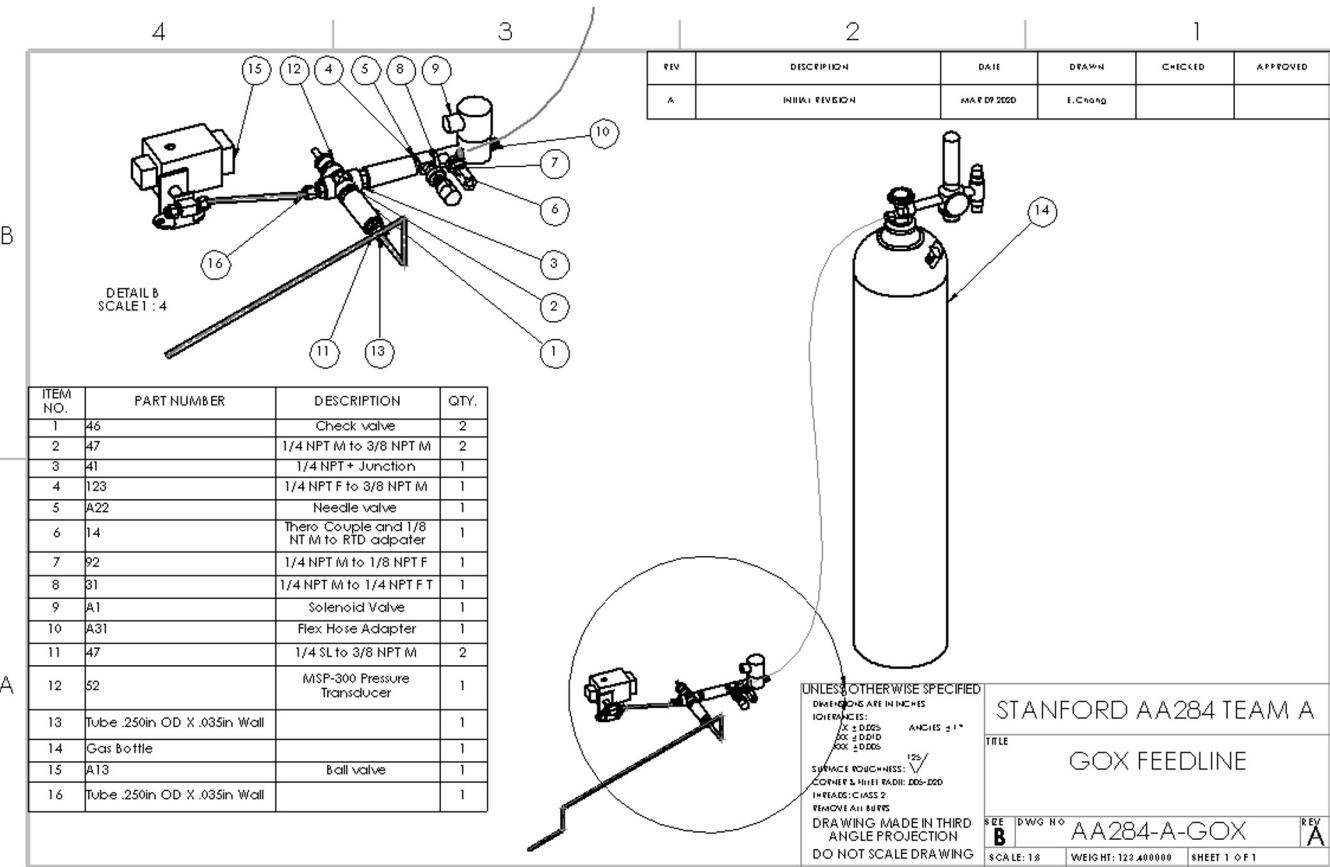
REV	DESCRIPTION	DATE	DRAWN	CHECLED	APPROVED
A	INITIAL REVISION	MAR 09 2020	E.Chang		



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
INTERFACES:  
XX = DODS ANGLES  $\pm 1^\circ$   
XXX = DODD  
SURFACE FINISHES: ✓  
CORNER & HOLE RADIUS: 0.05-0.20  
INTERFACE CLASS: 2  
REMOVABLE PARTS:  
DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

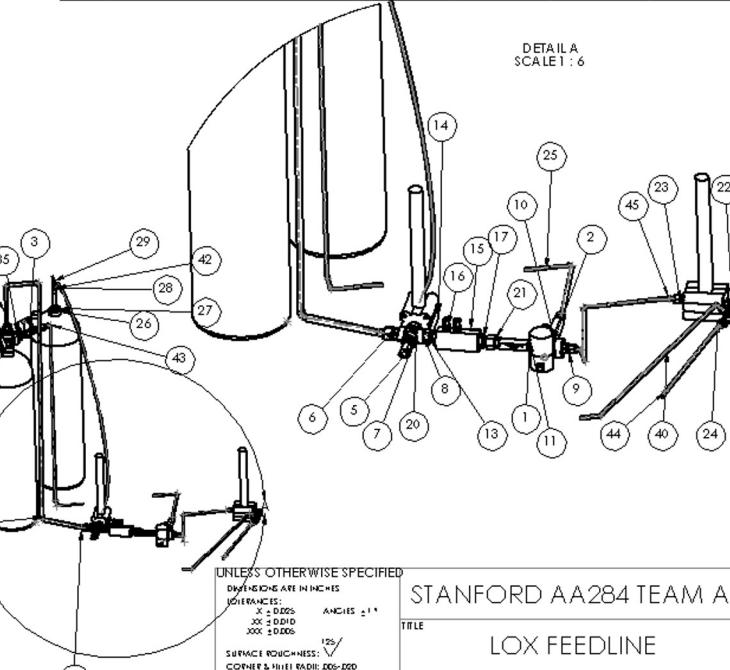
SEE DWG NO:	B	AA284-A-GCH4	REV A
SCALE:	1:16	WEIG HT:	122.400000
SHEET 1 OF 1			





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	SW Pipe Length
1		Check Valve	3	
2	94	Solenoid Valve	2	
3	119	3/8 NPT M to 3/8 NPT M	3	
4	30	Solenoid Adapter	1	
5	13	Temo-couple	1	
6	45	1/4 NPT to 1/2 SL	2	
7	14	1/8 NPT M to RTD fitting	1	
8	41	1/4 NPT F+	1	
9	47	3/8 NPT M to 1/4 SL	3	
10	118	3/8 NPT F+	1	
14	9	Cryogenic ball valve	2	
15	Cavitting Venturi		1	
16	168	PTMO adapter	2	
17	167	3/4 UNF M to 1/2 YL	2	
20	175	ORMO 1/4 NPT M to 1/2 STEM	1	
21	176	1/2 Stem to 3/8 NPT M	1	
22	120	1/4 NPT M to 3/8 SL	1	
23	47	1/4 NPT M to 3/8 NPT M	1	
25	Tube .250in OD X .035in Wall		1	10.534in
26	Tank		1	
27	35	3/4 Tank Nipple	1	
28	LOX Straw		1	
29	OX Straw		1	
30	Catalina S80 Tank		1	
31	80	1/4 NPT M to 1/4 NPT M	1	
32	41	1/4 NPT F+	1	
34	LOX Tube		1	
35	39	3/4 to 1/4 NPT Reducer	1	
36	42	1/4 NPT F Tjunction	1	
37	124	3/4 NPT M to 1/4 NPT F	1	
38	A25	Relief Valve	1	
39	Tube .500in OD X .035in Wall		1	45.437in
40	Tube .250in OD X .035in Wall		1	14.54in
41	Tube .500in OD X .035in Wall		1	6.622in
42	Tube .250in OD X .035in Wall		1	43.266in
43	Tube .250in OD X .035in Wall		1	35.485in
44	Tube .250in OD X .035in Wall		1	8.813in
45	Tube .250in OD X .035in Wall		1	14.041in

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL Revision	MAY 09 2020	E.Cheng		



4

3

2

1



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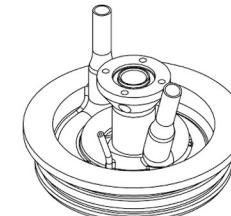
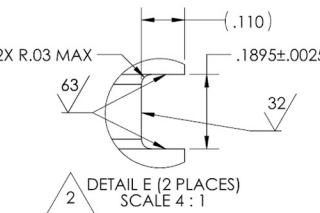
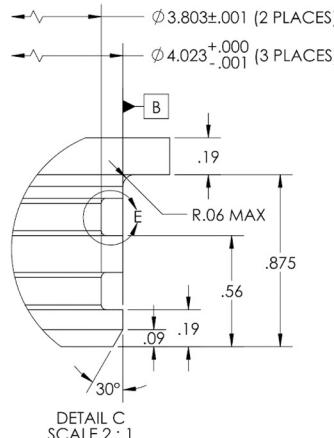
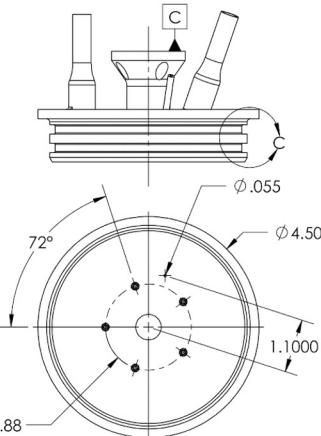
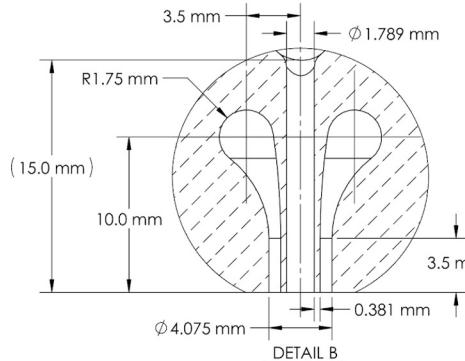
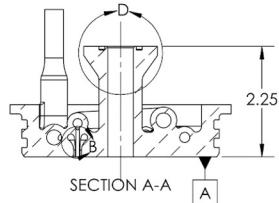
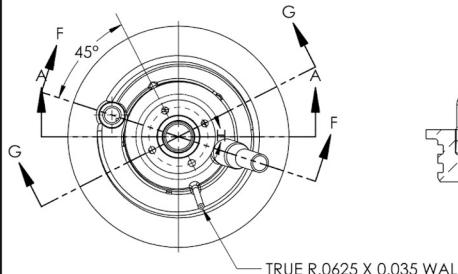
# Component Drawings



REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 10 2020	J. ROBINSON	W. KEHOE	G. ZILLIAC

**NOTES:**

- 1. MATERIAL: DMLS INCONEL 718, SOLUTION TREATED
  - 2. MALE GLAND FOR SIZE 240 O-RING
  - 3. FACE GLAND FOR SIZE 115 O-RING



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
 $\pm 0.025$       ANGLES  $\pm 1^\circ$   
 $\pm 0.010$   
 $\pm 0.005$   
SURFACE ROUGHNESS: ✓  
CORNER & FILLET RADI: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD  
ANGLE PROJECTION  
DO NOT SCALE DRAWING

# STANFORD AA284 TEAM A

SIZE <b>B</b>	DWG NO AA284A-A-MI	REV <b>A</b>
SCALE: 1:2	WEIGHT: 3.20 LB	SHEET 1 OF 2

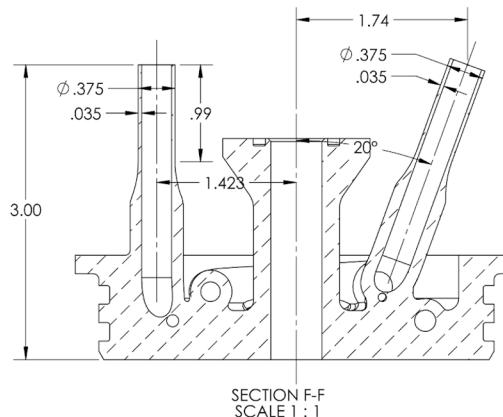
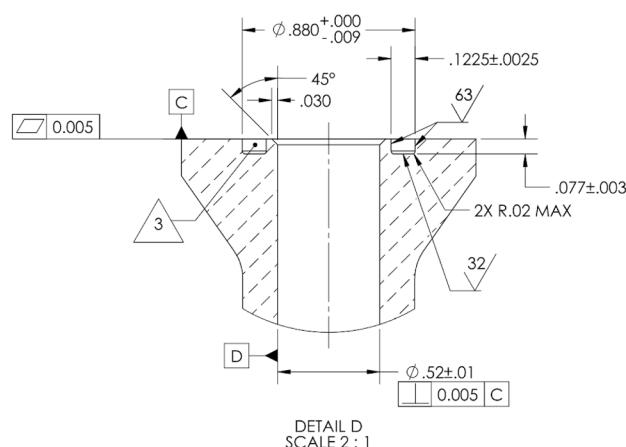
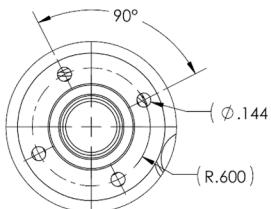
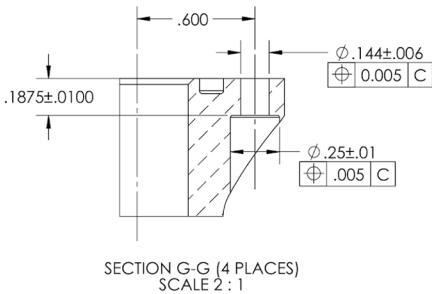


B

B

A

A



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES

TOLERANCES:  
 $X \pm .025$   
 $XX \pm .010$   
 $XXX \pm .005$

SURFACE ROUGHNESS:  
 CORNER & FILLET RADII: .005-.020

THREADS: CLASS 2  
 REMOVE ALL BURRS

DRAWING MADE IN THIRD  
 ANGLE PROJECTION  
 DO NOT SCALE DRAWING

# STANFORD AA284 TEAM A

## MAIN INJECTOR

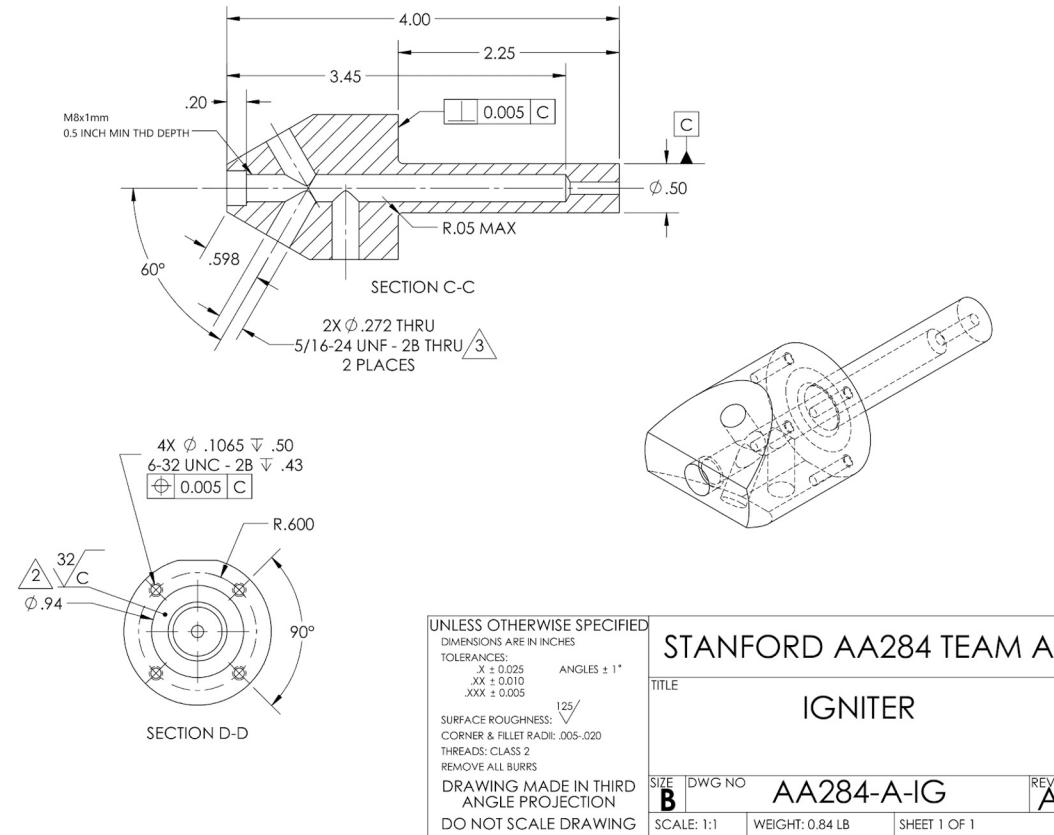
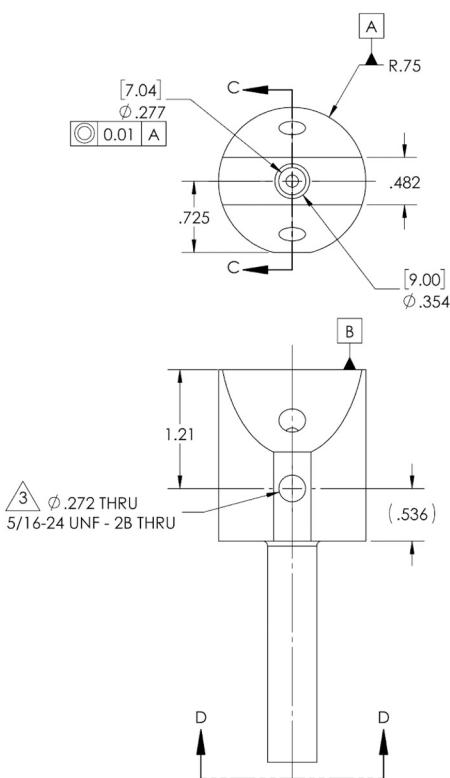
SIZE **B** DWG NO **AA284-A-A-MI** REV **A**  
 SCALE: 1:2 WEIGHT: 3.20 LB SHEET 2 OF 2



## NOTES:

- MATERIAL: 316 STAINLESS STEEL
- SURFACE ROUGHNESS APPLIES WITHIN DESIGNATED DIAMETER
- PORT PER SAE J1926-1 / MS16142, STRAIGHT THREAD O-RING PORT, SIZE -2

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 10 2020	W. KEHOE	J. ROBINSON	G. ZILLIAC



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
XX ± 0.025 ANGLES ± 1°  
XX ± 0.010  
XXX ± 0.005  
SURFACE ROUGHNESS:  
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

STANFORD AA284 TEAM A  
TITLE  
IGNITER  
SIZE B DWG NO AA284-A-IG REV A  
SCALE: 1:1 WEIGHT: 0.84 LB SHEET 1 OF 1

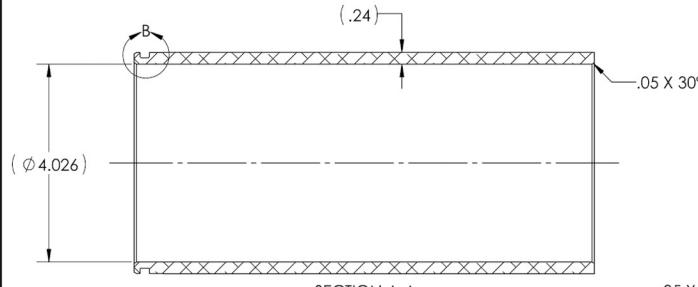


## NOTES:

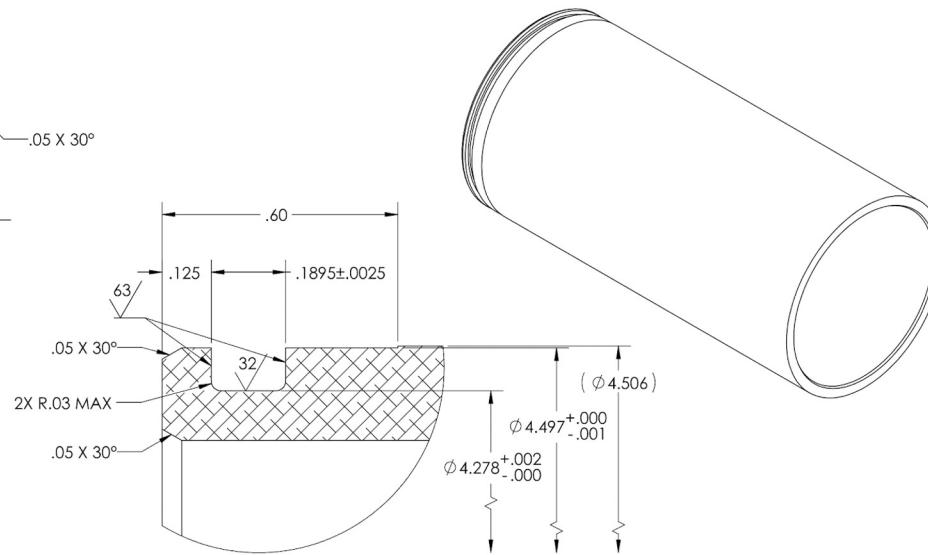
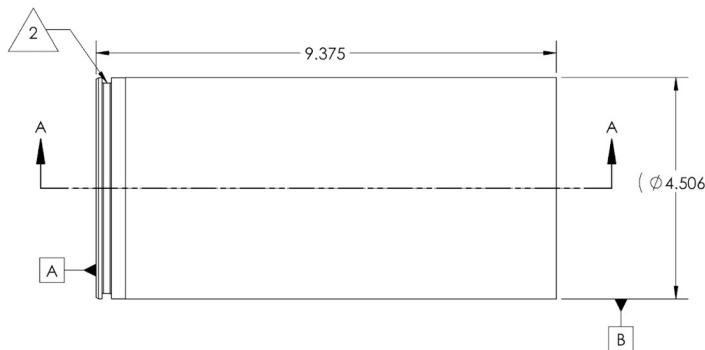
1. MATERIAL: AL6061-T6  
 2. MALE GLAND FOR SIZE 244 O-RING

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 09 2020	E. CHANG J. ROBINSON	W. KEHOE	G. ZILLIAC

B



SECTION A-A

DETAIL B  
SCALE 4 : 1

UNLESS OTHERWISE SPECIFIED  
 DIMENSIONS ARE IN INCHES  
 TOLERANCES:  
 $X \pm 0.025$   
 $XX \pm 0.010$   
 $XXX \pm 0.005$   
 SURFACE ROUGHNESS:  $125\sqrt{ } / 2$   
 CORNER & FILLET RADII: .005-.020  
 THREADS: CLASS 2  
 REMOVE ALL BURRS  
 DRAWING MADE IN THIRD ANGLE PROJECTION  
 DO NOT SCALE DRAWING

STANFORD AA284 TEAM A  
 TITLE  
**COMBUSTION CHAMBER TUBE**

SHEET B | DWG NO AA284-A-CCT | REV A  
 SCALE: 1:2 | WEIGHT: 3.02 LB | SHEET 1 OF 1

B

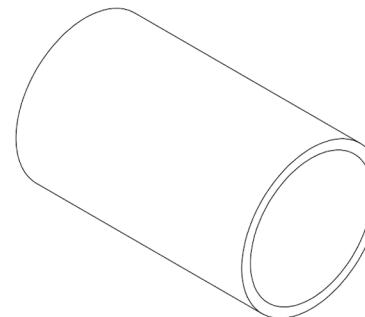
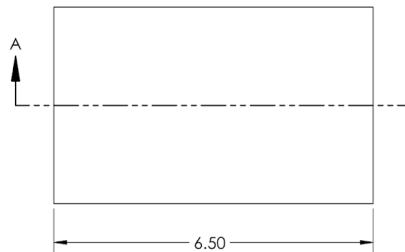
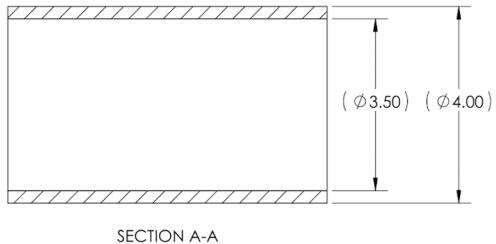
A



## NOTES:

- MATERIAL: CANVAS PHENOLIC TUBING

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 09 2020	J. ROBINSON	W. KEHOE	



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
 $X \pm 0.025$    ANGLES  $\pm 1^\circ$   
 $XX \pm 0.010$   
 $XXX \pm 0.005$   
SURFACE ROUGHNESS:  $125/$   
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS

DRAWING MADE IN THIRD  
ANGLE PROJECTION  
DO NOT SCALE DRAWING

STANFORD AA284 TEAM A  
TITLE  
CANVAS PHENOLIC  
CHAMBER LINER

SIZE **B** DWG NO AA284-A-CPCL REV **A**  
SCALE: 1:2 WEIGHT: 0.957 LB SHEET 1 OF 1



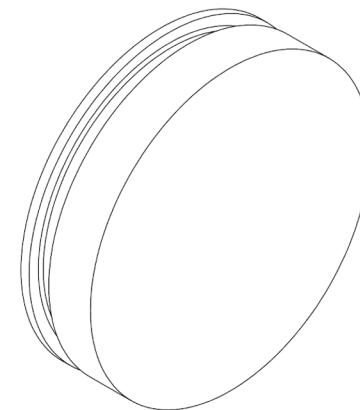
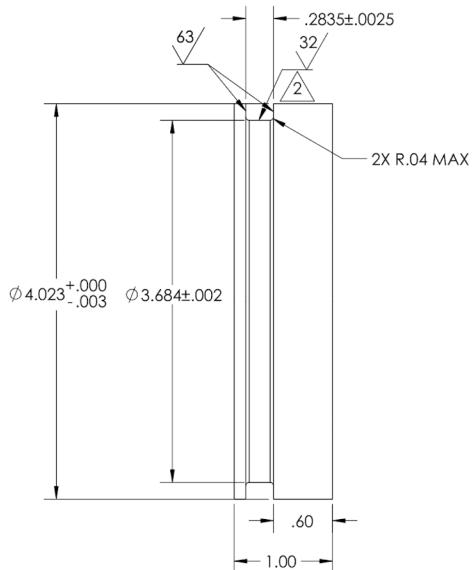
## NOTES:

1. MATERIAL: AL6061-T6  
 MALE GLAND FOR SIZE 342 O-RING

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 10 2020	J. ROBINSON		

B

B



UNLESS OTHERWISE SPECIFIED  
 DIMENSIONS ARE IN INCHES  
 TOLERANCES:  
 $X \pm 0.025$  ANGLES  $\pm 1^\circ$   
 $XX \pm 0.010$   
 $XXX \pm 0.005$   
 SURFACE ROUGHNESS:  $125/$   
 CORNER & FILLET RADII: .005-.020  
 THREADS: CLASS 2  
 REMOVE ALL BURRS  
 DRAWING MADE IN THIRD  
 ANGLE PROJECTION  
 DO NOT SCALE DRAWING

STANFORD AA284 TEAM A  
 TITLE  
**HYDRO TEST CHAMBER  
 PLUG**

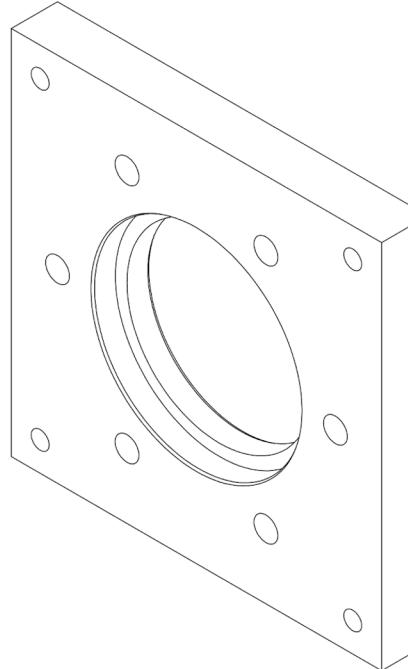
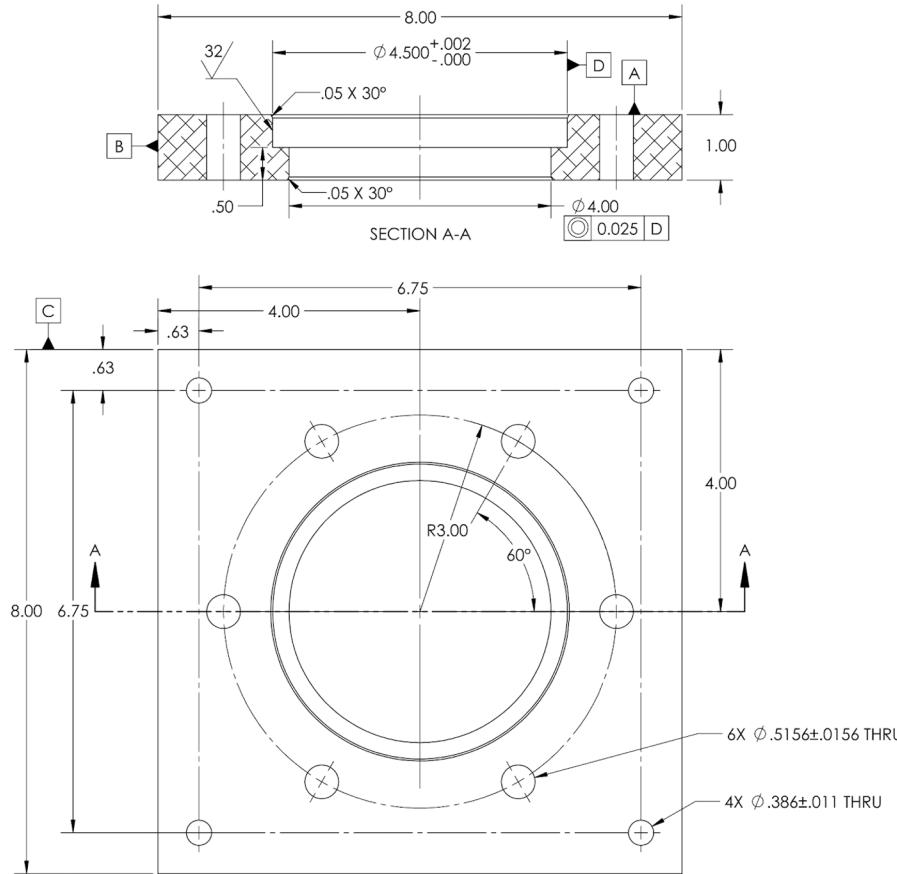
SIZE **B** DWG NO **AA284-A-HTCP** REV **A**  
 SCALE: 1:1 WEIGHT: 1.17 LB SHEET 1 OF 1



## NOTES:

1. MATERIAL: AL6061-T6

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 09 2020	J. ROBINSON	W. KEHOE	G. ZILLIAC



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
XX ± 0.025    ANGLES ± 1°  
XX ± 0.010  
XX ± 0.005  
SURFACE ROUGHNESS: 125/  
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

STANFORD AA284 TEAM A

TITLE  
NOZZLE END FLANGE

SIZE B DWG NO AA284-A-NEF REV A

SCALE: 1:1.5 WEIGHT: 4.78 LB SHEET 1 OF 1

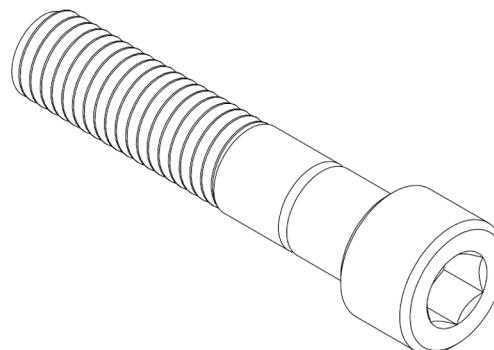
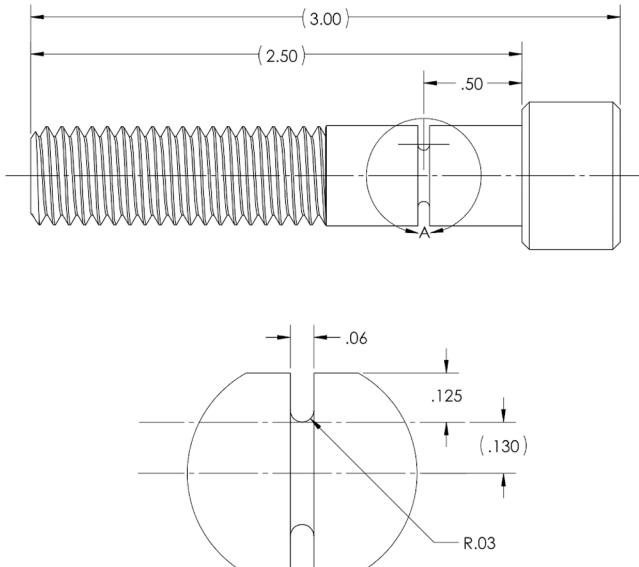


## NOTES:

1. MAKE FROM MCMASTER-CARR P.N. 92185A722, 1/2"-13 X 2.5" PARTIALLY THREADED 316 STAINLESS STEEL SOCKET HEAD SCREW
2. MATERIAL: 316 STAINLESS STEEL

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 10 2020	J. ROBINSON	W. KEHOE	G. ZILLIAC

B



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
 $X \pm 0.025$  ANGLES  $\pm 1^\circ$   
 $XX \pm 0.010$   
 $XXX \pm 0.005$   
SURFACE ROUGHNESS:  $125\text{ }/\text{\textmu}$   
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

STANFORD AA284 TEAM A  
TITLE  
NOZZLE RETAINER  
NOTCHED BOLT

SIZE **B** DWG NO AA284-A-NRNB REV **A**  
SCALE: 2:1 WEIGHT: 0.02 LB SHEET 1 OF 1

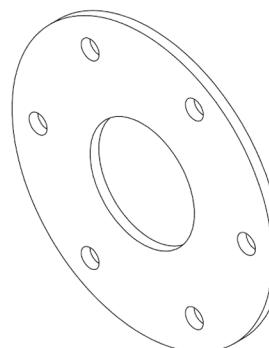
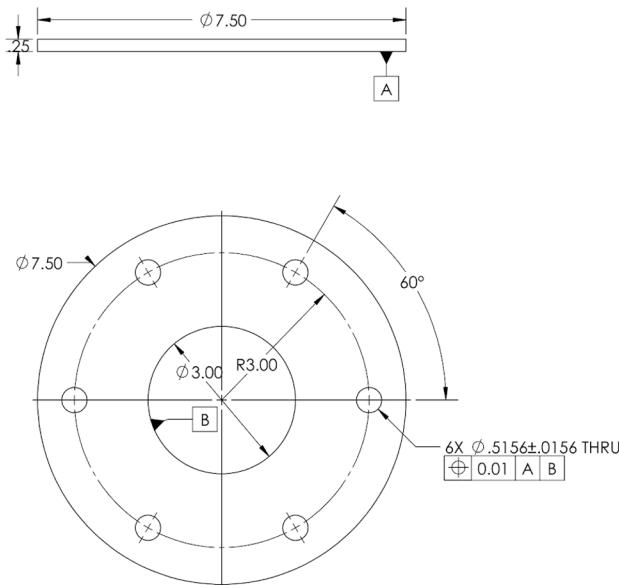


## NOTES:

- MATERIAL: AL6061-T6

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 09 2020	J. ROBINSON	W. KEHOE	

B



A

UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
X ± 0.025 ANGLES ± 1°  
XX ± 0.010  
XXX ± 0.005  
SURFACE ROUGHNESS: 125/  
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

STANFORD AA284 TEAM A  
TITLE  
NOZZLE RETAINING PLATE

SIZE B DWG NO AA284-A-NRP REV A  
SCALE: 1:2 WEIGHT: 0.87 LB SHEET 1 OF 1



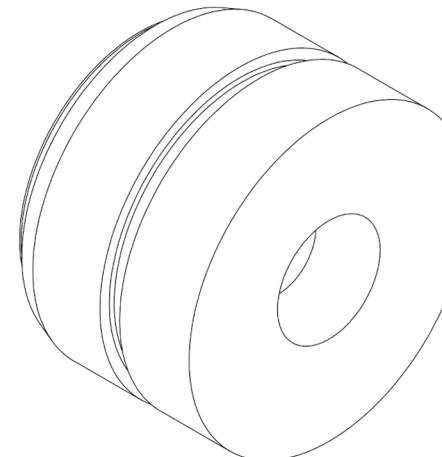
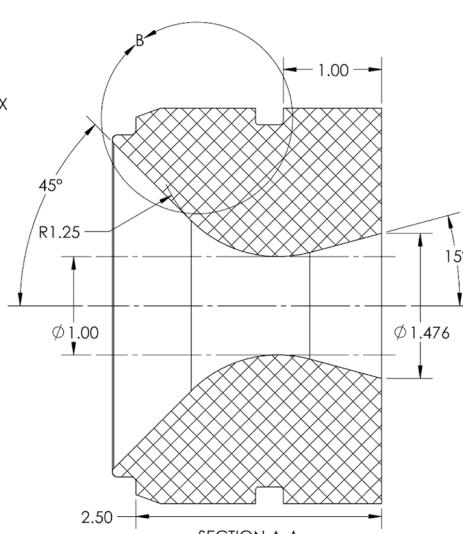
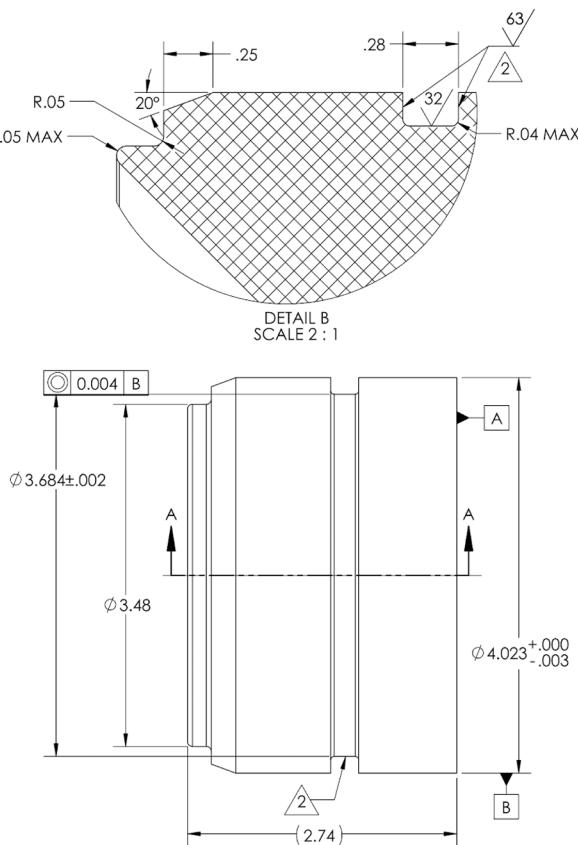
## NOTES:

1. MATERIAL: HIGH DENSITY GRAPHITE
2. MALE GLAND FOR SIZE 342 O-RING

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 10 2020	J. ROBINSON	W. KEHOE	G. ZILLIAC

B

B



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
X ± 0.025    ANGLES ± 1°  
XX ± 0.010  
XXX ± 0.005  
SURFACE ROUGHNESS:  
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

## STANFORD AA284 TEAM A

## TITLE

## NOZZLE

SIZE

B

DWG NO

AA284-A-NZL

REV

A

SCALE: 1:1

WEIGHT: 2.14 LB

SHEET 1 OF 1

A

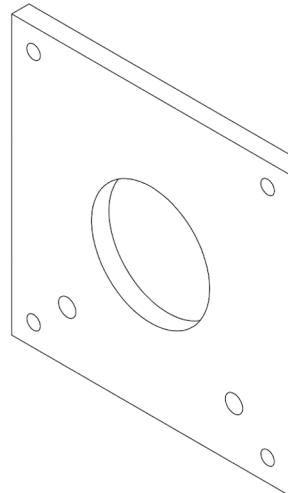
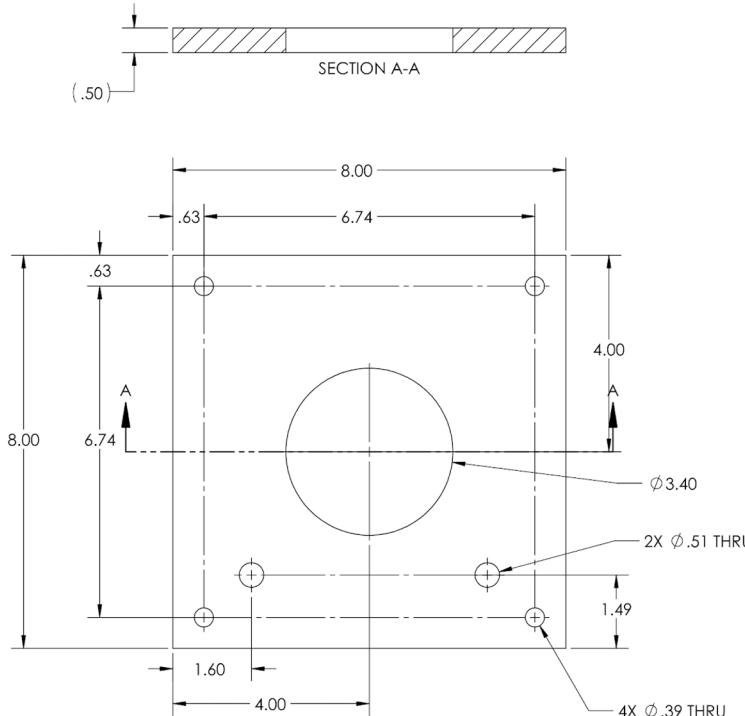
B



## NOTES:

- MATERIAL: A36 STEEL

REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 11 2020	J. ROBINSON		



UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
 $X \pm 0.025$   
 $XX \pm 0.010$   
 $XXX \pm 0.005$   
SURFACE ROUGHNESS:  $125\text{ }\mu\text{in}$   
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS

DRAWING MADE IN THIRD ANGLE PROJECTION  
DO NOT SCALE DRAWING

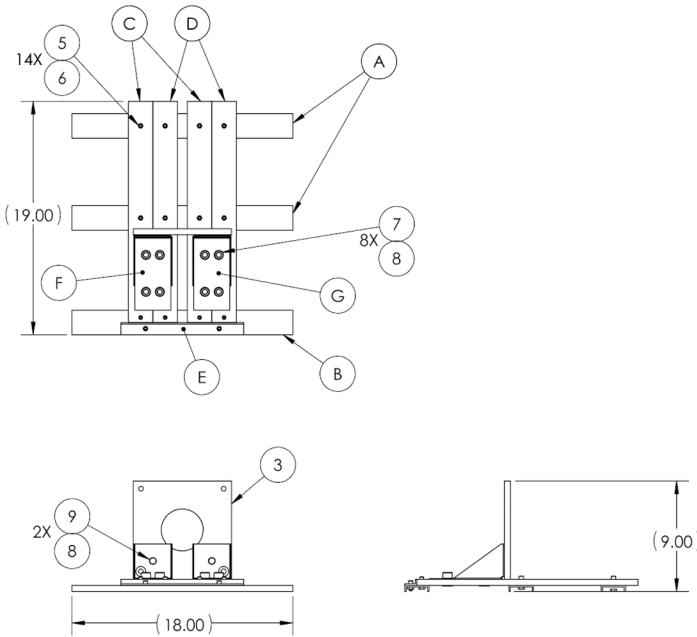
STANFORD AA284 TEAM A  
TITLE  
TEST STAND SUPPORT PLATE

SIZE **B** DWG NO AA284-A-TSSP REV **A**  
SCALE: 1:2 WEIGHT: 7.84 LB SHEET 1 OF 1



## NOTES:

1. MAKE ITEMS A, B, C, D FROM ITEM 1 PER SHEET 2
2. MAKE ITEM E FROM ITEM 2 PER SHEET 2
3. MAKE ITEMS F, G FROM ITEM 4 PER SHEET 2



REV	DESCRIPTION	DATE	DRAWN	CHECKED	APPROVED
A	INITIAL REVISION	MAR 09 2020	J. ROBINSON		

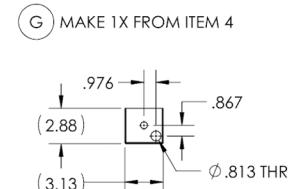
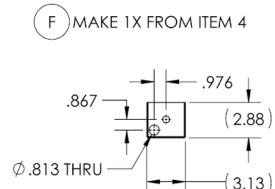
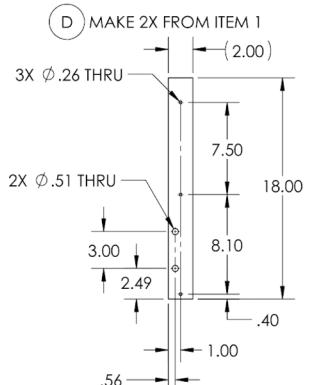
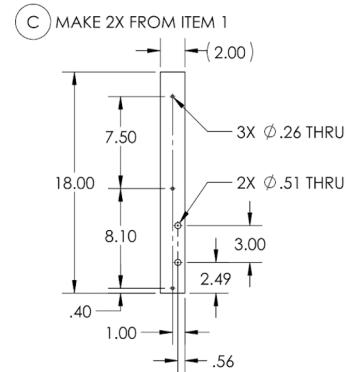
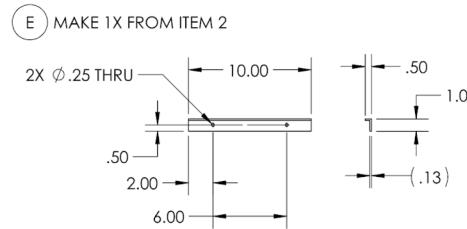
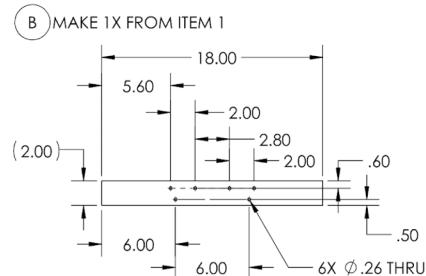
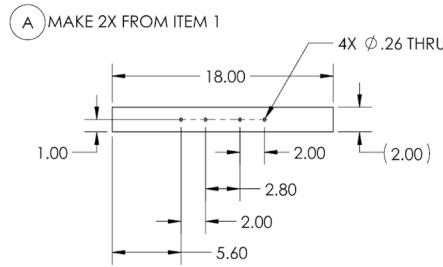
ITEM NO.	BOM NO.	DESCRIPTION	QTY.
1	71	2 in. x 36 in. Plain Steel C-Channel Bar with 1/8 in. Thick	4
2	73	1-1/2 in. x 48 in. Plain Steel Angle with 1/8 in. Thick	1
3	AA284-A-TSSP	TEST STAND SUPPORT PLATE	1
4	165	Corner Bracket Galvanized Steel, 2-7/8" x 6-1/8" x 3-1/8"	2
5	75	Black-Oxide Alloy Steel Socket Head Screw, 1/4"-20 Thread Size, 9/16" Long	14
6	76	High-Strength Steel Nylon-Insert Locknut, Grade 8, 1/4"-20 Thread Size	14
7	163	Black-Oxide Alloy Steel Socket Head Screw 1/2"-20 Thread Size, 3/4" Long	8
8	162	Medium-Strength Steel Hex Nut Grade 5, Zinc-Plated, 1/2"-20 Thread Size	8
9	164	Black-Oxide Alloy Steel Socket Head Screw 1/2"-20 Thread Size, 1-1/4" Long	2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES					
TOLERANCES: $X \pm 0.025$ ANGLES $\pm 1^\circ$ $XX \pm 0.010$ $XXX \pm 0.005$					
SURFACE ROUGHNESS: $125\text{ }/\text{\textmu}$ CORNER & FILLET RADII: .005-.020 THREADS: CLASS 2 REMOVE ALL BURRS					
DRAWING MADE IN THIRD ANGLE PROJECTION DO NOT SCALE DRAWING					
SIZE	DWG NO	AA284-A-TS			REV
B					A
SCALE: 1:8		WEIGHT: 23 LB		SHEET 1 OF 2	

B

A





UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN INCHES  
TOLERANCES:  
X ± 0.025    ANGLES ± 1°  
XX ± 0.010  
XXX ± 0.005  
SURFACE ROUGHNESS: ✓  
CORNER & FILLET RADII: .005-.020  
THREADS: CLASS 2  
REMOVE ALL BURRS  
DRAWING MADE IN THIRD  
ANGLE PROJECTION  
DO NOT SCALE DRAWING

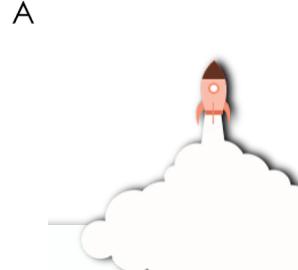
STANFORD AA284 TEAM A

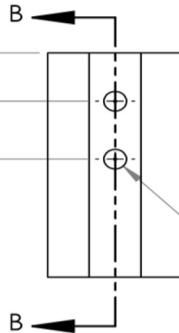
TITLE

TEST STAND

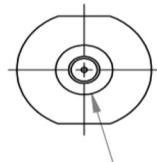
SIZE **B** DWG NO AA284-A-TS REV

SCALE: 1:8 WEIGHT: 23 LB SHEET 2 OF 2

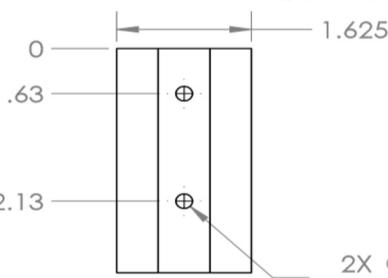
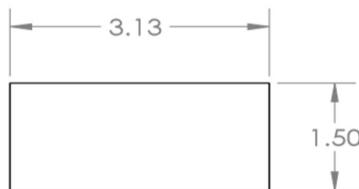




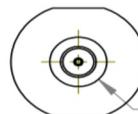
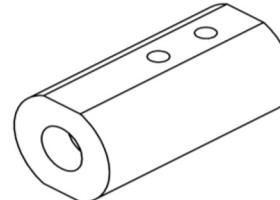
2X  $\phi$  .27  $\downarrow$  .40  
5/16-24 UNF  $\downarrow$  .40  
MS 16142  $\downarrow$  .40



$\phi$ .0700 THRU  
 $\phi$ .6875  $\downarrow$  .4400  
MS 16142  $\downarrow$  .44  
3/4-16 UNF  $\downarrow$  .44

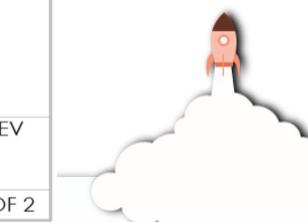


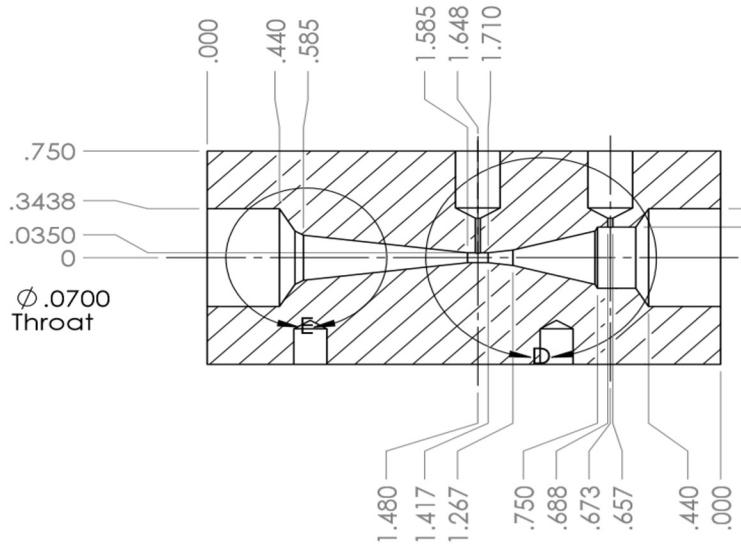
2X  $\phi$  .20  $\downarrow$  .25  
1/4-20 UNC  $\downarrow$  .19



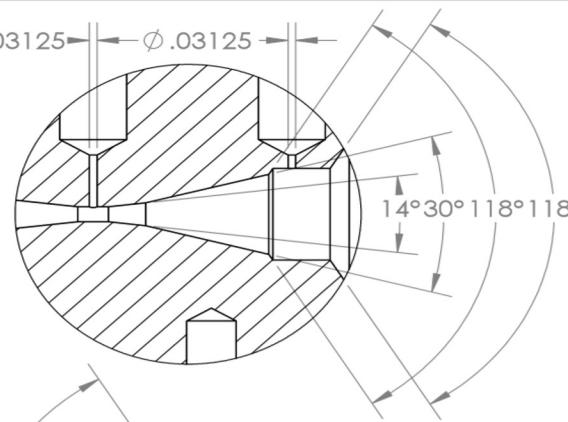
$\phi$ .07 THRU  
 $\phi$ .43  $\downarrow$  .67  
 $\phi$ .69  $\downarrow$  .44  
MS 16142  $\downarrow$  .44  
3/4-16 UNF  $\downarrow$  .44

UNLESS OTHERWISE SPECIFIED:			DRAWN	NAME	DATE	TITLE:
DIMENSIONS ARE IN INCHES						
TOLERANCES: FRACTIONAL: $\pm 1/64$ ANGULAR: MACH $\pm 0.5$ TWO PLACE DECIMAL $\pm 0.01$ THREE PLACE DECIMAL $\pm 0.005$			CHECKED			
INTERPRET GEOMETRIC TOLERANCING PER: MATERIAL SS 316			ENG APPR.			
FINISH			MFG APPR.			
DO NOT SCALE DRAWING			Q.A.			
COMMENTS:						
SIZE	DWG. NO.	REV				
<b>A</b>	<b>CavVent</b>					
SCALE: 1:2	WEIGHT:	SHEET 1 OF 2				

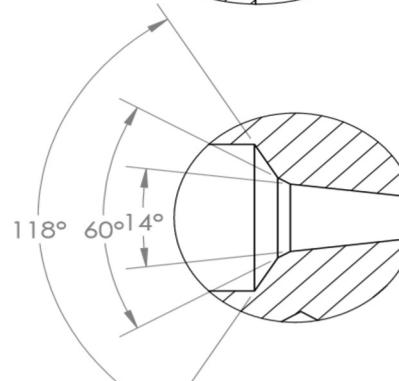




DETAIL D  
SCALE 1.5 : 1



DETAIL E  
SCALE 1.5 : 1

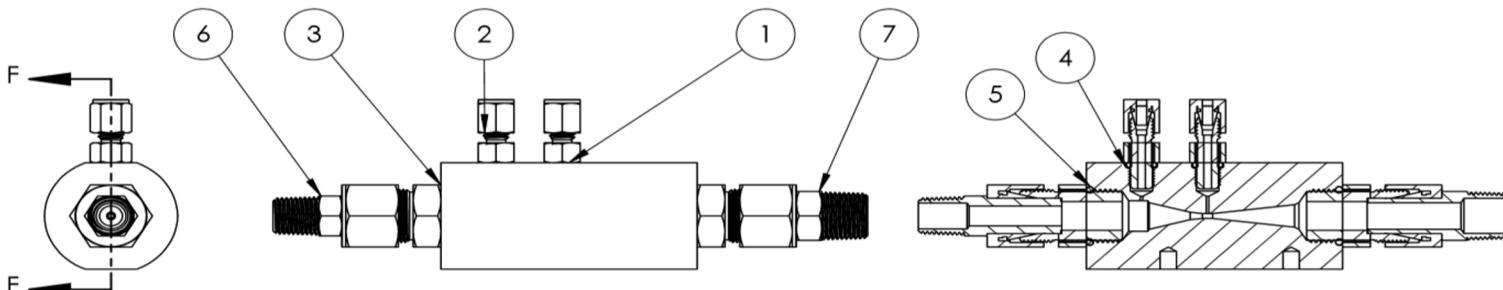
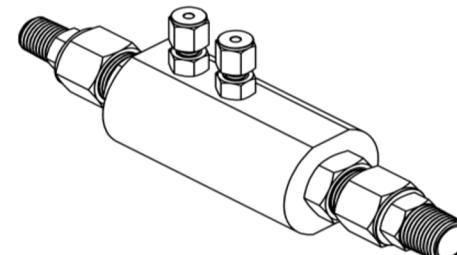


		UNLESS OTHERWISE SPECIFIED:		DRAWN	NAME	DATE	TITLE:  <b>Cavitating Venturi</b>				
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: MACH ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±									
		INTERPRET GEOMETRIC TOLERANCING PER:		CHECKED	ENG APPR.	MFG APPR.					
		MATERIAL									
NEXT ASSY		SS 316		Q.A.	COMMENTS:						
USED ON		FINISH									
APPLICATION		DO NOT SCALE DRAWING		SIZE DWG. NO.							
				<b>A</b> CavVent							
				REV							
				SCALE: 1:2							
				WEIGHT:							
				SHEET 2 OF 2							

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<INSERT COMPANY NAME HERE> IS  
PROHIBITED.



ITEM NO.	PART NUMBER	BOM Number	QTY.
1	CavVent_FinalNoRefs	171	1
2	5182K861	168	2
3	5182K867	167	2
4	6613N12	170	2
5	6613N18	169	2
6	5182K155	175	1
7	5182K161	176	1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES  
TOLERANCES:  
FRACTIONAL  $\pm 1/64$   
ANGULAR: MACH  $\pm 0.5$   
TWO PLACE DECIMAL  $\pm 0.01$   
THREE PLACE DECIMAL  $\pm 0.005$

INTERPRET GEOMETRIC  
TOLERANCING PER:

MATERIAL SS 316, PTFE

FINISH

DO NOT SCALE DRAWING

NAME DATE

DRAWN Team A Winter 2020

CHECKED

ENG APPR.

MFG APPR.

Q.A.

COMMENTS:

### SECTION F-F

TITLE:

Cavitating  
Venturi

SIZE DWG. NO. REV  
**CavVent\_Assembly**  
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

