Redus Engineering
Devine, Tx

Project Title - Evaluation of Over Pressure Valve, OP-1	Proj. Ref. **OP Valve**	Page **1 of 35**	File Ref. **TR-21-01**

Evaluation of Over Pressure Valve, OP-1

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1	2/3/21	Issued as Draft	CLR	AS	CLR	AS
2	2/10/21	Minor text corrections	CLR	AS	CLR	AS
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4	2/14/21	Removed Steel Fish, LLC	CLR	AS	CLR	AS

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1. EXECUTIVE SUMMARY

This document covers the design and testing of a Over Pressure valve model OP-01 manufactured by Alec Symth. The purpose of the OP valve is to prevent over pressurization of a manned submersible that could potentially cause a catastrophic flooding of the pressure hull due to pressure unseating either a viewport or hatch. Two test series were conducted, one to establish the maximum operating depth of the valve and the second to quantify the cracking pressure. A test chamber was designed and instrumented to complete these tests. A theoretical model of cracking pressure was developed and compared with test data. The maximum recorded pressure was 2,436 psig. This corrosponds to 5,481 fsw. Based on this test, the recommended maximum operating depth is 5,000 fsw. The differential cracking pressure test data was found to match the theoretical model below where Pc is expressed in psig.

$$P_c = 0.532 + 1.631\left(\frac{17-T}{17}\right) \quad \text{for } 0 \le T \le 17$$

$$P_c = 0.532 \quad \text{for} \quad T \ge 17$$

T is the number of turns of the wingnut starting from a completely compressed state. Seventeen is the number of wing nut turns to completely disengage the compression spring.

Note that the cracking pressure is a differential pressure. At any ambient pressure, from the surface to operating depth, the cabin pressure must exceed the ambient pressure for the OP valve by the cracking pressure P_c to start to vent air. When submerged the cracking pressure, defined by the equations above, is reduced by 0.053 psi for salt water and 0.053 psi for fresh water due to the buoyance of cap.

2. INTRODUCTION

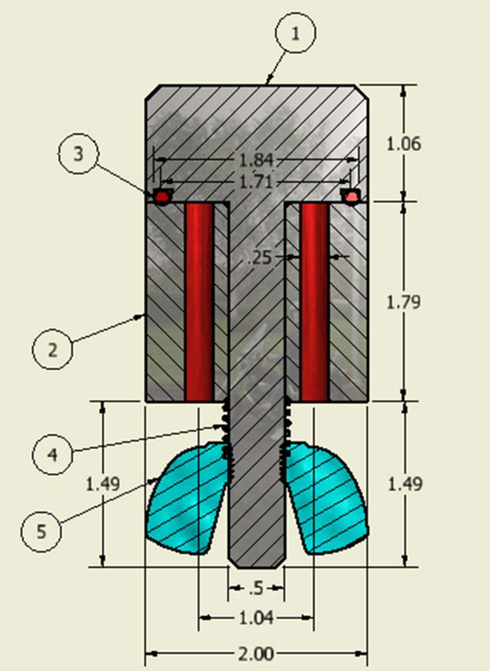
The goal of this project was to document the performance of the Psub.org Over Pressure Valve model number OP-1 shown in Figure 1. To determine the performance envelope, two tests were done. The first was establish a maximum operating depth. The second to establish the cracking pressure of the OP valve. To do this, a test chamber was fabricated shown in Figures 2 and 3. A positive displacement, triplex plunger pump was used to generate the pressure for the test with water as the media. The pressure relief valve for the pump was set at 2450 psig which sets the maximum pressure the chamber achieved. For the HP test, the flange with the penetrator welded in place was oriented upside down so that OP valve could be subjected to the internal pressure in the chamber. In Figure 1, you can see this by the wingnut being outside the chamber.

Figure 1 Psub.org Over Pressure Valve model number OP-1

Figure 2 Test Chamber for OP Valve model number OP-1, High Pressure Test

Figure 3 Test Chamber for OP Valve Cracking Pressure Test

A cross section of the OP valve as well as a parts list for the valve itself is shown in Figure 4.



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OP-01	Overpressure Cap - 316 SS
2	1	OP-02	OP Penetrator - 316L SS
3	1	OP-07	OP Buna-N O-Rings, Dash 222, Durometer 70A, McMaster CArr PN 9452K63
4	1	OP-08	1.25" Long, 0.3" OD, 1/4" ID, 316 Stainless Steel, McMAster Carr PN 9002T458_CORROSION-RST, COMPRESSION SPRINGS, CUT TO 1.2"
5	1	OP-06	OP Wing Nut, Thread 1/2"-20, 18-8 Stainless Steel, McMaster Carr PN 92001A333

Figure 4 Cross section of the Operating Valve OP-1

Appendix D includes a set of drawings for the OP valve as well as the test chamber.

3. RESULTS & CONCLUSIONS

3.1 Max Pressure Test

The maximum recored pressure was 2,436 psig. This pressure corrosponds to 5,481 fsw. Based on this test, the recommended maximum operating depth is 5,000 fsw.

3.2 Cracking Pressure Test

The differential cracking pressure test data was found to match the theoretical model below where Pc is expressed in psig.

$$P_c = 0.532 + 1.631\left(\frac{17-T}{17}\right) \quad \text{for } 0 \le T \le 17$$

$$P_c = 0.532 \quad \text{for} \quad T \ge 17$$

4. DISCUSSION

4.1 Purpose of the Over Pressure Valve

The purpose of the Over Pressure (OP) valve is to protect the pressure hull viewports and hatch from being exposed to pressures that would unseat them. The pressure hull is designed to withstand large ambient pressures. As such there are stiffeners that reinforce the shell to prevent the hull from failing either from bucking of the stiffeners or from the shell itself reaching the yield point of the material. The OP valve is protecting against a very different loading, that is a higher hull interior pressure than the ambient water pressure surrounding the hull. Unseating of a viewport or hatch could be achieved by a relatively small differential pressure due to the large surface areas of viewports and hatches. The overpressure in the hull for small manned submersibles could come from a number of sources but typically it would be from an air leak from a HP air tank used for blowing the main ballast tanks (MBT) or an oxygen leak from a HP O2 tank used for life support. With a sub on or near the surface even a small overpressure in the hull of few psi could unseat a viewport. To prevent this, the OP valve is installed at the highest point in the hull or hatch and sized to open to prevent this over pressure. The differential pressure (cabin pressure minus the ambient pressure) at the point the OP valve starts to relieve pressure is known as the “cracking pressure”.

4.2 Theoretical Cracking Pressure

If we sum the forces acting on the cap we have:

$$W_c + W_w + W_s + W_o + A_o P_a + \left(\frac{T_2 - T}{T_2 - T_0}\right) k = B + A_o P_i \qquad (1)$$

Where:

W_c = Weight of cap and stem, lbf
W_w = Weight of wing nut, lbf
W_s = Weight of spring, lbf
W_o = Weight of O-ring, lbf
B = Buoyancy of cap when submerged, lbf
T = Turns of wing nut where $T \geq T_0$
T_o = Turns when spring solid
T_2 = Turns when spring free
k = Spring constant, lb_f/in
P_i = Cabin interior pressure, psig
P_a = Ambient pressure, psig
A_o = Area O-ring, in^2
γ_w = Water specific weight lb_f/ft^3
V_c = Volume of the OP valve cap, ft^3

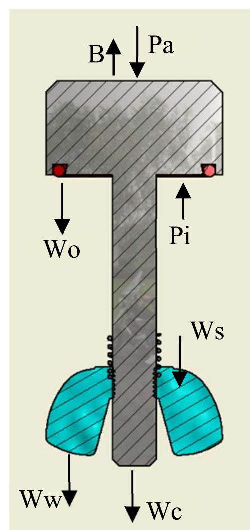


Figure 5 Forces on Cap

When the left and right sides of equation (1) are equal, the cabin pressure acting on the bottom of the cap and stem is just sufficient to counter the weight cap, stem, wing nut, spring and O-ring. The area A_o is the area associated with the diameter where the O-ring gland just touches penetrator.

Cracking pressure for the OP valve is defined as:

$$P_c = P_i - P_a \quad (2)$$

Substituting equation (1) into equation (2) gives the cracking pressure as:

$$P_c = \frac{(W_c + W_w + W_s + W_o)}{A_o} + \left(\frac{T_2 - T}{T_2 - T_0}\right)\frac{k}{A_0} - \frac{B}{A_0} \quad \text{for} \quad T_0 \leq T \leq T_2 \quad (3)$$

$$P_c = \frac{(W_c + W_w + W_s + W_o)}{A_o} - \frac{B}{A_0} \quad \text{for} \quad T \geq T_2 \quad (4)$$

Where:

$$B = \gamma_w V_c \quad for\ depth > 0 \quad (5)$$

$$B = 0 \quad for\ depth = 0 \quad (6)$$

Equation (3) is the cracking pressure when both the weight of the cap and the spring come into play and equation (4) is for the case where the wing nut has been unwound past T_2 so that it is free and does not generate a force on the cap.

For the OP-1 valve, physical parameters in equations (1) and (2) were measured as:

Table 1 Valve Parameters

W_c	1.116 lbf
W_w	0.097 lbf
W_s	0.005 lbf
W_o	0.003 lbf
T_o	0
T_2	17
k	3.74, lb_f/in
D_o	1.709, in
A_o	2.293, in^2
V_c	3.274, in^3
γ_w	64 lb_f/ft^3 for salt water

Substituting the parameters for the OP valve into equations (3) and (4) gives the cracking pressure for surfaced conditions as:

$$P_c = 0.532 + 1.631\left(\frac{17 - T}{17}\right) \quad \text{for } 0 \leq T \leq 17 \quad (7)$$

$$P_c = 0.532 \quad \text{for} \quad T \geq 17 \quad (8)$$

Note that the cracking pressure is a differential pressure. At any ambient pressure, from the surface to operating depth, the cabin pressure must exceed the ambient pressure for the OP valve by the cracking pressure P_c to start to vent air. When submerged the cracking pressure as defined by equations (7) and (8) is reduced by 0.053 psi for salt water and 0.053 psi for fresh water due to the buoyance of cap.

4.3 Theoretical Volumetric Flow Rate

If the differential pressure across the OP valve exceeds the cracking pressure then the volumetric flow rate through the device can be calculated as:

$$Q_a = n\frac{1360}{60}C_d\left(\frac{d_0}{0.183}\right)^2 P_i\left(1-\frac{\frac{P_i-P_a}{P_i}}{3F_\gamma x_T}\right)\sqrt{\frac{\frac{P_i-P_a}{P_i}}{T_a+459.67}} \quad for\ \frac{P_i-P_a}{P_i} < F_\gamma x_T \tag{9}$$

$$Q_a = n\frac{1360}{60}0.667C_d\left(\frac{d_0}{0.183}\right)^2 P_i\sqrt{\frac{F_\gamma x_T}{T_a+45\ .67}} \quad for\ \frac{P_i-P_a}{P_i} \geq F_\gamma x_T \tag{10}$$

Where:

Q_a = Volumetric Flow Rate in standard conditions, SCFM
T_a = Air temperature, ^oF
d_o = Diameter of port, in
C_d = Discharge Coefficient, assume 0.5 for sudden contraction (--)
F_γ = Specific heat ratio factor which is 1 or air (--)
x_T = Pressure differential ratio factor (0.72) (--)
n = Number of ports in the OP valve, (--)

Equation (9) is the volumetric flowrate in standard conditions when the ports are operating in subcritical flow while equation (10) is for critical flow.

Figure 6 is a plot of volumetric flow rate through the OP valve when the ambient pressure is 0 psig and the cabin pressure varies from 0.6 to 2.2 psig. For this case, cabin temperature is 80 ^oF. For these conditions, the ports are operating in subcritical flow so equation (6) is appropriate.

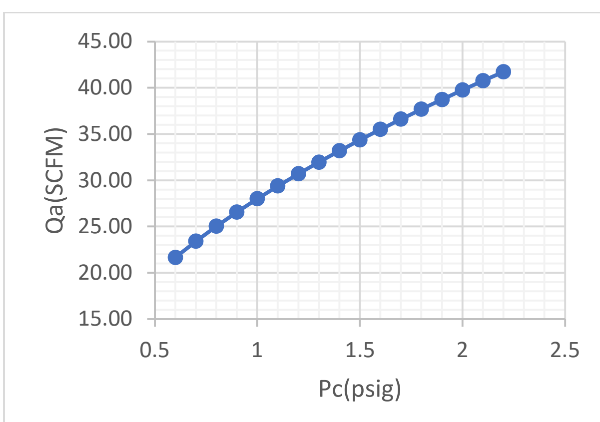


Figure 6 Volumetric Flow Rate, P_a=0.psig, P_i 0.6-2.2 psig, T_a=80^{o}F

4.4 Test Chamber Setup

To setup the high-pressure test of the OP valve, a 3,000 psig pressure transmitter was calibrated and wired into the Automation Direct 205 series PLC analog input card. A bourdon pressure gauge was also installed as a backup. The PLC hardware as well as the I/O for the test is shown in Appendix A.

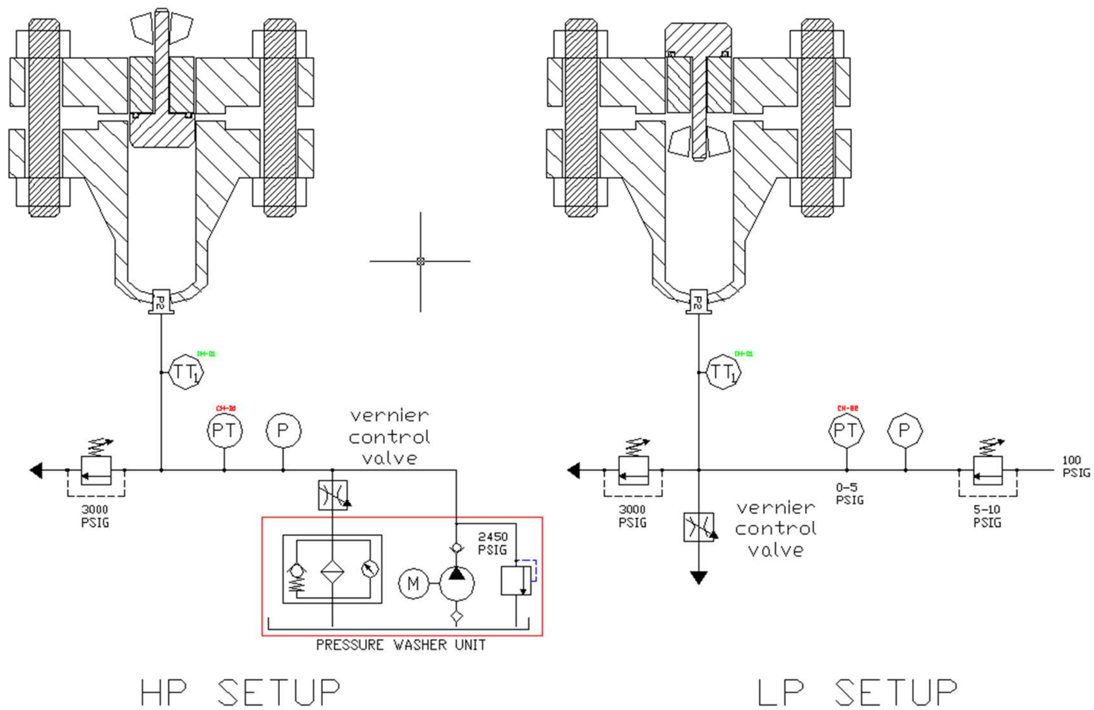


Figure 7 Setups for the HP and LP test

4.5 High Pressure Test Results

The high-pressure test was done on January 27 at 3 pm. Figure 8 shows the pressure over the test period.

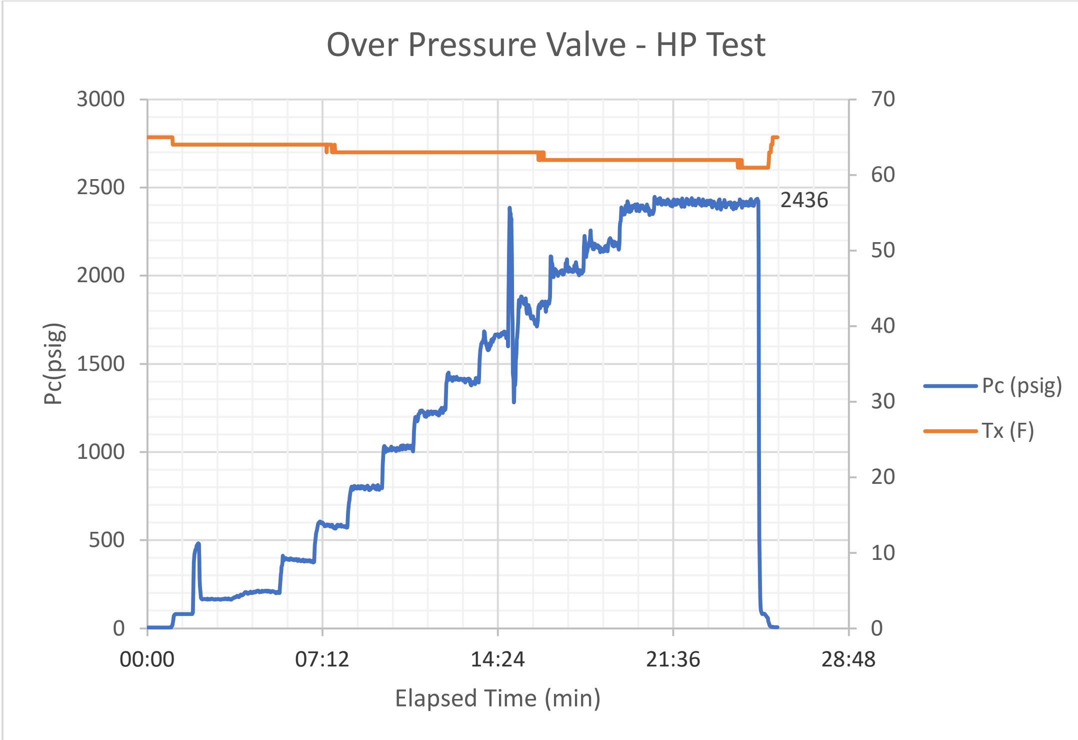


Figure 8 Plot of chamber pressure and temperature for HP test

Prior to starting the test, the OP O-ring was lubricated with Dow Corning Molykote 44 Medium O-ring grease. The test sequence started with the veneir bypass valve shown on the HP septup in Figure 7 wide open. This alowed all the water to by pass the test chamber resulting in zero pressure in the chamber. The pressure was then increased in increments of approximaley 200 psi by partically closing the bypass valve. The pressure was held at this level for approximaely 1.5 minutes and then the next pressure level was set. At about 19 minutes into the test, the pressure reached the maximum value that the pump could make. This pressure was held for this pressure for 5 minutes and then reduced to zero. The maximum recorded pressure was 2,436 psig. This pressure corresponds to 5,481 fsw. After the test was complete, the OP valve O-ring was removed from the cell and inspected. No damage was observed. There was zero leakage through the OP valve during the test.

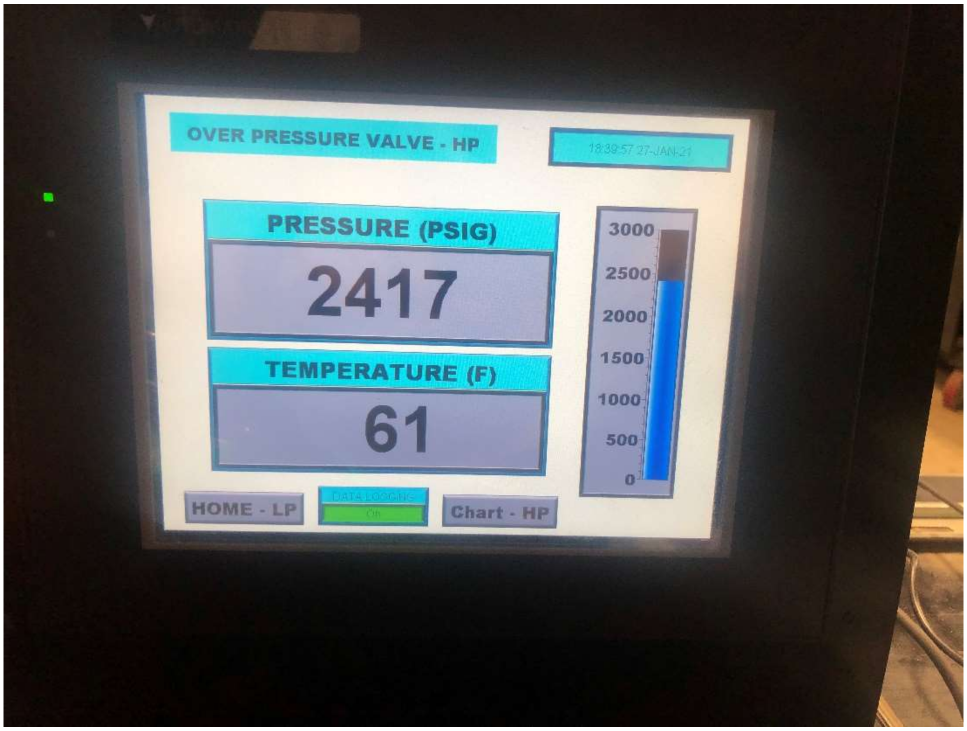


Figure 9   HMI display during HP test

4.6 Cracking Pressure Test Results

After completion of the high-pressure test, the test chamber was reconfigured to conduct the cracking pressure test. The setup is shown on LP side of Figure 7. The blind flange that has the OP valve penetrator welding in it was reversed so that the wingnut side was inside the chamber and the cap outside in the orientation it would be in an actual installation. The HP pump was disconnected and the air compressor with a pressure reducing regulator installed. Also, a 5 psig pressure transmitter was installed, calibrated and wired into channel B2 of the PLC analog input card. To calibrate the transmitter, a manometer was used. A low pressure vernier control valve was installed. A set of rails was installed inside the test chamber that would constrains the rotational movement of the wing nut but would allow it to move axially. This allowed us to adjust the gap between the O-ring mounted in the cap and its corresponding face on the penetrator by turning the cap a specific number of turns. It was observed that when the spring was completely compressed so that the coils touched, the turns count was zero. When the cap was turned 17 turns, the spring became free and only the weight of the movable portions of the OP valve resisted the chamber pressure. To start the test, the cap was backed out 17 turns. The pressure regulator was set to 5 psig and the vernier control valve adjusted until first traces of air began to bypass the cap. At this point the cap was turned 360 degrees in the clockwise direction to close the gap by one turn. The vernier valve was adjusted to again just have a trace of air escaping from the cap. This process was repeated until the cap reached the point the spring was completely collapsed at T=0. The results of the cracking pressure test are shown in Figure 9. Along with the test data, the theoretical model of cracking pressure as described in equations (4) and (5) is presented.

Table 2 Cracking Pressure

T	Pc(psig)	Pc*(psig)
17	0.530	0.532
16	0.600	0.628
15	0.700	0.724
14	0.850	0.82
13	0.910	0.916
12	1.030	1.012
11	1.070	1.108
10	1.220	1.204
9	1.280	1.3
8	1.450	1.396
7	1.500	1.492
6	1.630	1.588
5	1.630	1.684
4	1.910	1.78
3	1.970	1.876
2	1.960	1.972
1	2.170	2.068
0	2.240	2.164

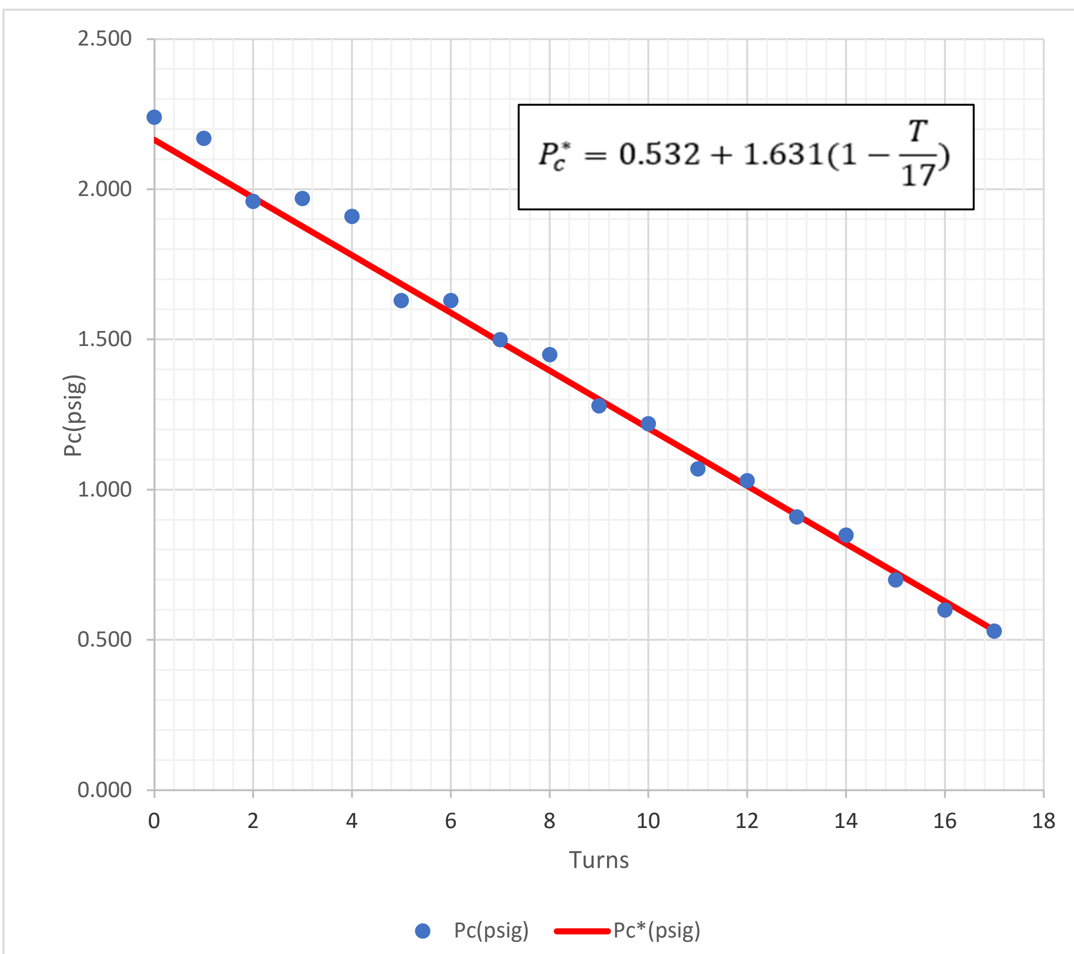


Figure 10 Cracking Pressure, experimental vs. theorotical

5. NOMENCLATURE

Variable	Description	Units
A_o	Area of contact of O-ring	in^2
B	Buoyancy force on cap when submerged	lbf
k	Spring constant	lb_f/in
P_i	Cabin interior pressure	psig
P_a	Ambient pressure	psig
P_c	Cracking pressure (experimental)	psig
P_c*	Cracking pressure (theoretical)	psig
T	Turns of wing nut where $T \geq T_0$	(--)
T_o	Turns when spring is solid	(--)
T_2	Turns when spring is free	(--)
W_c	Weight of cap and stem	lbf
W_w	Weight of wing nut	lbf
W_s	Weight of spring	lbf
W_o	Weight of O-ring	lbf
Q_a	Volumetric Flow Rate in standard conditions	SCFM
d_o	Diameter of port	in
C_d	Discharge Coefficient, assume 0.5 for sudden contraction	(--)
F_γ	Specific heat ratio factor which is 1 or air	(--)
x_T	Pressure differential ratio factor (0.72)	(--)
n	Number of ports in the OP valve	(--)
γ_w	Water specific weight lb_f/ft^3	lb_f/ft^3
V_c	Volume of the OP valve cap	ft^3

Appendix A – PLC I/O and Hardware

Programmable Logic Controller I/O

1/26/2021

I/O	Description	Type	Slot	Address	Status	Alarm Associated
Alarms						
1	High pressure in test chamber, > 3000 psig					
2						
3						
4						
5						
6						
Inputs	Description	Type	Slot	Address	Status	Alarm Associated
CH-B1	HP TEST CHAMBER PRESSURE (0-3000 PSIG)	Analog	0	V2000	Installed	Alarm-1, High pressure in test chamber, > 3000 psig
CH-B2	LP TEST CHAMBER PRESSURE (0-5PSIG)	Analog	0	V2001	Installed	
CH-B3	CURRENTLY NOT USED	Analog	0	V2002		
CH-B4	CURRENTLY NOT USED	Analog	0	V2003		
CH-B5	CURRENTLY NOT USED	Analog	0	V2004		
CH-B6	CURRENTLY NOT USED	Analog	0	V2005		
CH-B7	CURRENTLY NOT USED	Analog	0	V2006		
CH-B8	CURRENTLY NOT USED	Analog	0	V2007		
CH-B9	CURRENTLY NOT USED	Analog	0	V2020-V2021		
CH-B10	CURRENTLY NOT USED	Analog	0	V2022-V2023		
CH-B11	CURRENTLY NOT USED	Analog	0	V2024-V2025		
CH-B12	CURRENTLY NOT USED	Analog	0	V2026-V2027		
CH-C1	CURRENTLY NOT USED	Digital	1	X40		
CH-C2	CURRENTLY NOT USED	Digital	1	X41		
CH-C3	CURRENTLY NOT USED	Digital	1	X42		
CH-C4	CURRENTLY NOT USED	Digital	1	X43		
CH-C5	CURRENTLY NOT USED	Digital	1	Y40		
CH-C6	CURRENTLY NOT USED	Digital	1	Y41		
CH-C7	CURRENTLY NOT USED	Digital	1	Y42		
CH-C8	CURRENTLY NOT USED	Digital	1	Y43		
CH-D1	TEST CHAMBER TEMPERATURE (F)	Analog	2	V2040	Installed	
CH-D2	CURRENTLY NOT USED	Analog	2	V2044		
CH-D3	CURRENTLY NOT USED	Analog	2	V2042		
CH-D4	CURRENTLY NOT USED	Analog	2	V2046		

PLC Modules

Slot	Name	Module	Points	Address	Description
-1	A	D2-260-1	NA	NA	CPU 30.4K WORDS W/1 RS232 & 1 RS232/422/485 PORT
0	B	F2-08AD-2	16	X0-X17	8 Channel Analog Input Voltage 12-Bit Res.
1	C	D2-08CDR	8	X20-X27	Combo 4 PT 24VDC Input and 4 PT Relay Output
2	D	F2-04RTD	32	X30-X47	4 Channel RTD, 0.1 Deg C Resolution

D2-04B-1 DL205 BASE 4-SLOT REQ 110/220VAC PWR W/300mA 24VDC AUX P/S

HMI EA9-T8CL

Appendix B – Transmitter Specifications

Item	Description
Application	High Pressure Transmitter
Manufacturer	TE Connectivity Measurement Specialties
Mfg. Model No.	M5231-000005-03KPG
Digi-Key Part Number	223-1726-ND
Description	TRANSDUCER 0.5-4.5VDC 3000PSI
Pressure Type	Vented Gauge
Operating Pressure	3000PSI (20684.27kPa)
Type	Analog Voltage
Output	0.5 V ~ 4.5 V
Accuracy	±0.25%
Voltage - Supply	4.75V ~ 5.25V
Port Size	Male - 1/4" (6.35mm) NPT
Features	Temperature Compensated
Termination Style	Cable
Maximum Pressure	6000PSI (41368.54kPa)
Operating Temperature	-40°C ~ 125°C
Package / Case	Cylinder
Datasheet	[M5200 Industrial Pressure Transducer (te.com)]

Item	Description
Application	Low Pressure Transmitter
Manufacturer	BENXU
Mfg. Model No.	Ebay 0-5 psi(Gauge Pressure)
Description	TRANSDUCER 0-5 psi (Gauge Pressure)
Pressure Type	Vented Gauge
Operating Pressure	5 PSI (34.4738kPa)
Type	Analog Voltage
Output	0.5-4.5V linear voltage output
Accuracy	+/-(0.5%FS)
Voltage - Supply	4.75V ~ 5.25V
Port Size	Male - 1/8" NPT
Features	Temperature Compensated
Termination Style	Cable
Maximum Pressure	1000PSI (6894.76 kPa)
Operating Temperature	-40°C ~ 85°C
Package / Case	Cylinder

Item	Description
Application	Test Chamber Temperature RTD
Manufacturer	DC Direct
Mfg. Model No.	314-140 Small Budget RTD Sensor
Description	100 ohm RTD element, Alpha = 0.00385, Class B
Temperature Range	-58ºF to +390ºF (-50°C to +200°C)
Probe Diameter	1/4″
Probe Length	1.18” long
Termination Style	3 wire configuration
Sheath	316 Stainless Steel
Extension Leads:	72” long, 24 AWG stranded PFA insulated cores with silicone rubber
Wire Color Code	3 wire - 2 colored red and 1 colored white
Datasheet	TC Direct for Temperature Sensing, Measurement and Control

Appendix C – PLC Ladder Logic

2/3/2021 OP PROJECT 2021 260 op test chamber

Path: c:\users\public\documents\directsoft6\projects\op test chamber.prj
Save Date: 02/03/21 13:03:57
Creation Date: 01/21/21 11:40:32
PLC Type: 260
Class ID: DirectLogic 205 Series
Link Name: 260 KSeq

LED PROJECT TEST CHAMBER

Page 1

2/3/2021 OP PROJECT 2021 260 op test chamber

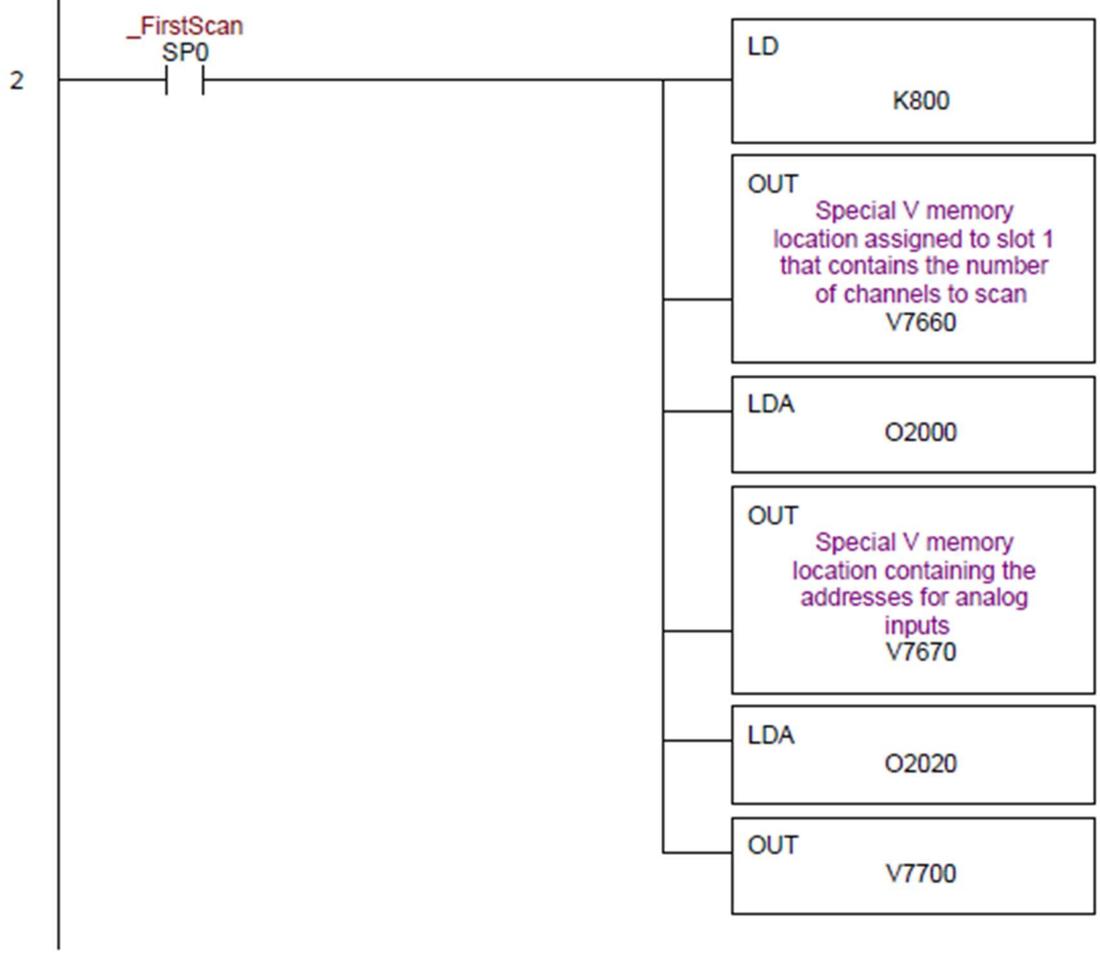
Ladder logic for the OP Tester
Date 1-24-21
CLR

REVISION HISTORY:

1-24-21 Initial setup for HP Test
1-26-21 Added F2-08AD-2 in slot B

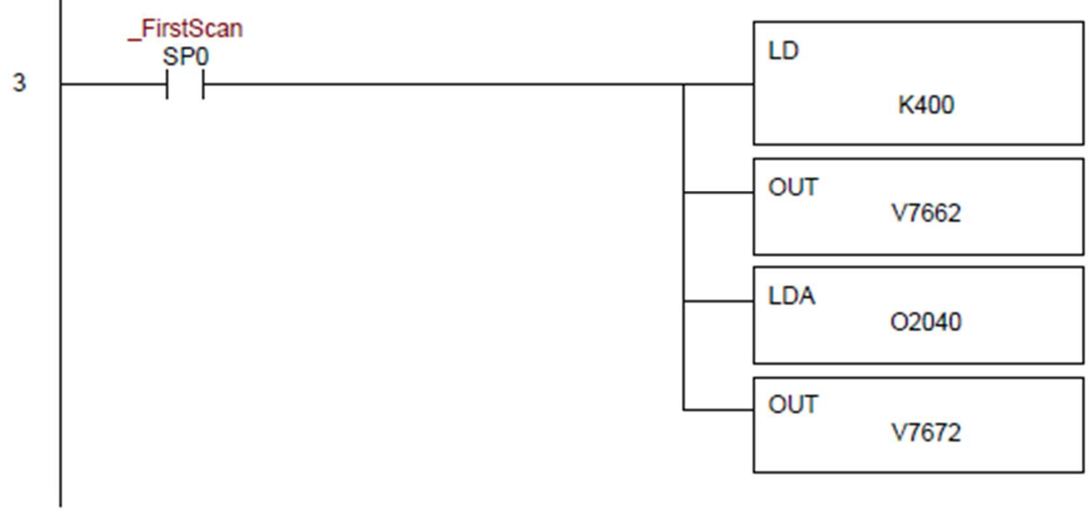
This rung specifies the number and location of V memory addresses into which the analog input signal from F2-08AD-2 module in slot 0, just to eft of CPU, will be stored. Channels are:

CHB1 V2000 Chamber HP Pressure, psig (0-3000 psig)
CHB2 V2001 Chamber LP Pressure, psig (0-5 psig)
CHB3 V2002 Currently not used
CHB4 V2003 Currently not used
CHB5 V2004 Currently not used
CHB6 V2005 Currently not used
CHB7 V2006 Currently not used
CHB8 V2007 Currently not used



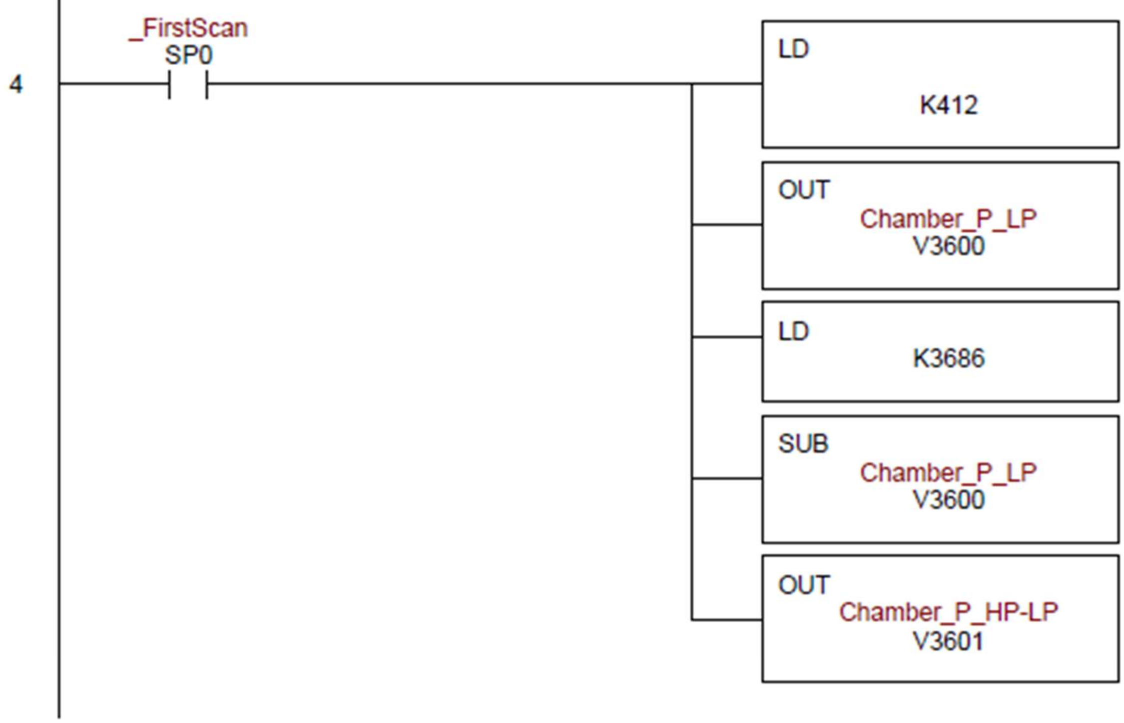
This rung specifies the number and location of V memory addresses into which the analog input signal from F2-04RTD module in slot 2 will be stored. Channels are:

CHD1 V2040 Chamber Temperature, F *10
CHD2 V2042 Currently Not Used
CHD3 V2044 Currently Not Used
CHD4 V2046 Currently Not Used



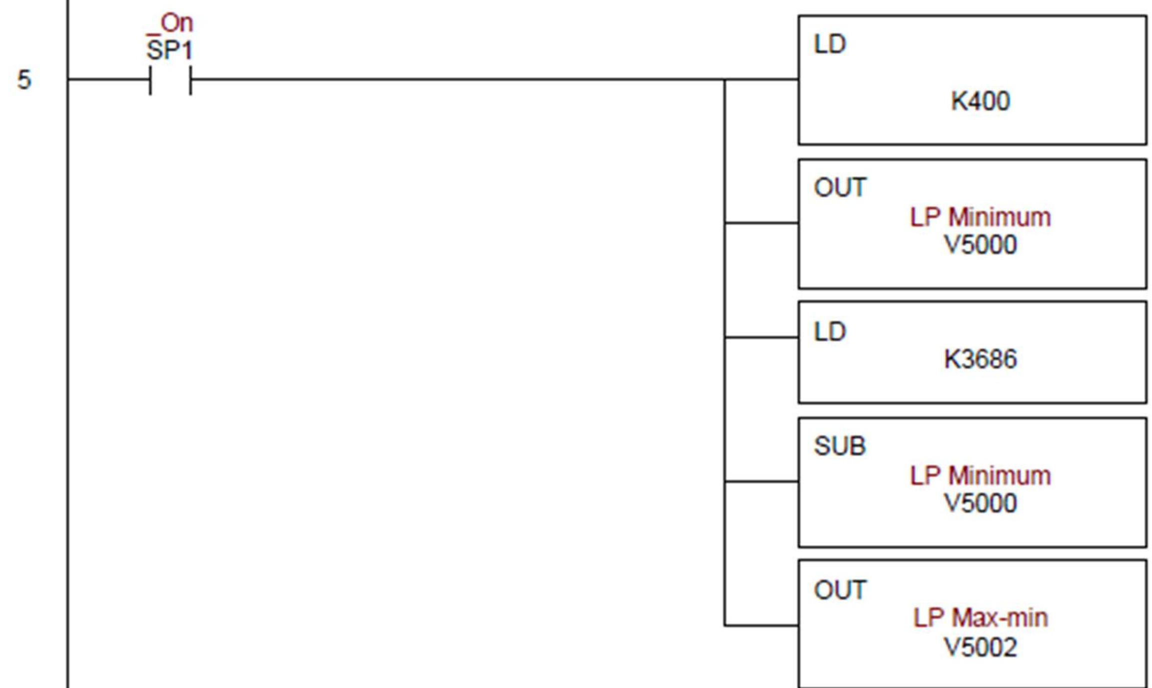
The rung sets up chamber HP pressure sensor processing. This sets the low pressure value and the difference in pressure between the LP and HP readings.

V2000 = Chamber pressure signal (0-4095)
V3600 = Pressure signal minimum value (0-4095)
V3601 = Pressure signal maximum - Pressure signal minimum (0-4095)
V3000 = Chamber pressure psig

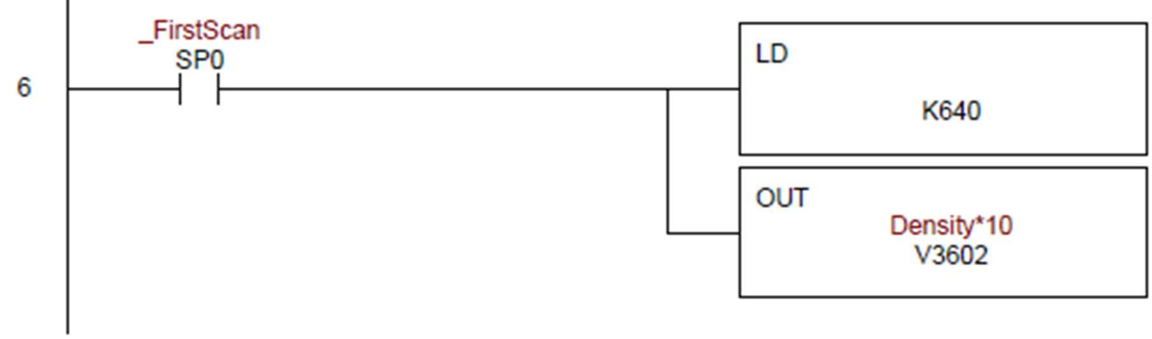


The rung sets up chamber LP pressure sensor processing. This sets the low pressure value and the difference in pressure between the LP and HP readings.

V2001 = LP Chamber pressure signal (0-4095)
V5000 = LP Pressure signal minimum value (0-4095)
V5002 = LP Pressure signal maximum - Pressure signal minimum (0-4095)
V5004 = LP Chamber pressure psig*100



This rung sets water density for water depth calculation during startup.



This rung sets a trigger discreet bit that is used to dispay the time and date on the touch scr...
display as a dynamic text. When C21 is set, the System time and date are displayed on ea...
screen.

7
_On
SP1
TIME/DATE_Trig
C21
(OUT)

This rung converts the signal for chamber pressure, rangeing from 0-4095, into psig.
Sensor range is 0 to 3000 psig.

V2000 = Chamber pressure singnal (0-4095)
V3600 = Pressure signal minimum value (0-4095)
V3601 = Pressure signal maximum - Pressure signal minimum (0-4095)
V3000 = Chamber pressure psig

V3000=(V2000-V3600)*K500/V3601

8
_On
SP1

Math - BCD
MATHBCD IB-521
Cham_P_psig
Result (WORD) V3000
Expression ((V2000 - V3600) * K3000) / V3601

A

9
_On
SP1
Cham_P_psig
V3000
<
K3

A

LD
K0

OUT
Cham_P_psig
V3000

LD
K0

OUT
V13000

This rung calculates the equvalent water depth using the chamber pressure and the density.

V3000 = Chamber pressure psig
V3602 = Water density * 10 (0-4095)

V3001=V3000 *K14400/V3602

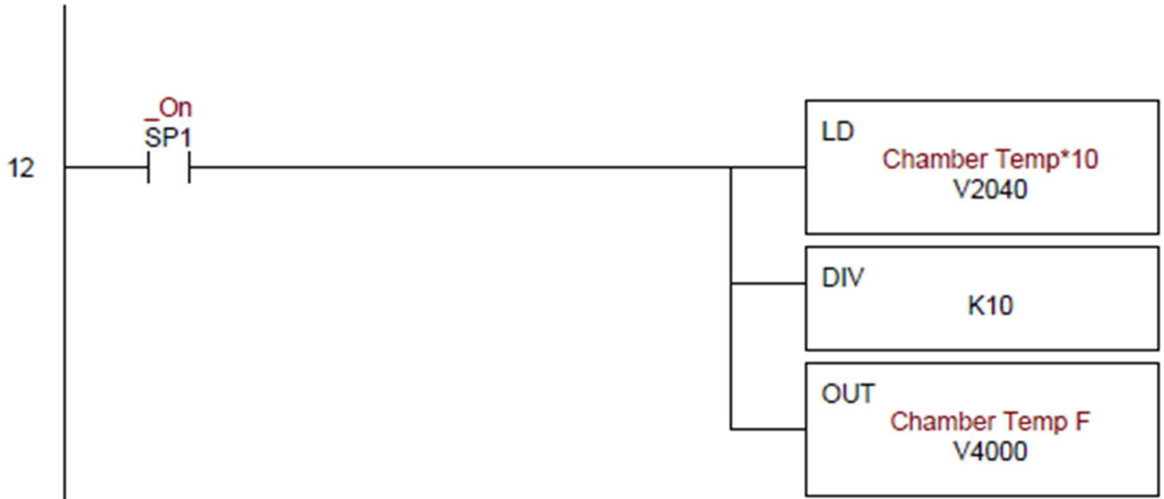
10 _On SP1

Math - BCD
MATHBCD IB-521
Depth -FSW
Result (WORD) V3001
Expression (V3000 * K1440) / V3602

11 _On SP1

Filter Over Time - BCD
FILTER IB-422

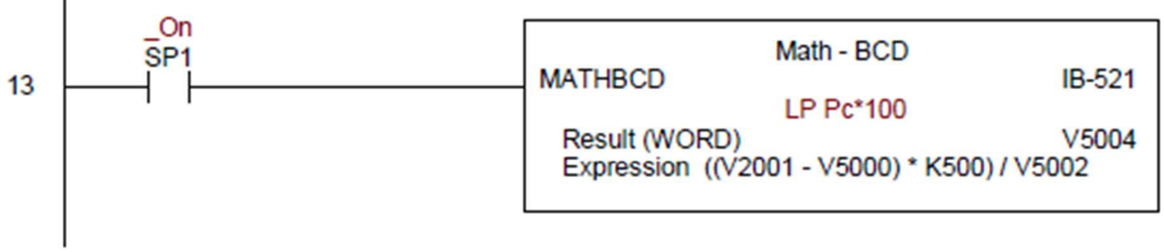
Filter Freq Timer	T14
Filter Freq Time (0.01 sec)	K50
Raw Data (BCD)	V3000
Filter Divisor (1-100)	K3
Filtered Value (BCD)	V13000

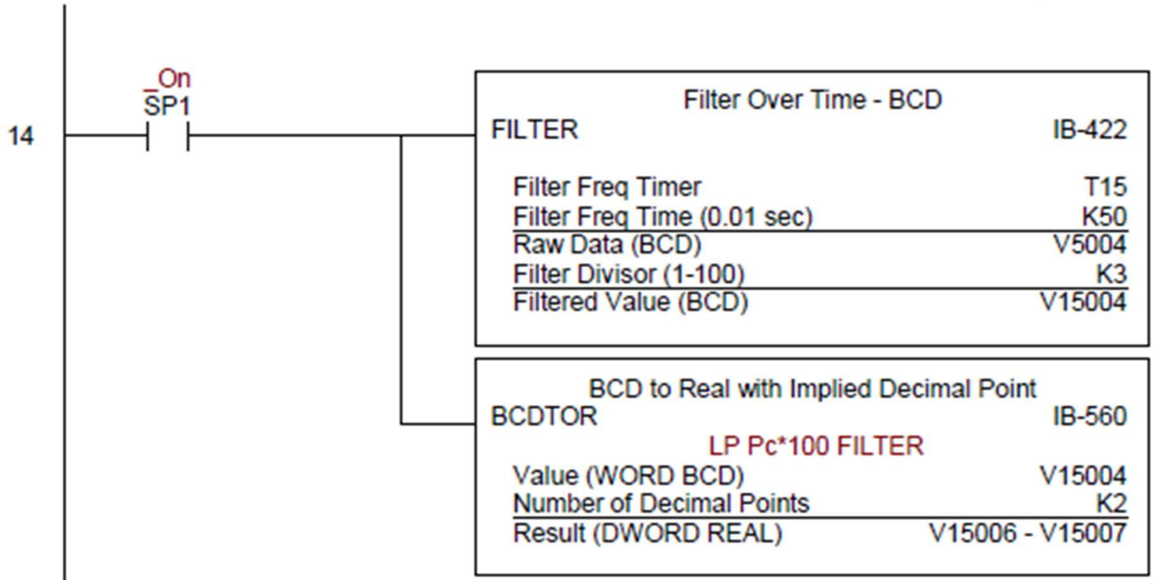


This rung converts the signal for LP chamber pressure sensor, rangeing from 0-4095, into psig*100. Sensor range is 0 to 5 psig.

V2001 = LP Chamber pressure singnal (0-4095)
V5000 = LP Pressure signal minimum value (0-4095)
V5002 = P Pressure signal maximum - Pressure signal minimum (0-4095)
V5004 = LP Chamber pressure psig*100

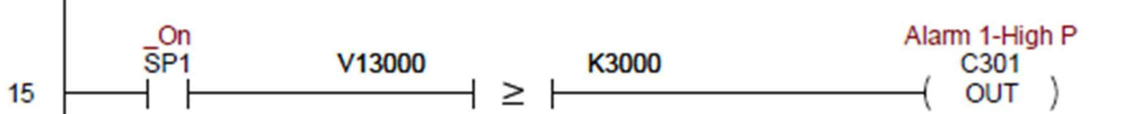
V5004=(V2002-V5000)*K500/V5002



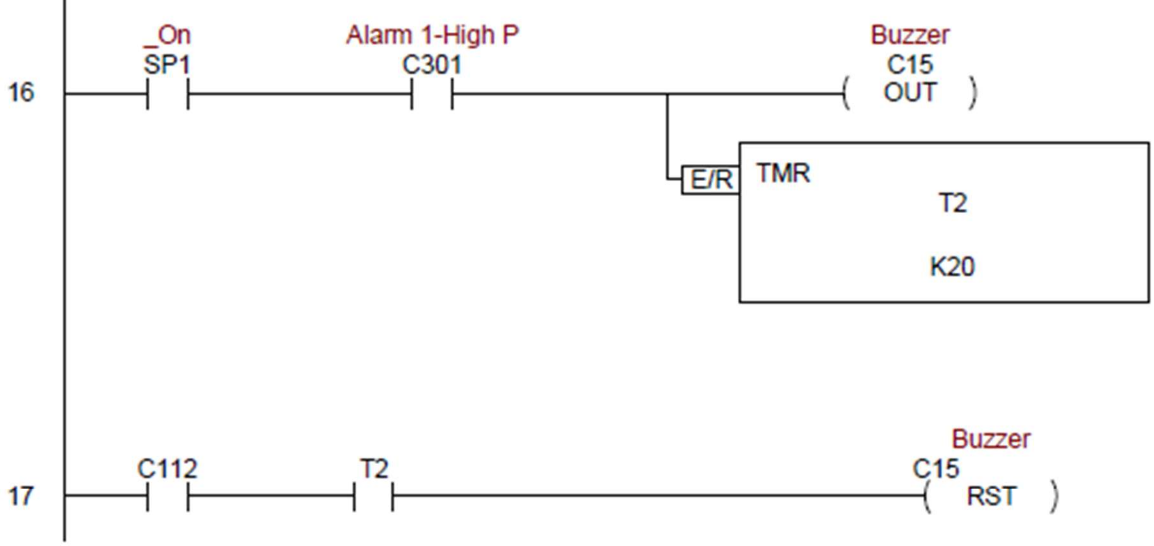


The following six rungs text for alarm conditions and set discreet flags that are used to sound an alarm buzzer.

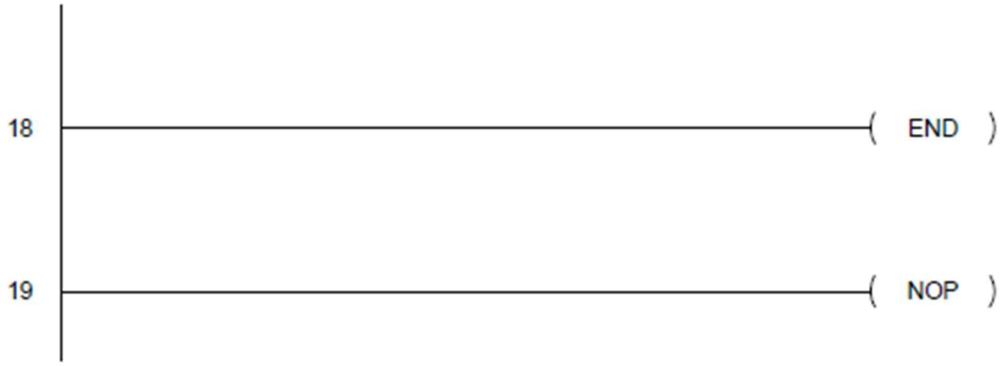
Alarm 1 - High Pressure in Test Chamber, >3000psig



If alarms are enbled then if any individual alarm has been set, turn on buzzer fo two seconds.



2/3/2021 OP PROJECT 2021 260 op test chamber



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Appendix D - Drawings

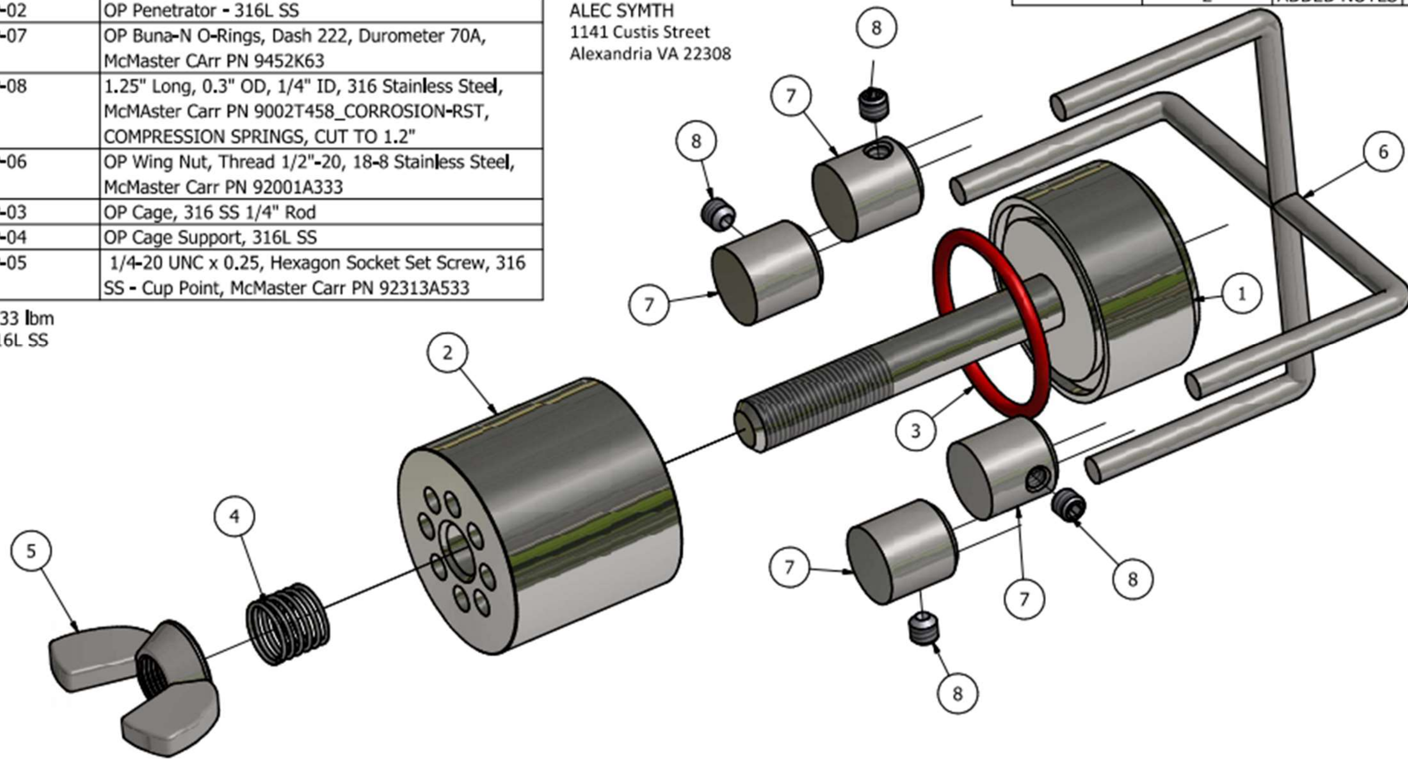
PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OP-01	Overpressure Cap - 316 SS
2	1	OP-02	OP Penetrator - 316L SS
3	1	OP-07	OP Buna-N O-Rings, Dash 222, Durometer 70A, McMaster CArr PN 9452K63
4	1	OP-08	1.25" Long, 0.3" OD, 1/4" ID, 316 Stainless Steel, McMAster Carr PN 9002T458_CORROSION-RST, COMPRESSION SPRINGS, CUT TO 1.2"
5	1	OP-06	OP Wing Nut, Thread 1/2"-20, 18-8 Stainless Steel, McMaster Carr PN 92001A333
6	1	OP-03	OP Cage, 316 SS 1/4" Rod
7	4	OP-04	OP Cage Support, 316L SS
8	4	OP-05	1/4-20 UNC x 0.25, Hexagon Socket Set Screw, 316 SS - Cup Point, McMaster Carr PN 92313A533

WEIGHT 1.333 lbm
MATERIAL 316L SS

OP VALVE WAS DESIGNED AND FABRICATED BY ALEC SYMTH

ALEC SYMTH
1141 Custis Street
Alexandria VA 22308

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	Initial	11/24/2020	CLR
	2	ADDED NOTES	11/28/2020	CLR



NOTES:
1) PURPOSE IS TO VENT CABIN PRESSURE WHEN PRESSURE EXCEEDS AMBIENT PRESSURE BY CRACKING PRESSURE
2) THE OP VALVE SHOULD BE ASSEMBLED AS HIGH AS POSSIBLE
3) THE HULL PENETRATOR IS MADE of 316L STAINLESS STEEL
4) THE CRACKING PRESSURE DEPENDS ON COMPRESSION OF SPRING OP-08 AND POSTION OF WINGNUT
5) VISUAL INSPECTION THAT THE O-RING IS LANDED IN O-RING GROVE IS RECOMMENDED PRIOR TO SUBMERGING
6) O RING GLAND GROVE HAS AN INNER DOVEFACE TO KEEP THE GLAND FROM INADVERNTETLY BECOMMING DISLODGED
7) GLAND SEAT IS DEEPER THAN NORMAL BECASUSE THE VALVE IS DESIGNED TO SEAT WITH MINIMAL DIFFERENTIAL PRESSURE
8) GAGE SUPPORTS, 7 SHOULD BE GROUNDED AND WELDED TO HATCH. MATCH CURVATURE OF HATCH
9) MAXIMUM OPERATING PRESSURE TBT, CRACKING PRESSURE TBT
10) DO NOT INSTALL THE OP VALVE IN AN INVERTED POSITION

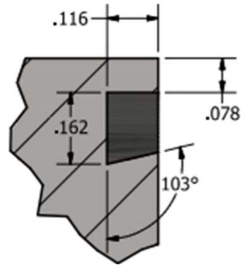
DRAWN ALEC SYMTH	11/24/2020	ALEC SYMTH
CHECKED CLR	11/24/2020	
QA		TITLE
MFG AS	11/24/2020	OP Valve
APPROVED AS	11/24/2020	
		SIZE B; DWG NO OP Valve Assembly; REV 1
		SCALE; SHEET 1 OF 1

WEIGHT 3.141 lbm
MATERIAL 316 SS AND 316L WHERE WELDED

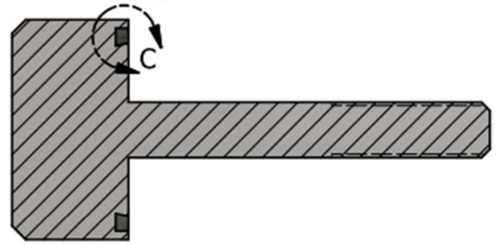
OP VALVE WAS DESIGNED AND FABRICATED BY ALEC SYMTH

ALEC SYMTH
1141 Custis Street
Alexandria VA 22308

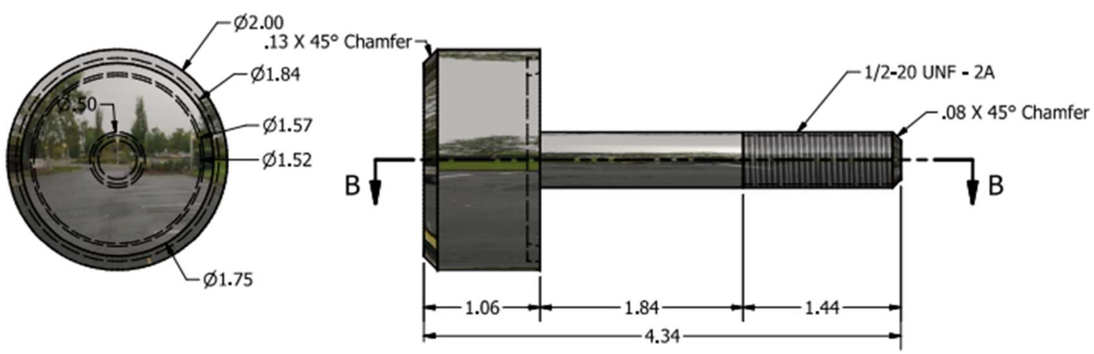
REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	INITIAL	11/24/2020	CLR
B-4	2	MODIFIED DOVE GROVE ANGLE	11/28/2020	CLR
A-4	3	ADDED NOTE 4	11/28/2020	CLR
A-3	4	ADDED CHAMFER DIMSION	11/28/2020	CLR



DETAIL C
SCALE 4: 1



SECTION B-B
SCALE 1 : 1



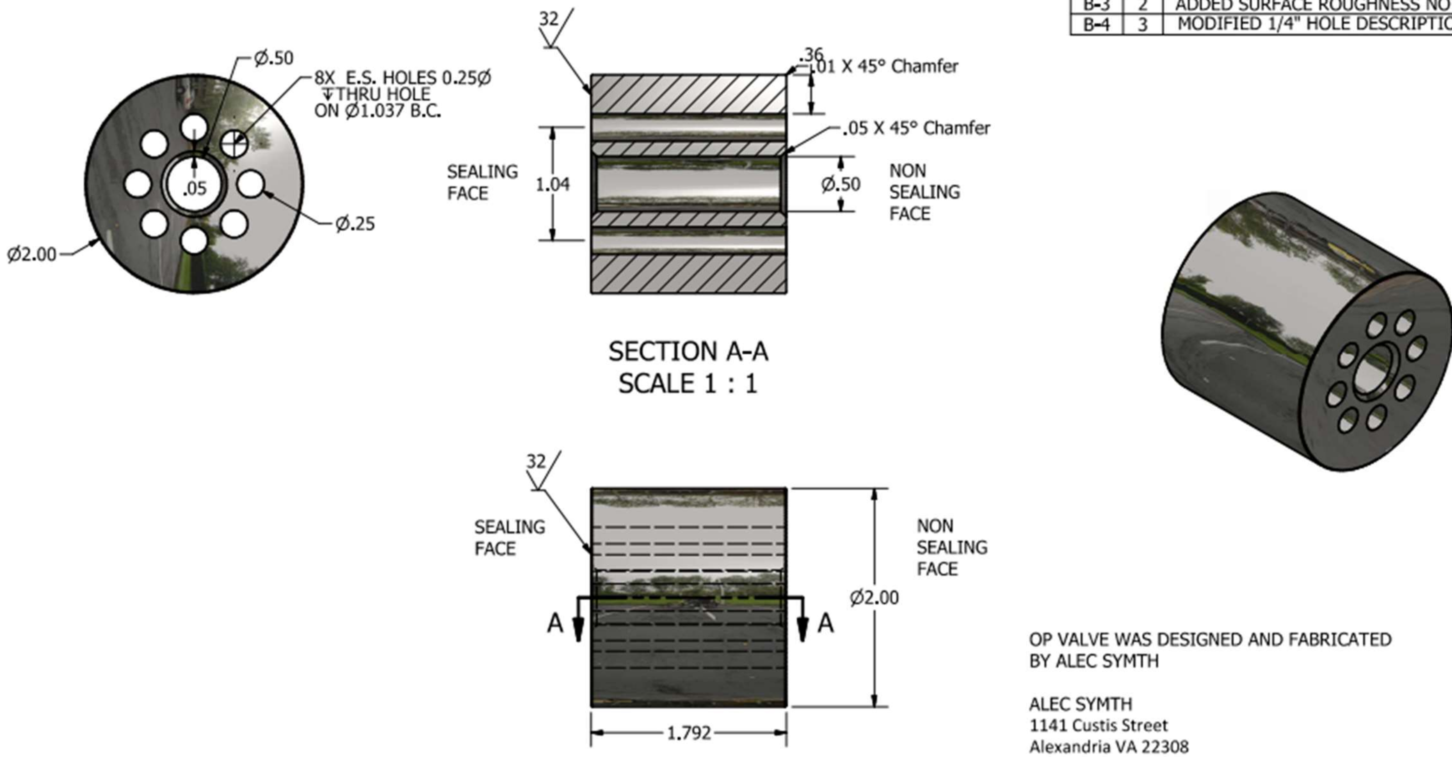
NOTES:
1) O RING GLAND GROVE HAS AN INNER DOVEFACE TO KEEP THE GLAND FROM INADVERNTETLY BECOMMING DISLODGED
2) GLAND SEAT IS DEEPER THAN NORMAL BECASUSE THE VALVE IS DESIGNED TO SEAT WITH MINIMAL DIFFERENTIAL PRESSURE
3) GLAND IS Buna-N O-Rings, Dash 222, Durometer 70A
4) NOP, VISUAL INSPECTION THAT THE O-RING IS LANDED IN O-RING GROVE IS RECOMMENDED PRIOR TO SUBMERGING

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OP-01	Overpressure Cap - 316 SS

DRAWN AS	11/24/2020	ALEC SYMTH
CHECKED AS	11/24/2020	
QA		TITLE
MFG AS	11/24/2020	OP Valve - Cap
APPROVED AS	11/24/2020	
SIZE B	DWG NO OP-01	REV 1
SCALE		SHEET 1 OF 1

WEIGHT 1.333 lbm
MATERIAL 316L SS

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	INITIAL	11/24/2020	CLR
B-3	2	ADDED SURFACE ROUGHNESS NOTE	11/28/2020	CLR
B-4	3	MODIFIED 1/4" HOLE DESCRIPTION	11/28/2020	CLR



OP VALVE WAS DESIGNED AND FABRICATED BY ALEC SYMTH

ALEC SYMTH
1141 Custis Street
Alexandria VA 22308

NOTES:
1) OP PENETRATOR SHOULD BE WELDED IN HATCH SHELL
2) SURFACE ROUGHNESS VALVE NO TO EXCEED 32 MICRO-INCES (32 RMS) ON THE SEALING SURFACES.

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OP-02	OP Penetrator - 316L SS

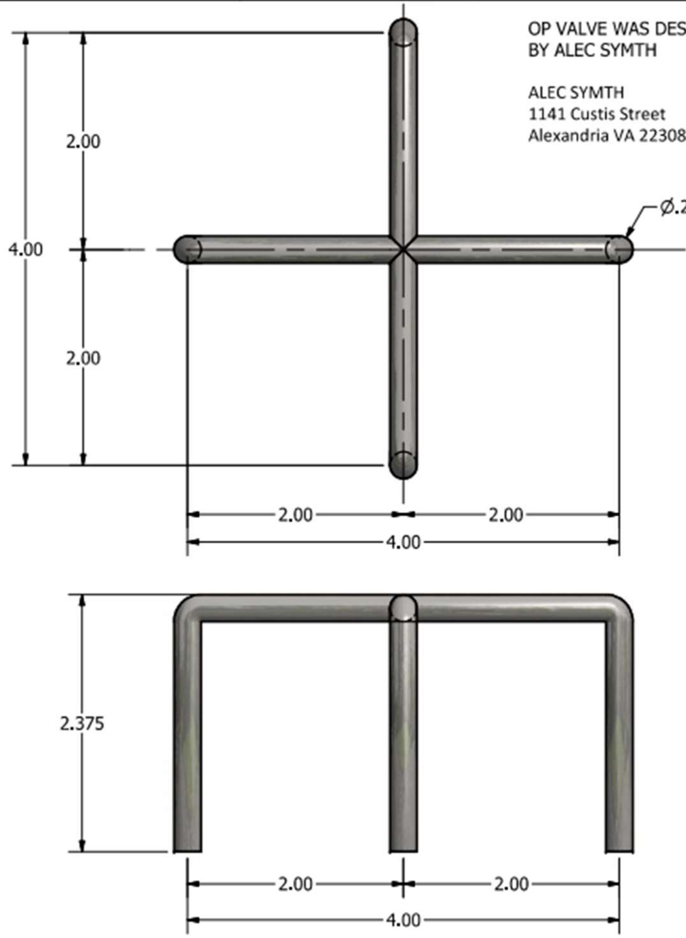
DRAWN AS	11/24/2020	ALEC SYMTH
CHECKED CLR	11/24/2020	
QA		TITLE
MFG AS	11/24/2020	OP Penetrator
APPROVED AS	11/24/2020	
		SIZE B · DWG NO OP-02 · REV 1
		SCALE · SHEET 1 OF 1

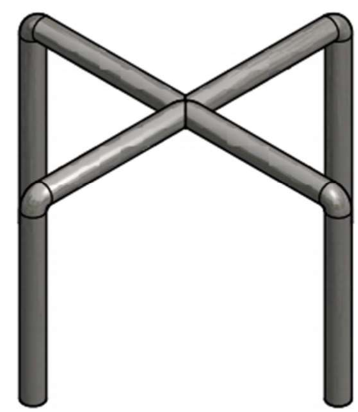
WEIGHT 0.237 lbm
MATERIAL 316L SS

OP VALVE WAS DESIGNED AND FABRICATED BY ALEC SYMTH

ALEC SYMTH
1141 Custis Street
Alexandria VA 22308

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	INITIAL	11/24/2020	CLR
	2	ADDED MC PN	11/28/2020	CLR





NOTES:

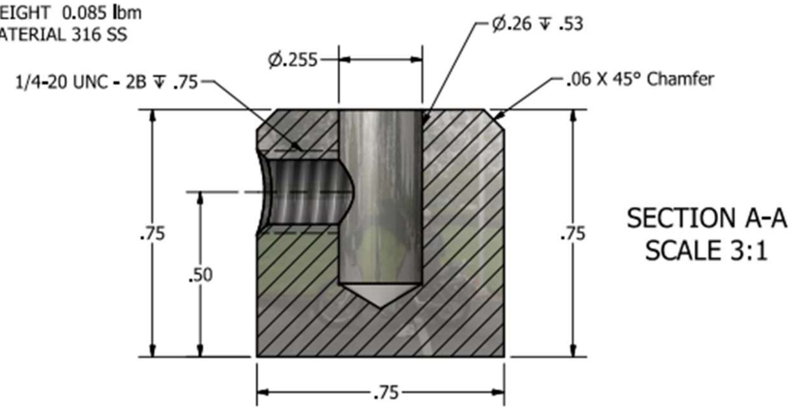
1) PURPOSE OF CAGE IS TO PREVENT INADVERTANT OPENING OF OP VALVE CAUSED BY A LINE SNAGGING THE VALVE
2) CAGE IS FABRICATED FROM TWO 303 SS DRAWER HANDLES, MCMASTER CARR PN 1726A1

DRAWN AS	11/24/2020	ALEC SYMTH
CHECKED CLR	11/24/2020	
QA		TITLE
MFG AS	11/24/2020	OP Cage
APPROVED AS	11/24/2020	
		SIZE B · DWG NO OP-03 · REV 1
		SCALE · SHEET 1 OF 1

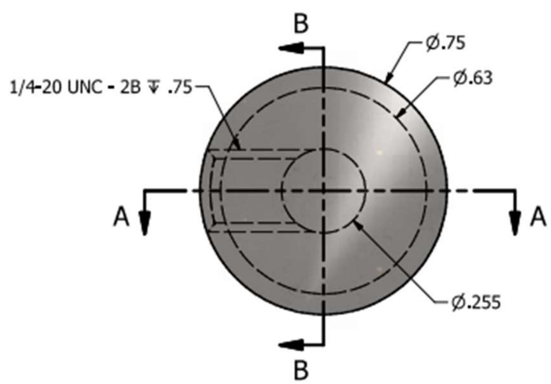
PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OP-03	OP Cage, 316 SS 1/4" Rod

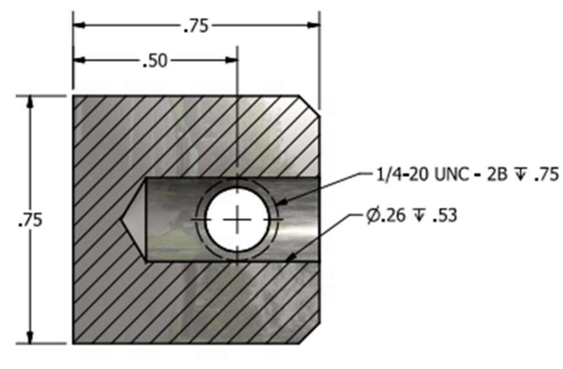
WEIGHT 0.085 lbm
MATERIAL 316 SS

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	INITIAL	11/24/2020	CLR
B-4	2	CHANGED THREAD OF SET SCREW	11/28/2020	CLR



SECTION A-A
SCALE 3:1





SECTION B-B
SCALE 3:1

OP VALVE WAS DESIGNED AND FABRICATED BY ALEC SYMTH

ALEC SYMTH
1141 Custis Street
Alexandria VA 22308

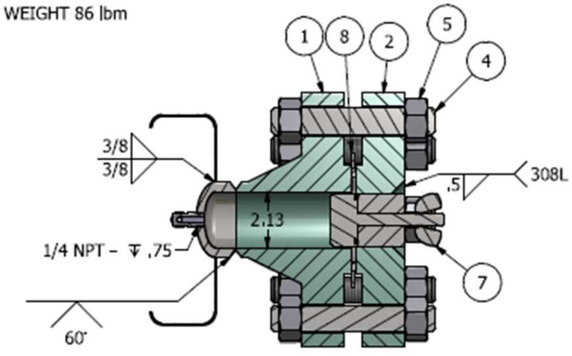
NOTES:

1) GAGE SUPPORTS, SHOULD BE TIG WELDED TO HATCH AND GROUND TO MATCH CURVATURE OF THE HATCH

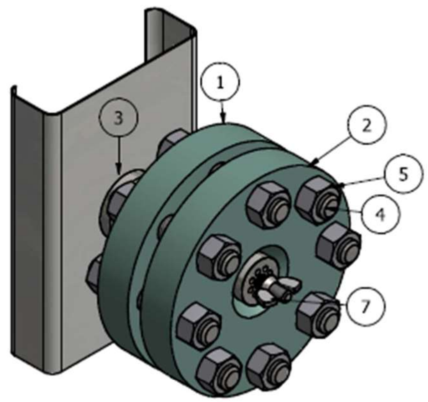
PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	OP-04	OP Cage Support, 316L SS

DRAWN AS	11/24/2020	ALEC SYMTH
CHECKED AS	11/24/2020	
QA		TITLE
MFG AS	11/24/2020	OP Cage Support
APPROVED AS	11/24/2020	
		SIZE B · DWG NO OP-04 · REV 1
		SCALE · SHEET 1 OF 1

WEIGHT 86 lbm



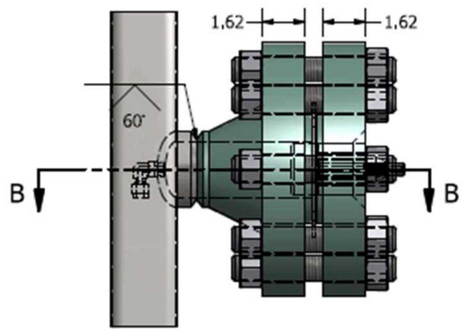
SECTION B-B
SCALE 1 : 4

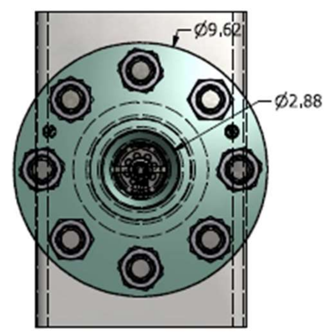


REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	INITIAL	12/3/2020	CLR
B-4	2	Removed chamfer	12/3/2020	CLR
B-1	3	Revised notes	12/4/2020	CLR
B-4	4	Changed Welding symbol	12/4/2020	CLR
B-4	5	Added Stand	12/4/2020	CLR
	6	Stand, 8x1-1/2 purlin	12/23/2020	CLR

NOTES:
1) Purpose is to test the maximum external pressure of the OP valve
2) Penetrator on the OP valve is welded to the blind flange
3) Test chamber is filled with water and pressurized with a power washer
4) The chamber will also be used to measure cracking pressure
5) The MAWP for the chamber is 3705 psig at T< 100°F
6) Cracking pressure of the OP valve will be determined by reversing the OP valve
7) 0-10 psi pressure reducing regulator will be used for cracking pressure test
8) PRV to be set at MAWP, 3000 psig

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	2.5" Weld Neck Flange	2.5 in Weld Neck RF Flange, Sch 160, ANSI B16.5 Class 1500
2	1	2.5-1500-BLIND-RF-FLANGE	2.5" Blind RF Flange, Sch 160, ANSI Class 1500
3	1	2.5" Pipe Cap Sch 160	Carbon Steel Buttweld Cap, Sch 160, FOR 2-1/2" PIPE (2.875 OD) XH (.276 WALL) ANSI B16.9
4	8	1-8 Stud	1" - 8 Class 1500 Stud for RF Flange, 6.25"
5	16	ANSI B18.2.2 - 1 - 8	Hex Nuts (Inch Series) Hex Nut
7	1	OP Assembly Without cage	
8	1	2.5" Flange Gasket	1.5" Metallic Gasket, Class 1500
11	1	Tester base 8x2 and half purlin	
14	1	SS-400-2-4	316 SS 14/ MNPT X 1/4 tube





NOTES:
1) Both the max pressure and cracking pressure tests will be done with purlin as base. This will insure that OP cap is on top during cracking test which is the oriention of the valve under NOP.
2) When conducting the cracking pressure test, blind flange will be reversed so the OP cap faces outward.
3) During Cracking pressure test, wing nut will be contrained from turning but allowed to move axially to enable the gap between OP base and cap to be changed without unbolting the flanges by turning the OP cap.
4) Cracking pressure will be measured as a function of the gap beween the OP base and cap.

DRAWN CLR	12/3/2020	Redus Engineering
CHECKED CLr	12/3/2020	
QA		TITLE
MFG CLR	12/3/2020	Pressure Test Cell for OP Valve
APPROVED CLR	12/3/2020	
		SIZE B · DWG NO Test Cell OP Valve · REV 1
		SCALE · SHEET 1 OF 1