Redus Engineering
Devine, Tx

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|---|---|---|---|

# Evaluation of CruzPro ATU120BT Active Sonar Transducer for Manned Submersibles

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| | | | | | | |
|---|---|---|---|---|---|---|
| 1<br>2<br>3 | 5/1/21<br>5/2/21<br>5/5/21 | Issued as Draft<br>Added Future work<br>Added Pool Test | CLR<br>CLR<br>CLR | JW<br>JW<br>JW | CLR<br>CLR<br>CLR | JW<br>JW<br>JW |
| Rev No | Date | Description | Issued By | Checked By | Approved By | Client Approval |

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# 1. EXECUTIVE SUMMARY

This document covers the testing of the CruzPro ATU120BT active sonar transducer conducted on April 20th 2021 in Devine, Tx. The objective of the test was to determine if the off-the-shelf (OTS) transducer could continue to transmit NMEA 0183 sentences at a depth of 1,000 fsw. The test was conducted in a test chamber capable of achieving a pressure of 2,500 psig or 5,600 fsw. Chamber pressure and temperature were logged on a PLC. The simulated depth in the chamber was increase in 100 ft increments until the1,000 fsw target depth was achieved. At each of these depth increments, the transponder was held at this pressure for approximately 5 minutes. When the chamber pressure reached the targeted 1,000 fsw, it was held at this pressure for one hour. As the transponder successfully past this test by continuing to transmit NMEA 0183 sentences, a decision was made to increase the depth to 1,200 fsw (533.3 psig). This equivalent hydrostatic pressure was maintained for an additional hour. The transponder continued to operate throughout the extended test. On disassembly of the test chamber and removal of the transponder, no obvious damage had occurred to the transponder other than minor separation that occurred between the supply cable and the epoxy potting compound. This was due to the softness of the insulation around the cable. Even though this separation occurred, it did not affect the ability of the transponder to transmit data.

A FEA analysis of the transponder was conducted prior to the test to understand the stress on the transponder caused by hydrostatic pressure as the original design basis for the transponder is surface operations. A key finding of the FEA analysis is that the yield stress was reached in the epoxy filled hole in the 5 mm cork pad that is potted above the piezoelectric element when the device is subjected to a depth of 2,000 fsw. Therefore, the maximum submergence depth for the OTS unit is somewhere between 1,200 and 2,000 fsw. The analysis indicates this maximum depth could be extended if the 4 mm diameter hole in the 5 mm cork pad was increased to 7 mm.

On May 4th, a pool test was conducted to determine if the sounder output of depth and temperature were still accurate after the pressure test. While admittedly, the test was shallow, the sounder results agreed with measured valves.

## 2. INTRODUCTION

The goal of this project was to document the performance of the CruzPro model ATU120BT active sonar transducer shown in Figure 1. Specifically, the ability of the unit to continue to transmit NMEA 0183 sentences at a target depth of 1,000 fsw was to be determined. If the unit passed this test, then a stretch goal of 1,200 fsw was planned. Prior to the test a FEA analysis was conducted to determine the stress imposed on the transducer due to the hydrostatic pressure.

To conduct the experiment, a test chamber was utilized shown in Figures 2 and 3. A positive displacement, triplex plunger pump was used to generate the pressure for the test with salt water as the media. The adjustable pressure relief valve for the pump was set at 500 psig which sets the maximum pressure the chamber achieved.

*Figure 1 CruzPro ATU120BT Active Sonar Transducer*

*Figure 2  Test Chamber with transducer installed*

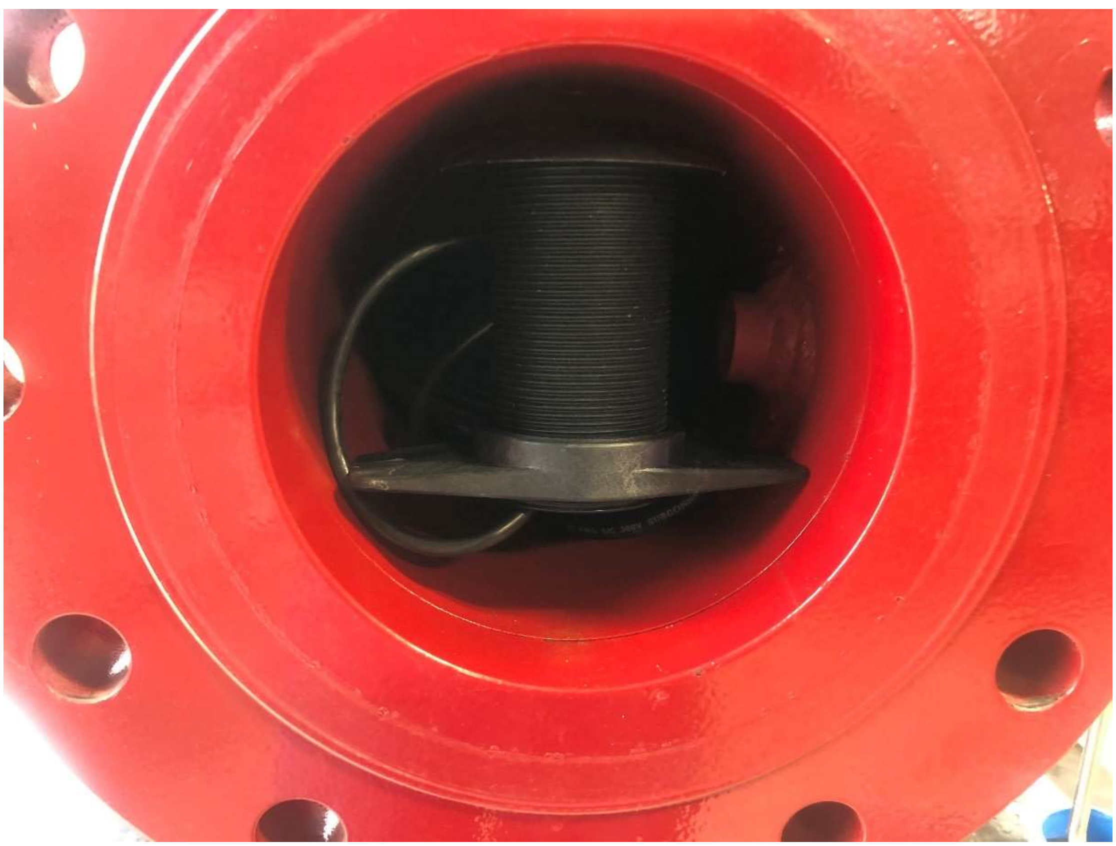


*Figure 3 - Transducer orientation during test*

# 3. RESULTS & CONCLUSIONS

## 3.1 Max Pressure Test

1) The maximum recorded pressure was 539 psig. This pressure corrosponds to 1,213 fsw assuming a 64 lbm/ft$^3$ salt water density.
2) The ATU120BT continued to operate for 1 hour at 1,000 fsw and an additonal hour at 1,200 fsw.
3) Based on this test, the recommended maximum operating depth is 1,200 fsw without any changes to the OTS transducer. The unit may be able to operate at a deeper depth with modifications to how the cable is mated to the transducer and further testing.

## 3.2 FEA Results & Conclusions

1) The inclusion of the 4 mm diameter cutout in the 5 mm cork pad reduces the maximum displacement of the sea side face by 42% dropping it from 0.0179 in (0.45m) to 0.0103 in (0.26mm). This epoxy filled cutout is acting as a column transferring the load from the seaside face of the transponder to the upper epoxy section.
2) With the addition of the 4 mm column, the maximum Von Mises stress goes above the yield stress of the epoxy. The location of the maximum stress is the 4 mm column with the stress being in compression. Exceeding the yield stress at this point indicates this column will plastically deform to some extent to relieve the stress on the first excursion to 2,000 fsw. In other words, it will not spring back to the original thickness as it would if the stress had been below the yield valve of the epoxy. The column is still reducing the deflection of the seaside face. As such, as long as the epoxy does not separate from the body of the housing, the transducer should be OK even with a slight deformation of the 4 mm cutout.
3) Due to the hydrostatic pressure and the lack of structural support of the housing wall at the location of the 5mm pad, the housing displaces radially outward at the location of the 5 mm pad but not as much as when the 4 mm column was not in place.
4) Structurally, the transponder could be made stronger by increasing the diameter of the 4 mm diameter cutout to the same inside diameter of the piezoelectric element, around 7 mm. This would enable an epoxy column to fill this space and prevent most of this compression. While this would help structurally, it might adversely affect the performance of the piezoelectric element. Note this change in not necessary for the normal topside deployment of these transponders because of the low ambient water pressure.
5) This preliminary FEA was done with the PCB removed. Inclusion of the potted PCB will weaken the epoxy pad above the 5 mm disk because of added void space. A future FEA could be done by detailing the PCB and potting in the model.

# 4. DISCUSSION

## 4.1 Description of Transducer

The CruzPro DSP (Digital Signal Processing) active transducers outputs NMEA 0183 serial data of depth and water temperature. The Active Transducer does not require a separate black box driver device, it has all the transducer driving electronics included in a single compact transducer case.

The ATU120BT transmits digital depth and temperature in NMEA 0183 $SDDPT, $SDDBT and $SDMTW sentence format.

According to the manufacturer the DSP technology used by the CruzPro active transducers provide for reliable depth tracking to over 300M (990 fsw). The active transducers operate at 120khz to prevent interference with other nearby depth sounders and fish finders.

To wire the device, connect 12V to unit and connect the NMEA 0183 data wire to any NMEA compatible instrument, computer or NMEA data repeater. See Appendix D for a drawing that shows how the ATU120BT is wired. The ASCII NMEA 0183 information can be used to log depth and water temperature.

CruzPro ATU120BT Specifications:

- Operating Voltage: 9.5 - 16.0 VDC.
- Current Drain: 0.035 amps nominal.
- Output power: 320 watts RMS.
- Equivalent processed power: DSP power of 6400 watts.
- Sounding Depth: 300M (990 fsw).
- Water Temperature: 32 deg F (0 deg C) to 90 deg F (32 deg C)
- Data Output: NMEA 0183 v1.x serial Signal voltage 0 to +5v.

## 4.2 Test Chamber Setup

As seen in Figure 2, to setup the pressure test of the ABU120BT transducer, 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. A positive displacement pump in the pressure washer was used to develop the pressure. An RTD was installed in the test chamber to measure the temperature. The ABU120BT was wired to a DB-9 connector that was plugged into the serial port of a laptop. Tera Term, an open-source, free, software implemented, terminal emulator (communications) program, was used to display the NMEA 0183 output sentences. Note that the RX wire normally included on RS-232 serial devices is not included on the ABU120BT. As such, there is no mechanism for uploading firmware changes to the ABU120BT transducer. The cold-water supply to the test-stand supplied pressure at approximately 76 psig. This corresponds to 171 fsw which is the minimum depth test conducted. For higher pressures, a bypass vernier valve was used. By closing off more and more of the bypass flowrate, the pressure in the chamber is increased. For the 1,000 fsw test (444 psig), the external pressure relief valve was set to 500 psig.

A 64 $lb_m/ft^3$ brine solution was made by adding 1.07 $lb_m$ of salt to 5 gals of fresh water. The chamber was manually filled with this brine. The intent of the brine was to make an electrolyte so that any brine that penetrated the ABU120BT to the electronics would short out the electronics.

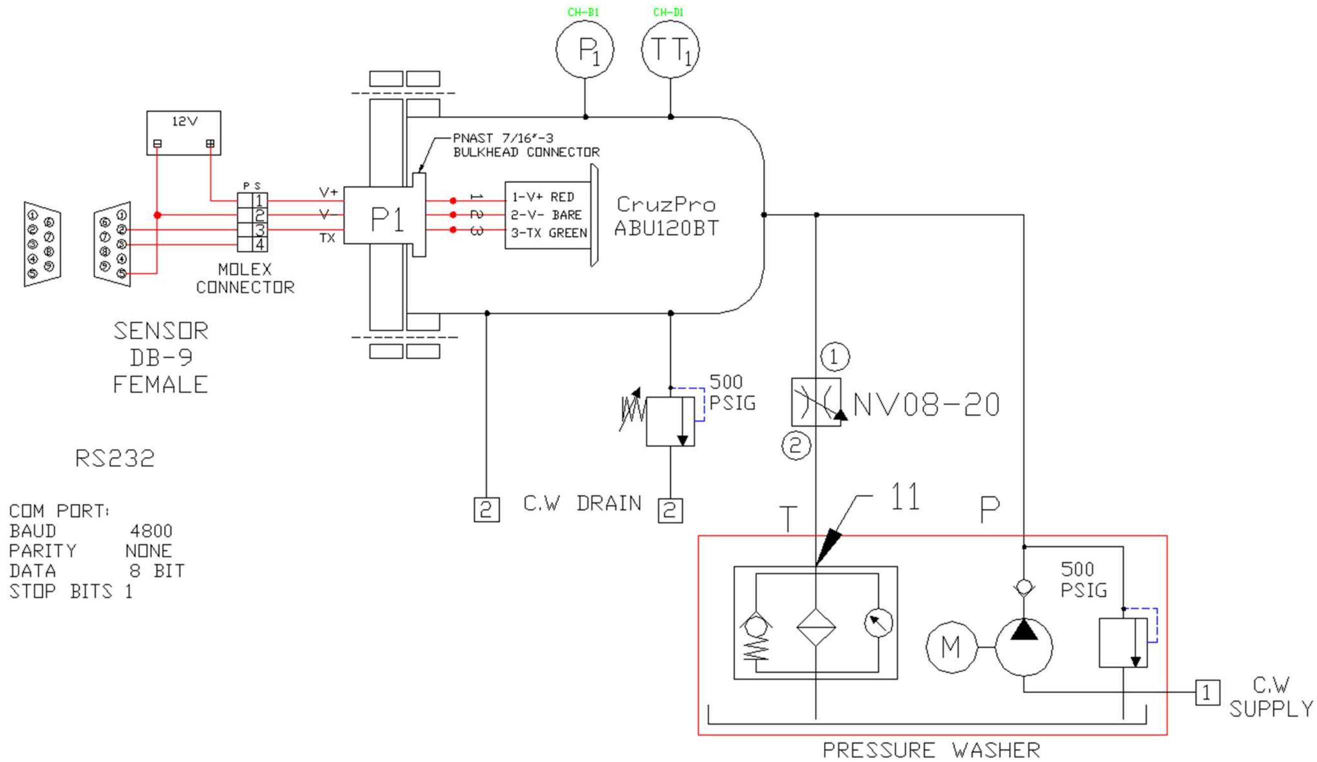



*Figure 4 - Setups for Pressure Test*

## 4.3 Depth Test Results

The target test pressures are shown in Table 1.

*Table 1 Test Depths and Hydrostatic Pressures*

| Depth (fsw) | Pressure*(psig) |
|---:|---:|
| 171 | 76.0 |
| 300 | 133.3 |
| 400 | 177.8 |
| 500 | 222.2 |
| 600 | 266.7 |
| 700 | 311.1 |
| 800 | 355.6 |
| 900 | 400.0 |
| 1,000 | 444.4 |
| 1,200 | 533.3 |

At each of these test points, the pressure was held steady for approximately 5 minutes until the target depth of 1,000 fsw was reached. The pressure was held steady at this depth approximately 1 hour. The intention of the test was to determine if the housing could withstand the pressure without cracking or flooding. As such the pass/fail criteria for the test was the ABU120BT's ability to transmit data.

The test was done on April 30th at starting at 10:37 am. Figure 5 shows the depth and temperature over the test period.

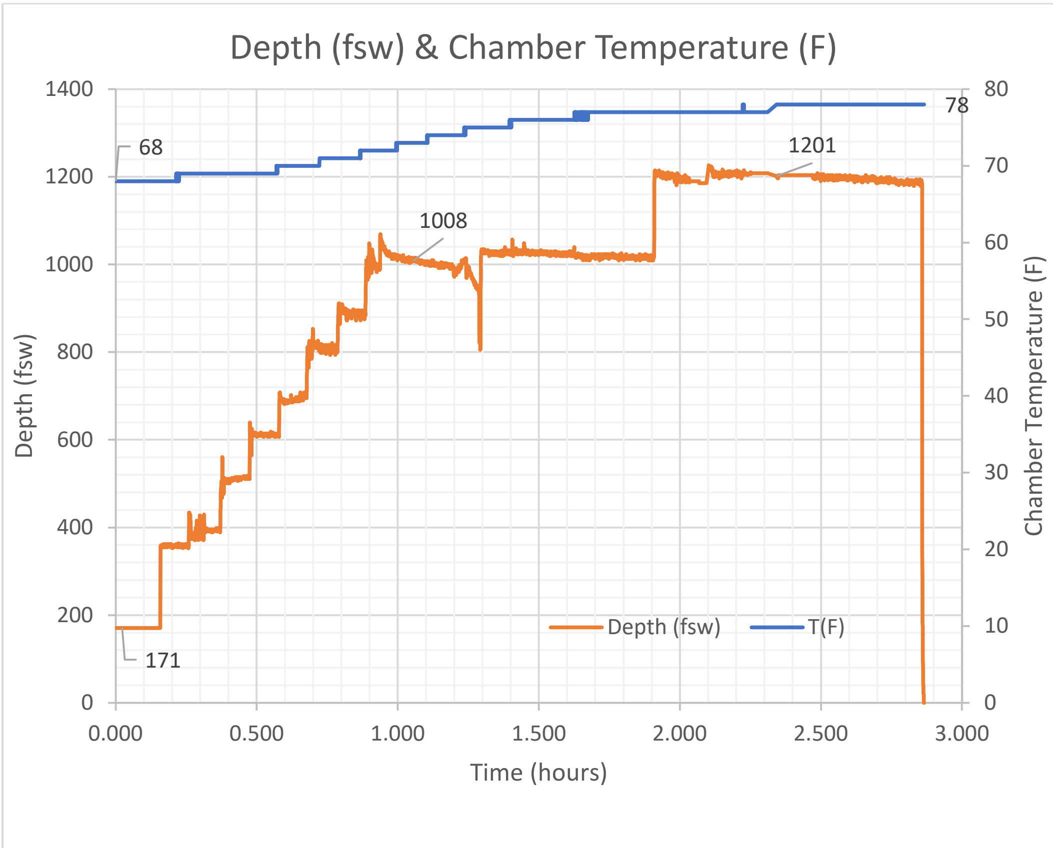



*Figure 5 - Plot of depth (fsw) and chamber temperature*

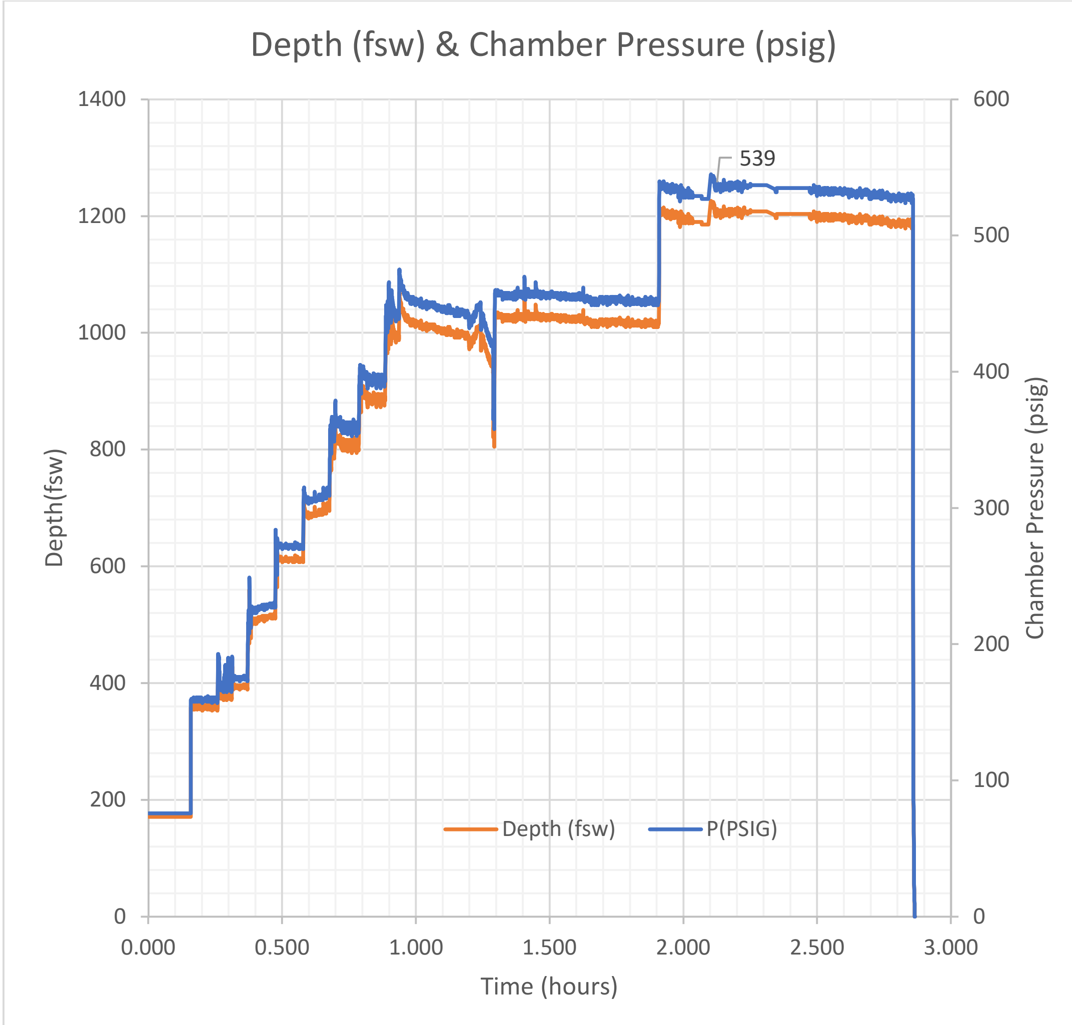



*Figure 6 - Plot of depth (fsw) and chamber pressure (psig)*

The pressures and temperatures shown in Figures 5 and 6 are from test chamber instrumentation not from the ABU120BT.

Figure 7 plots the ABU120BT transmitted data converted to imperial units. As shown from the data, the unit continued to output data though out the test. As the transponder was in a steel test chamber with only a small distance from the transducer head to the chamber wall, any sounder data is meaningless. If you compare the temperature from the ABU120BT to that of the RTD on the test chamber, you see some discrepancy.

*Table 2 Test Chamber vs. ABU120BT Temperatures (F)*

| | Test Chamber (F) | ABU120BT (F) |
|---|---|---|
| Start | 68 | 73 |
| End | 78 | 75 |

A hypothesis for the discrepancy has to do with location of the sensors and the operation of the test chamber. Makeup water to the test chamber comes into the bottom of the chamber near the mid point. The RTD is just above this in a thread-o-let pipe fitting in the wall of the chamber. There was a small amount of water being emitted from the PRV so over the three hours test makeup water was added to replace this lost volume (3 quarts) by the pump. The pump was connected to the supply hose bibb by a long water hose. As the day went on the ambient temperature increased significantly (+20 °F) which in turned heated up the water hose. This hot water was being added slowly to the chamber and possibly heating up the water near the RTD. The ABU120BT located near the blind flange at the back of the cell was in stagnant water well away from this warmer water.

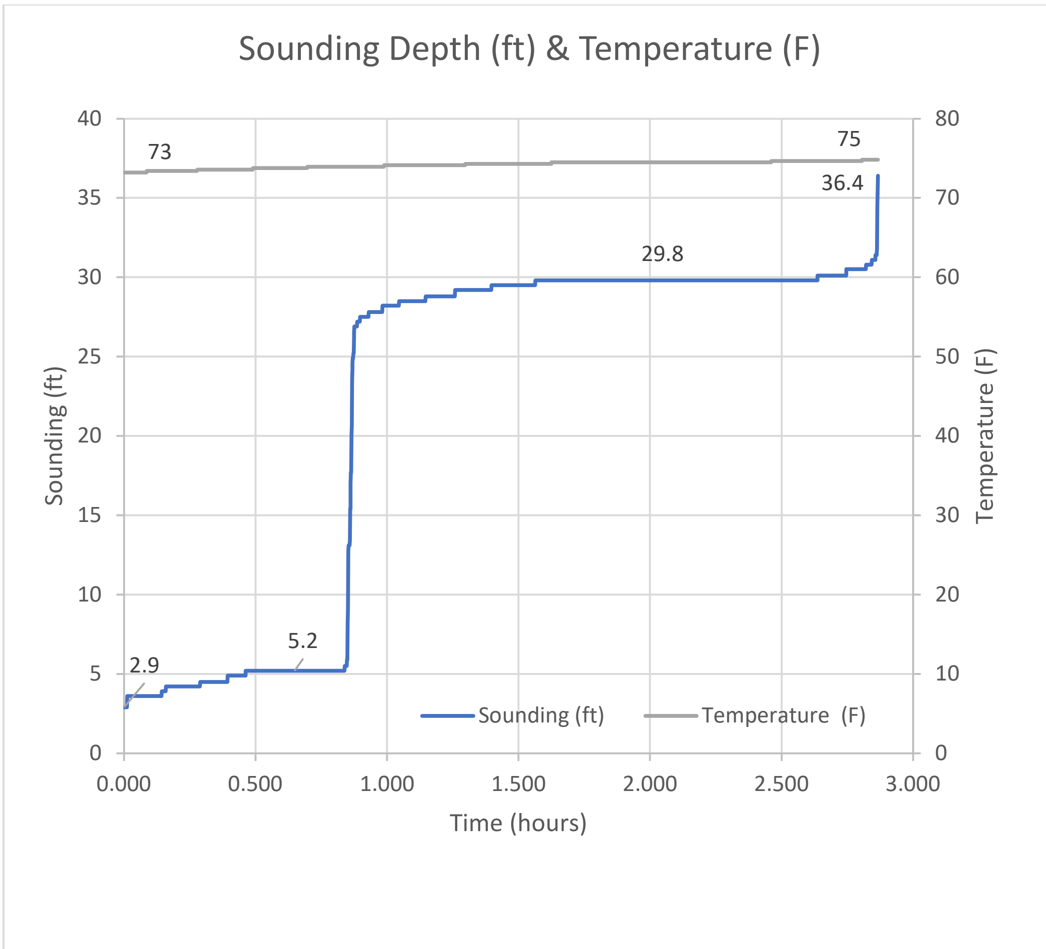



*Figure 7 - Plot of sounding (fsw) and temperature (F)*

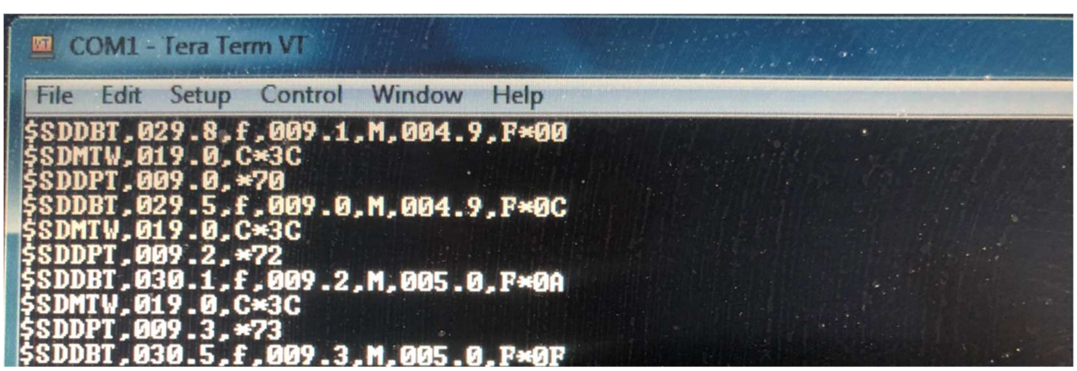



*Figure 8 - NMEA 0183 sentences being outputted from ATU120BT*

Figure 9 shows the before and after images of the ATU120BT. After inspection a separation was observed between the epoxy potting and the transducer cable where it enters the unit. It is probable that the pressure caused the soft insulation around the cable to compress away from the epoxy potting material. No other cracks are separation was observed and this separation did not lead to the unit failing. Preventing this possible water egress location is an area that for future development particularly if deeper utilization of the device is expected.


*Figure 9 - Before and after images of ATU120BT*

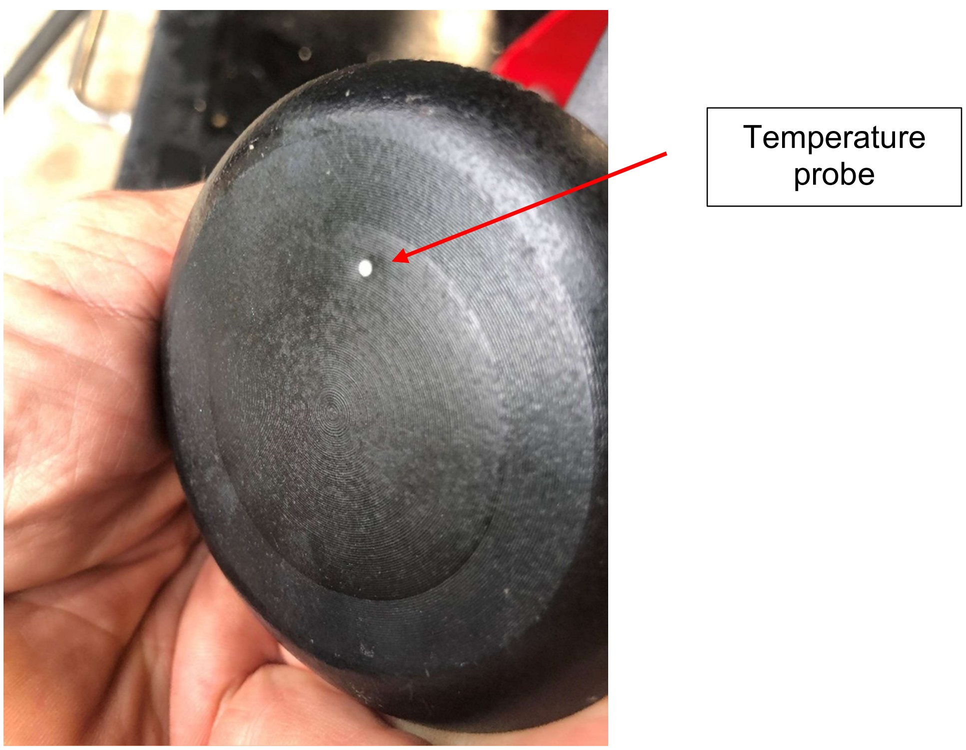



*Figure 10 - After image of ATU120BT face*

# 5. FEA ANALYSIS - CruzPro ATU120BT

## 5.1 Overview

On April 15-16, 2021, an FEA analysis was conducted of the CruzPro ATU120BT to understand the stress associated with taking the transponder to a depth of 2,000 fsw. This corresponds to a hydrostatic pressure of approximately 889 psig.

See Figure 11 for picture of an ATU120BT that has been cut along the long axis of transponder with a table saw. Note the orange areas in the figure are cork.


*Figure 11 - Cross sections of CruzPro ATU120BT*


*Figure 12 - ATU120BT depth sounder. Before potting electronics*

*Figure 13 - ATU120BT depth sounder. PCB Before potting*

A ¾ section view of the model is shown in Figure 14. The geometry used in the analysis is given inf Figure 14. As a worst-case scenario, the analysis was done with the assumption that the cork parts and the piezoelectric element and were removed. These would be parts 4, 5 and 6 in Figure 15. Cork is roughly 15% solid and the rest is air. Its density is typically about 15% that of water. Structurally it does not provide significant support.

The loading case was 889 psig distributed on the exterior of the transponder. The model was fixed at the inside face of the 3” mounting flange.

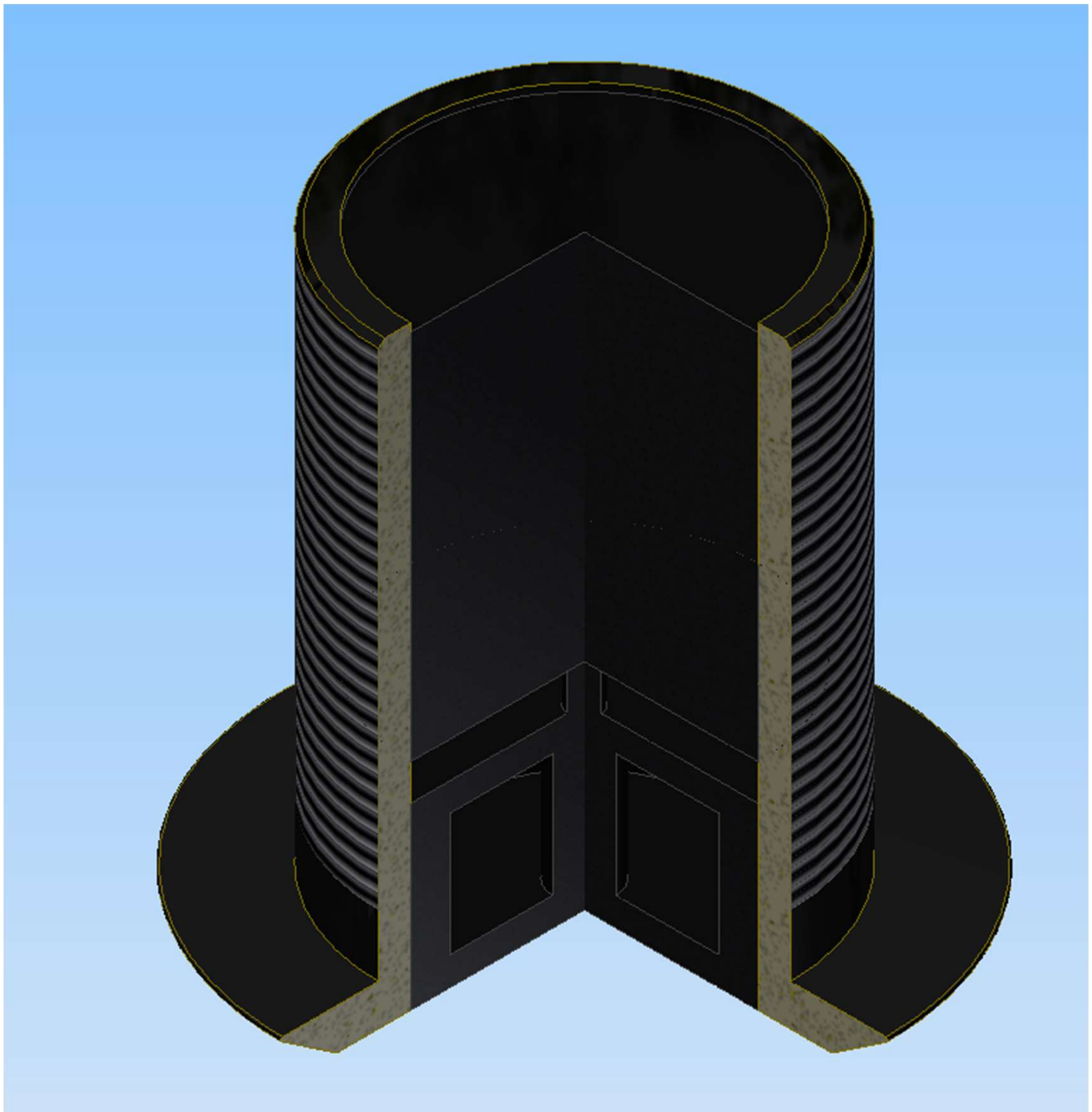
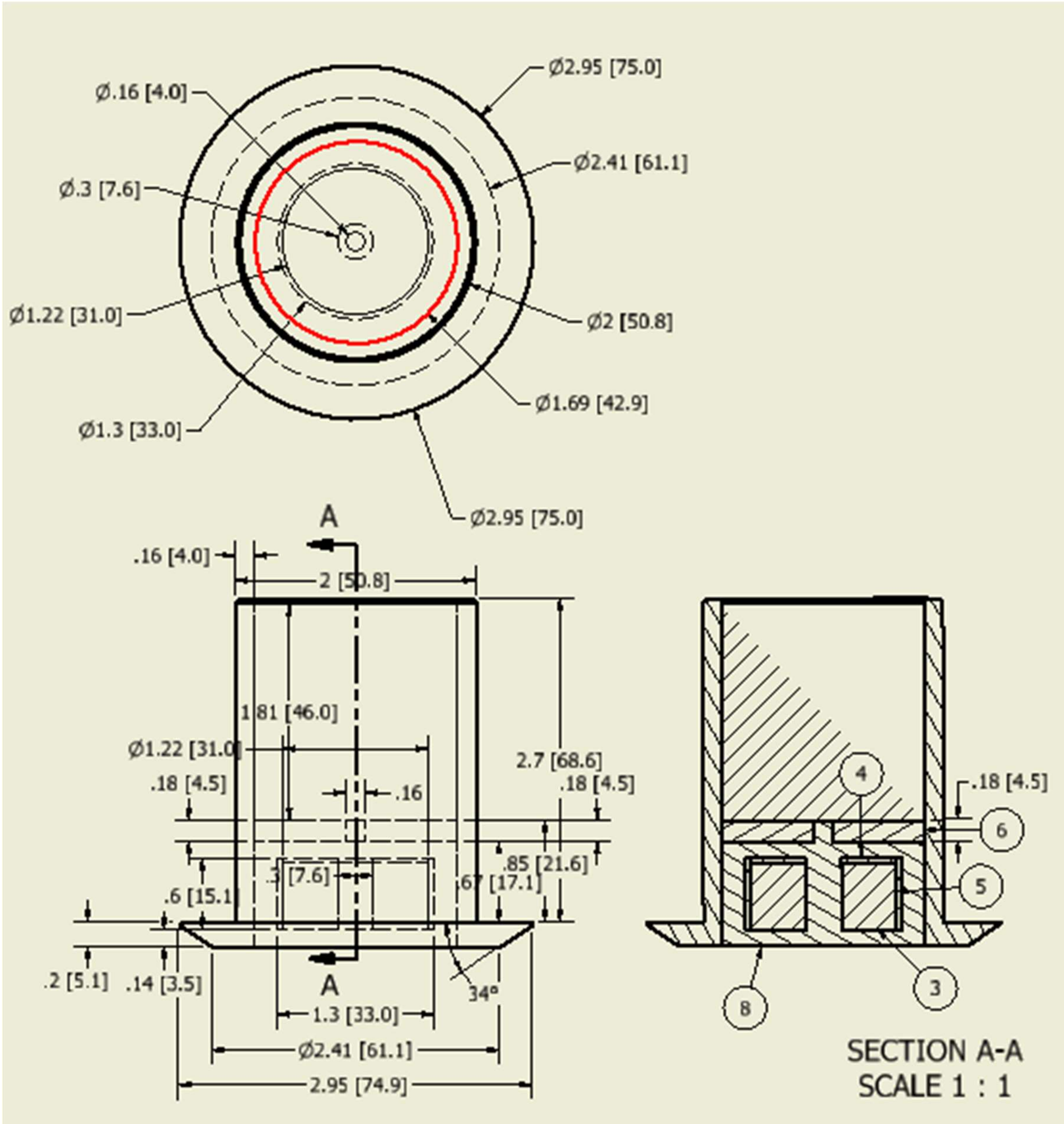


*Figure 14 - ¾ section view of the assembly (electronics omitted)*




| PARTS LIST | | | |
|---|---|---|---|
| ITEM | QTY | PART NUMBER | DESCRIPTION |
| 1 | 1 | ABT120BT-01 | Radarsonics 408 Plastic Housing |
| 3 | 1 | ABT120BT-03 | Piezoelectric element |
| 4 | 1 | ABT120BT-04 | CruzPRo120BT-Cork on top of element |
| 5 | 1 | ABT120BT-05 | CruzPro ABT120BT - Cork shell around element |
| 6 | 1 | ABT120BT-06 | CruzPro ATU120BT - Thick cork pad 5mm pad |
| 8 | 1 | ABT120BT-02A | West systems 105 Epoxy Resin, below the 5mm cork |
| 9 | 1 | ABT120BT-02B | WEst systems 105 Epoxy Resin, abovethe 5mm cork |

*Figure 15 - Geometry of CruzPro ATU120BT use for FEA analysis*

## 5.2 Discussion of Results

For the modeling study, this left two 1-atm void volumes, the first is the space occupied by the piezoelectric element and the second the 5 mm thick disk where the upper cork pad would occupy.

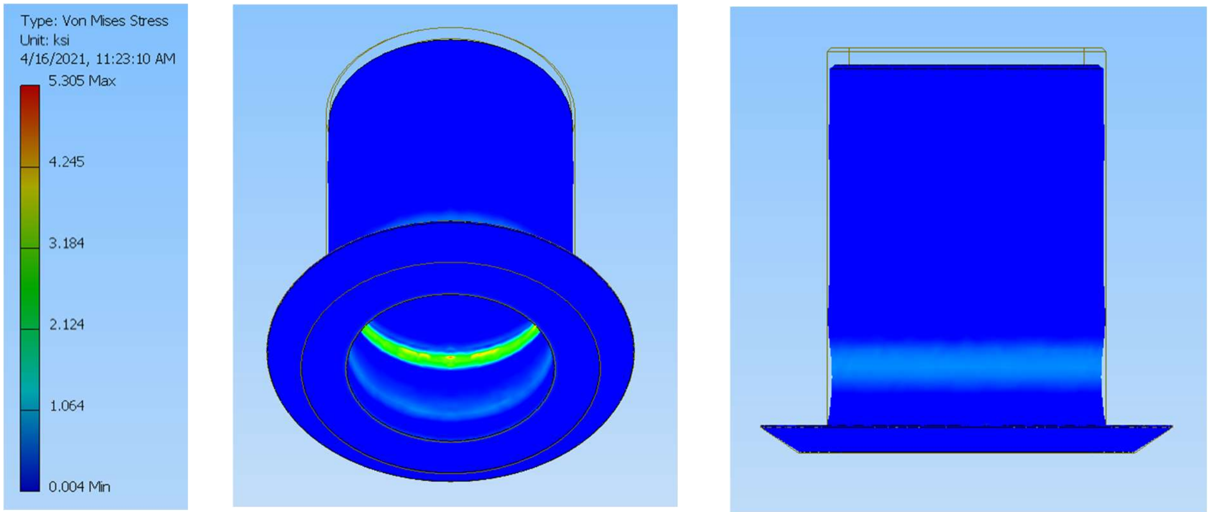



*Figure 16 - Von Mises stress of the Radarsonic 408 housing*

The primary effect on the housing was the bulging out (radial displacement) of the wall in an accordion fashion due to compression of space occupied by the 5 mm cork pad.

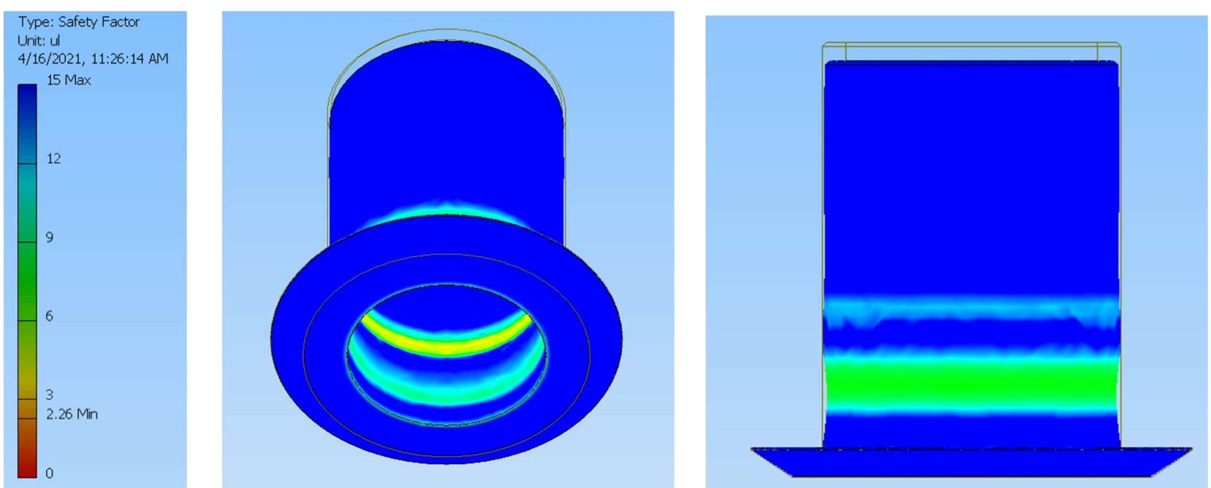



*Figure 17 - FS for the Radarsonics 408 housing*

For Nylon 6/6, the yield stress is 12,000 psi giving a minimum factor of safety (FS) of 2.26. Note that all the figures showing deflection are exaggerated to better show displacement.

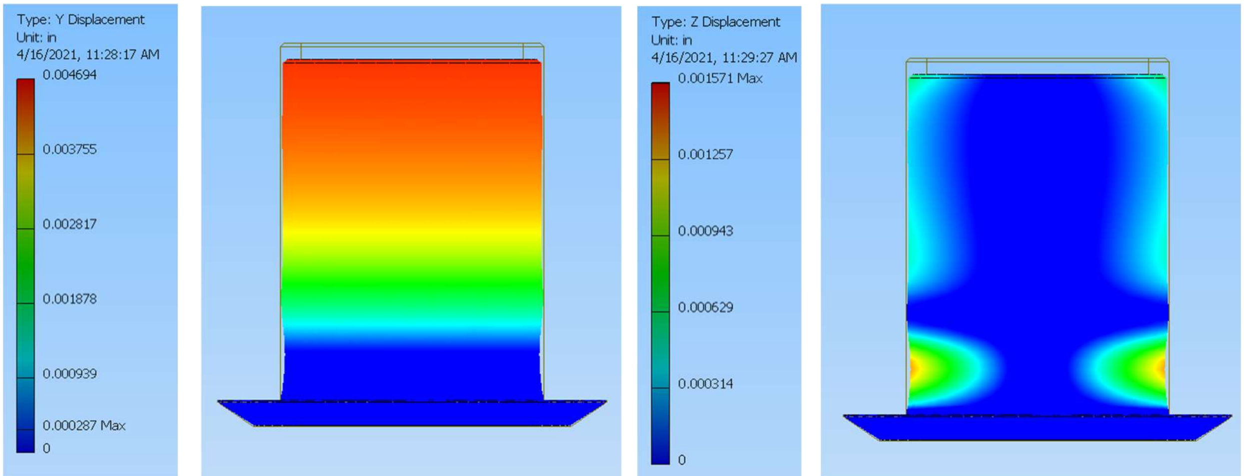



*Figure 18 –Displacement Radarsonics 408 housing*

Removing the 408 housing and showing just the epoxy resin above and below the 5mm pad enables us to look at the effect of the 889 psig hydrostatic pressure on this part of the transponder. Figure 19 shows the Von Mises stresses in the epoxy.

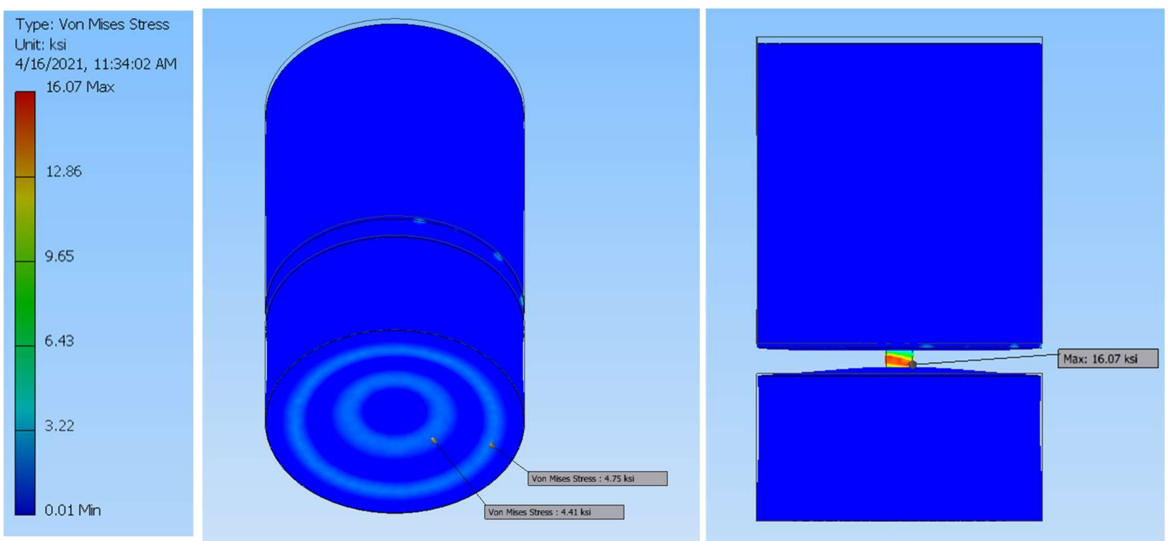



*Figure 19 - Von Mises stresses in the epoxy around the 5mm cork pad*

With the addition of the 4 mm diameter column through the 5 mm thick cork section, the displacement of the seaside face has been reduced by 42% but the column is under considerable stress to point that it has exceeded the yield stress. The maximum Von Mises stress in this column is 16.07 ksi. The seaside face of the transponder von Mises stress decreased from 8.134 ksi to 4.75 ksi due to the column. Figure 21 shows a close up of the stress in the 4 mm diameter column. Factor of safety (FS) are shown in Figure 22. Note that the lowest FS for the assembly is the 4 mm diameter column in the 5 mm thick cork pad. Figure 23 shows the displacement in the Y-axis (log axis of transponder). The maximum displacement of the sea side face of the transponder is 0.0103 in (26mm).

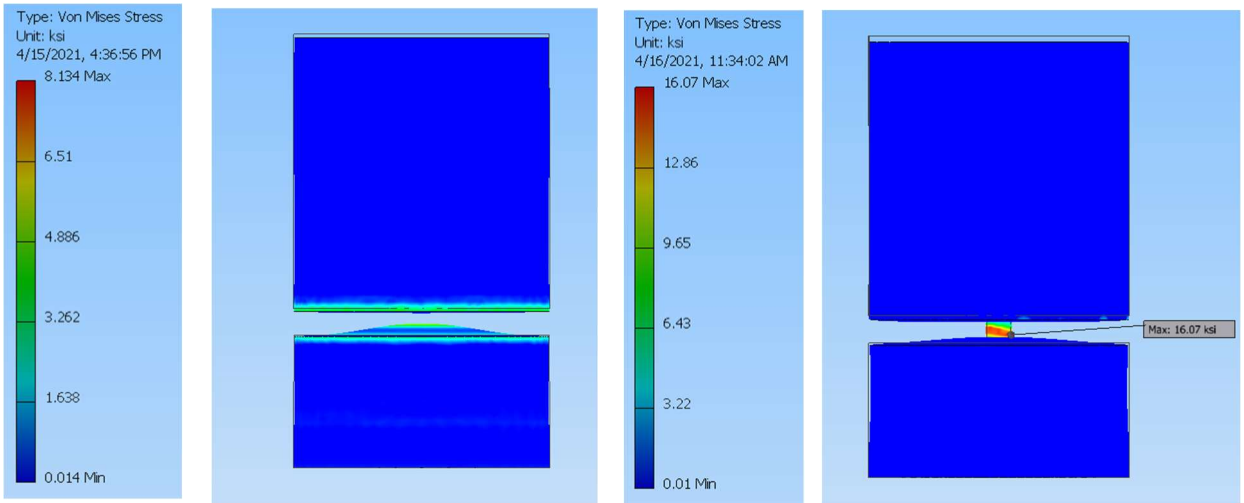



*Figure 20 - With and without epoxy column of Von Mises stresses*

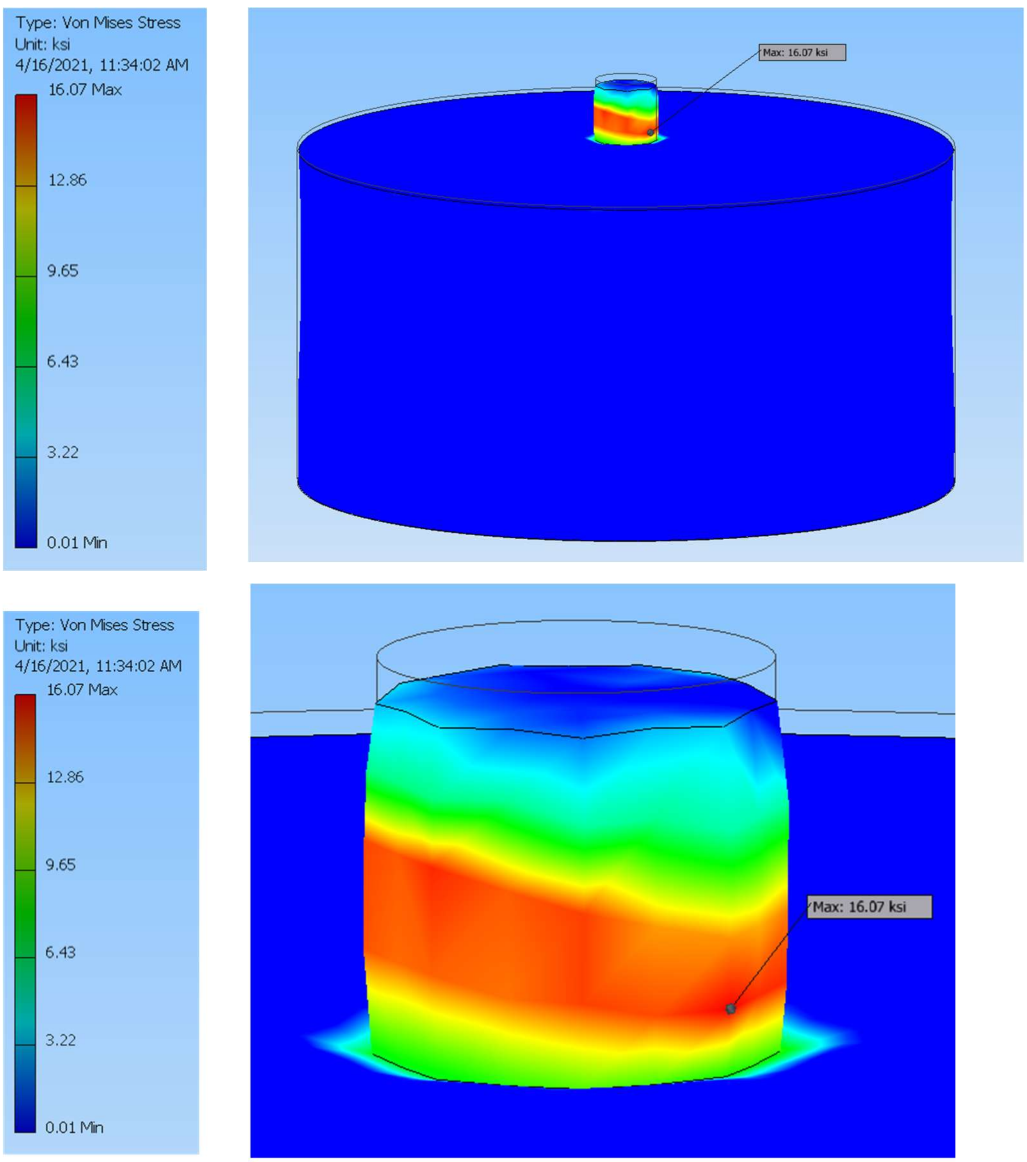



*Figure 21 - Von Mises stresses in the epoxy in the 5mm cork pad hole*

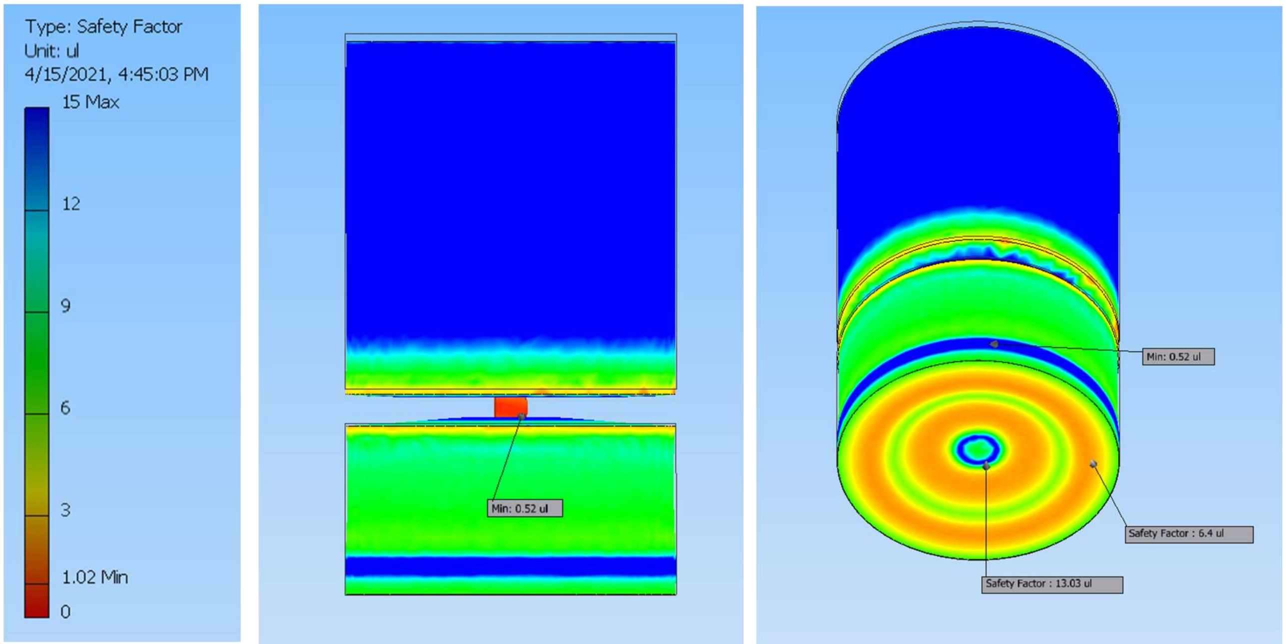



*Figure 22 - FS in the epoxy above and below the 5mm cork pad*

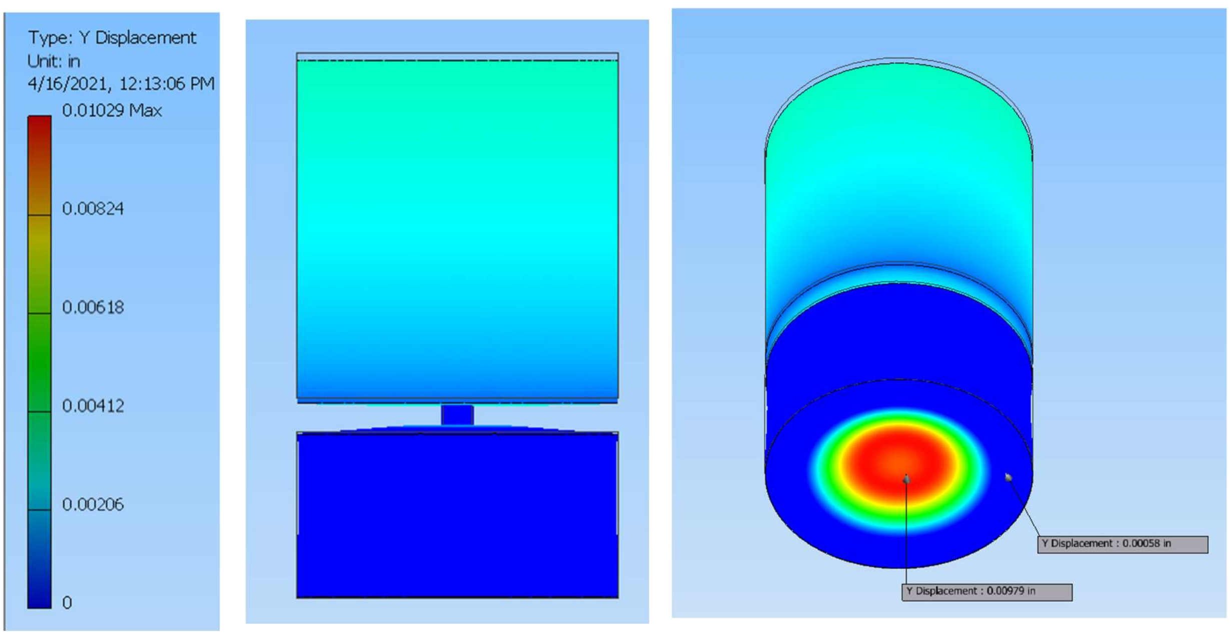



*Figure 23 - Displacement in the epoxy above and below the 5mm cork pad*

Comparing with and without the 4 mm diameter epoxy column, as seen in Figure 24, with the column, the maximum displacement of the seaside face is reduced from 0.0179 in (0.45mm) to 0.0103 in (26mm).

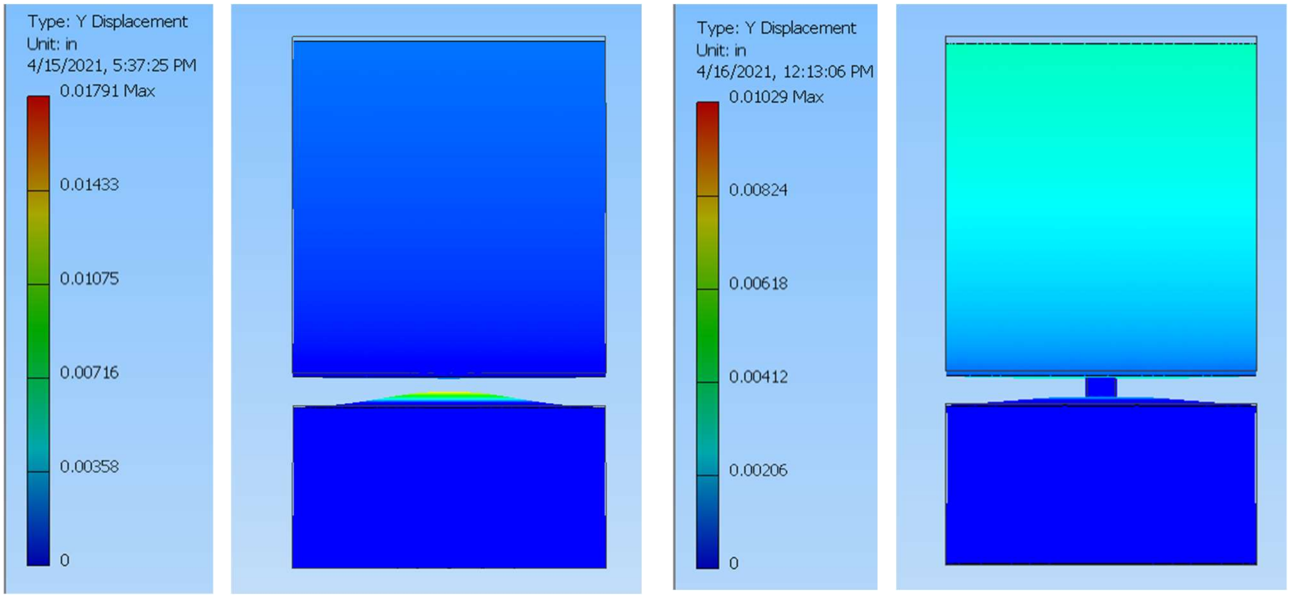



*Figure 24 - Comparing displacement with and without the 4 mm epoxy column*

## 5.3 Results Summary

*Table 3 Without 4 mm dia. cutout in 5 mm pad*

| **Name** | **Minimum** | **Maximum** |
|---|---|---|
| Von Mises Stress | 0.00347892 ksi | 8.12828 ksi |
| Displacement | 0 in | 0.0179124 in |
| Safety Factor | 1.02065 ul | 15 ul |
| X Displacement | -0.00329623 in | 0.00330254 in |
| Y Displacement | -0.00566645 in | 0.0179124 in |
| Z Displacement | -0.00329893 in | 0.00329794 in |
| Equivalent Strain | 0.0000377831 ul | 0.0157428 ul |

*Table 4 With 4 mm dia. cutout in 5 mm pad*

| **Name** | **Minimum** | **Maximum** |
|---|---|---|
| Von Mises Stress | 0.00394822 ksi | 16.0574 ksi |
| Displacement | 0 in | 0.0102964 in |
| Safety Factor | 0.516658 ul | 15 ul |
| X Displacement | -0.00229458 in | 0.00229343 in |
| Y Displacement | -0.00469419 in | 0.0102945 in |
| Z Displacement | -0.0022974 in | 0.00229831 in |
| Equivalent Strain | 0.000185888 ul | 0.0309078 ul |

## 6. POOL TEST

On 5/4/21, a pool test was conducted in which the sounder was suspended over the deep end of a swimming pool as shown in Figure 25.

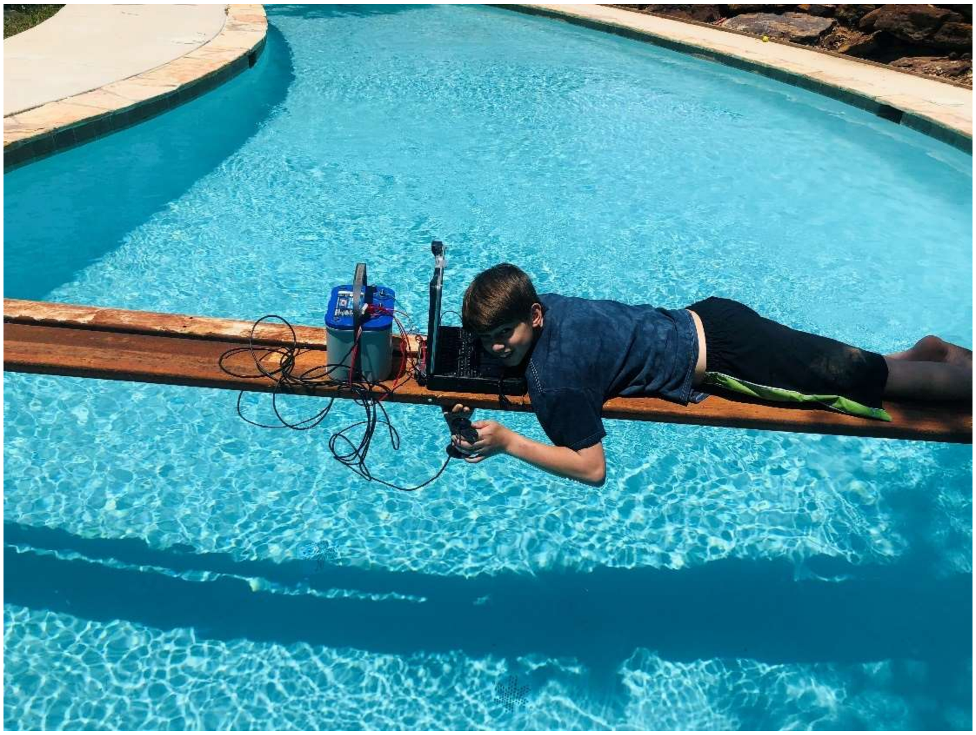


*Figure 25 - Setup for Pool Test*

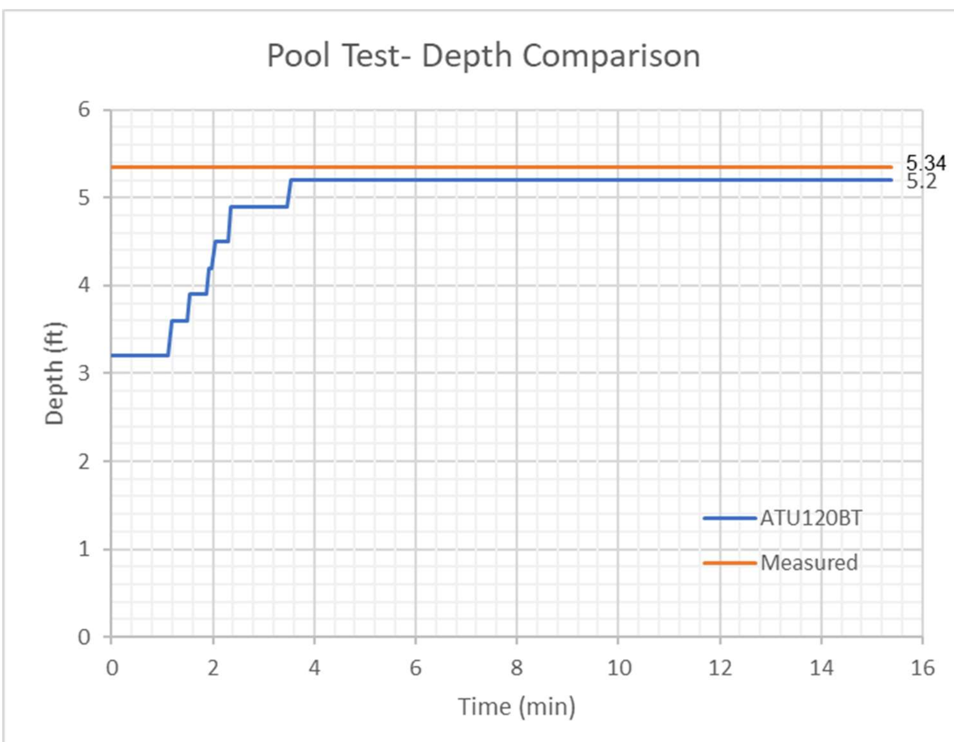



*Figure 26 - Pool Test - Depth Comparison*

Depth sounding from the ATU120BT are plotted against a tape measured depth in Figure 26 and also presented in Table 5. The first three minutes after the data logging began was getting in position in which the sounder was not in final position.

*Table 5 Pool Test – Depth Results*

| Name | Measured | ATU120BT |
|---|---|---|
| Depth (ft) | 5.2 | 5.34 |

Likewise, the temperature comparison is shown in Figure 27. The measured values were from an inexpensive floating pool thermometer.

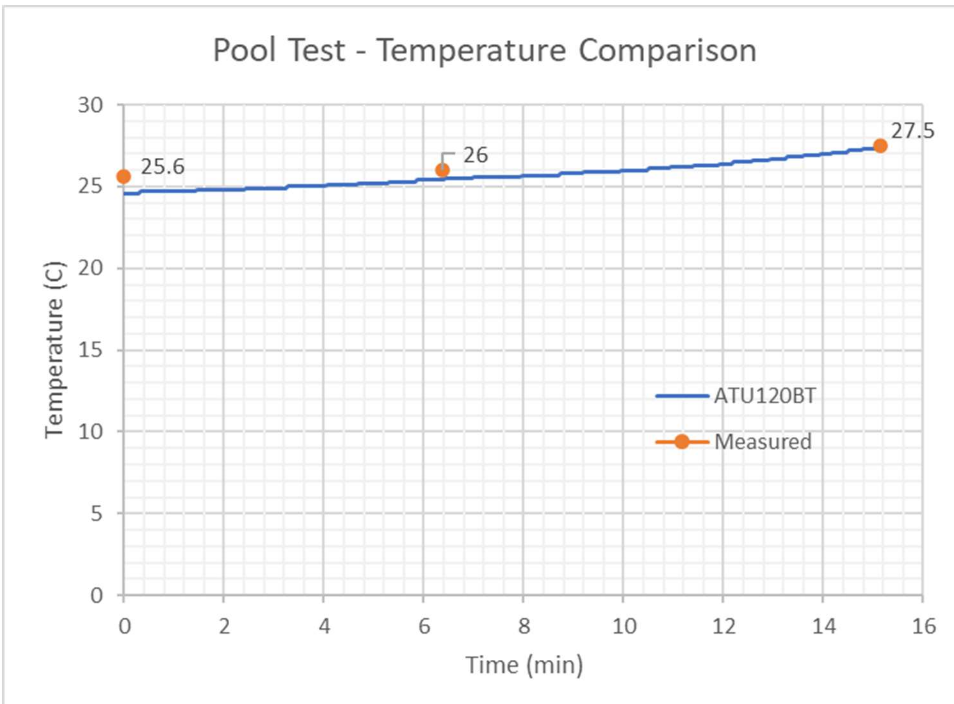



*Figure 27- Pool Test - Temperature Comparison*

The conclusion from the pool test was that based on this shallow test, the sounder seems to be behaving correctly.

# 7. FUTURE WORK

This work has confirmed the sounder will continue to output NMEA sentences when exposed to pressures associated with 1,200 fsw. What it has not been established is if the sounder readings are affected by pressure. Future work might include building a vertical test chamber, say 10 ft tall and with 6 inch schedule 40 pipe that has a blind flange on the bottom and has the sounder mounted at the top beneath a removable blind flange. The test chamber would be configured similar to that used in the current study but tall enough to enable the sounder to ping signals off the bottom. In this way the correct depth is known and the test would be to see if the results from the sounder were impacted by pressure. For this test the sounder NMEA output wires would be wired into the PLC serial port so that the test chamber data as well as the sounder data could be logged simultaneously. It is unknown if the steel pipe test chamber would cause any distortion of the sounding.

One possible solution for the separation issue around the cable would be to use RTV108 silicone sealant around the area the cable protrudes from the back of the sounder after roughing up the cable jacket as well as the top of the ATU120BT with a fine grit sand paper. IPA would be used to clean the cable and the top of the sounder prior to applying the sealant. This fix could be tested in the vertical test chamber described above.

# 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 |

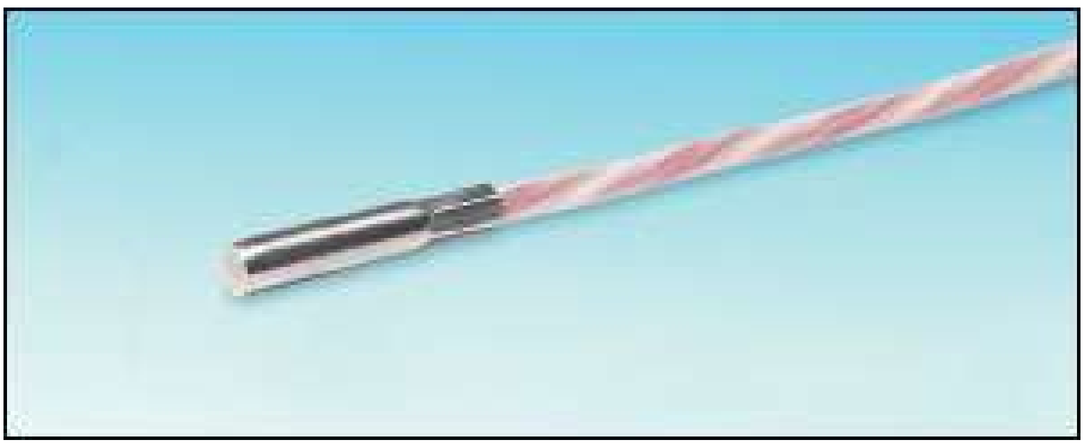
D2-04B-1 DL205 BASE 4-SLOT REQ 110/220VAC PWR W/300mA 24VDC AUX P/S

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 | 3000 PSI (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 | 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 configurations |
| 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



Path: c:\users\public\documents\directsoft6\projects\abu120bt.prj
Save Date: 05/01/21 17:38:48
Creation Date: 05/01/21 17:38:47
PLC Type: 260
Class ID: DirectLogic 205 Series

ABU120BT PROJECT TEST CHAMBER

---

Ladder logic for the Compass HousincruzPro ATU120BT Pressure Test
Date 4/29-21
CLR

---

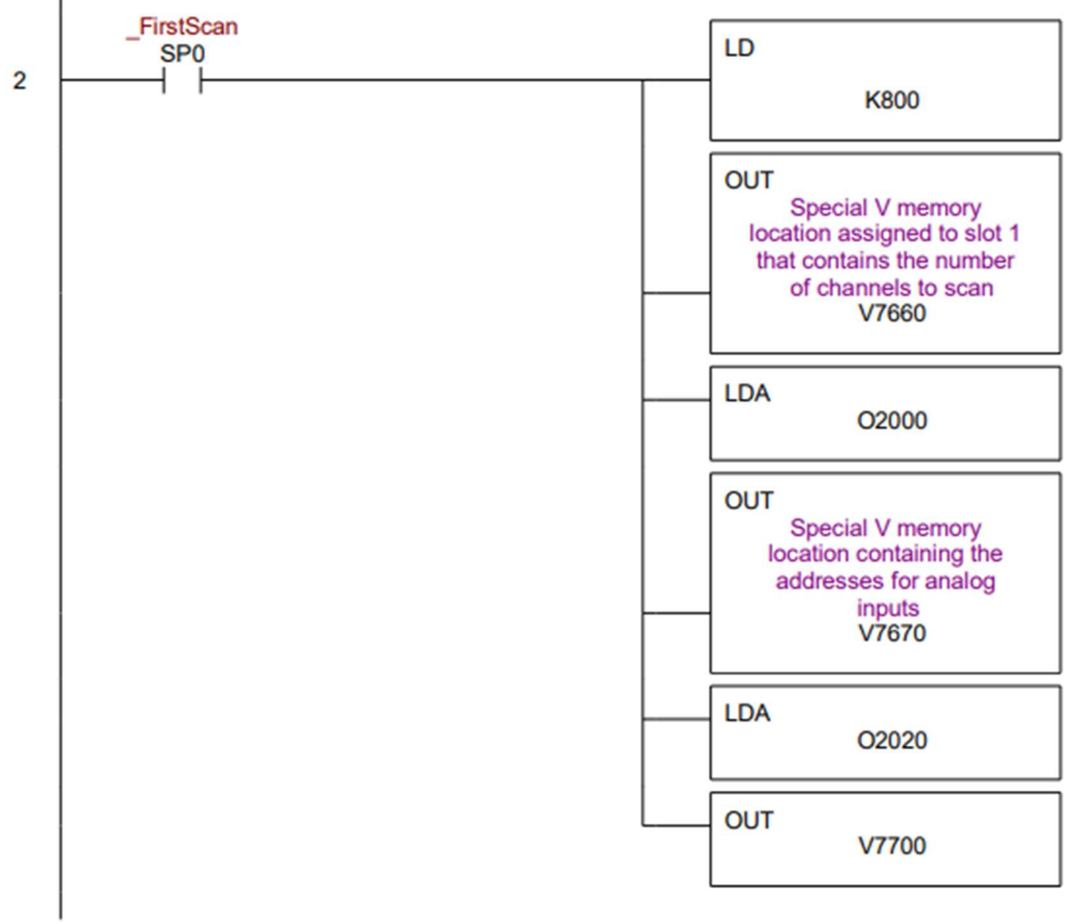
REVISION HISTORY:

1-24-21 Initial setup for HP Test
1-26-21 Added F2-08AD-2 in slot B
3-17-21 Updated code from OP test to Compass Housing Test. Will leave LP transmitter

---

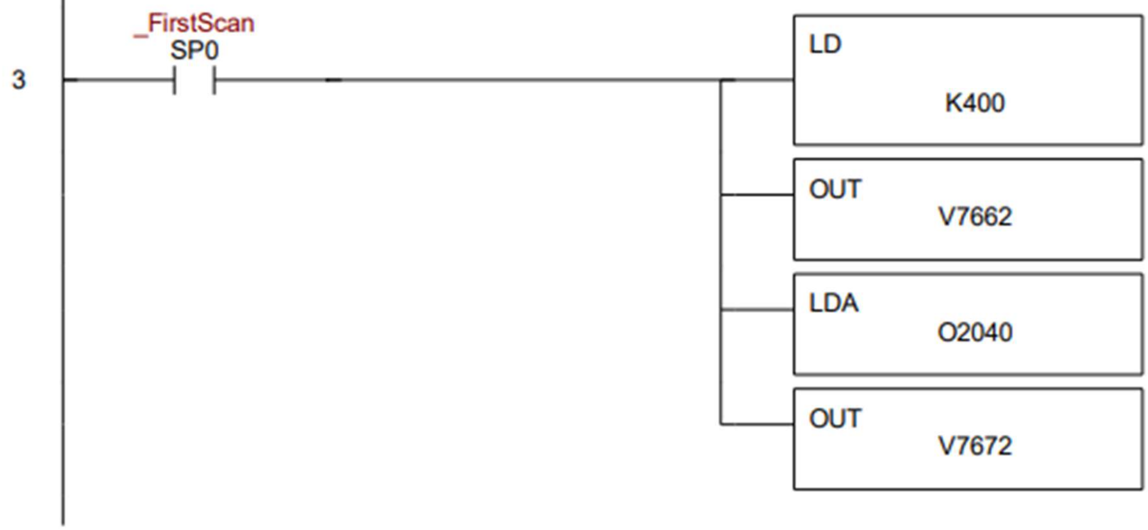
This rung specifies the number and location of V memory addresses into which the analog input signal from F2-08AD-2 module in slot 0, just to eft of CPU, will be stored. Channels are:

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



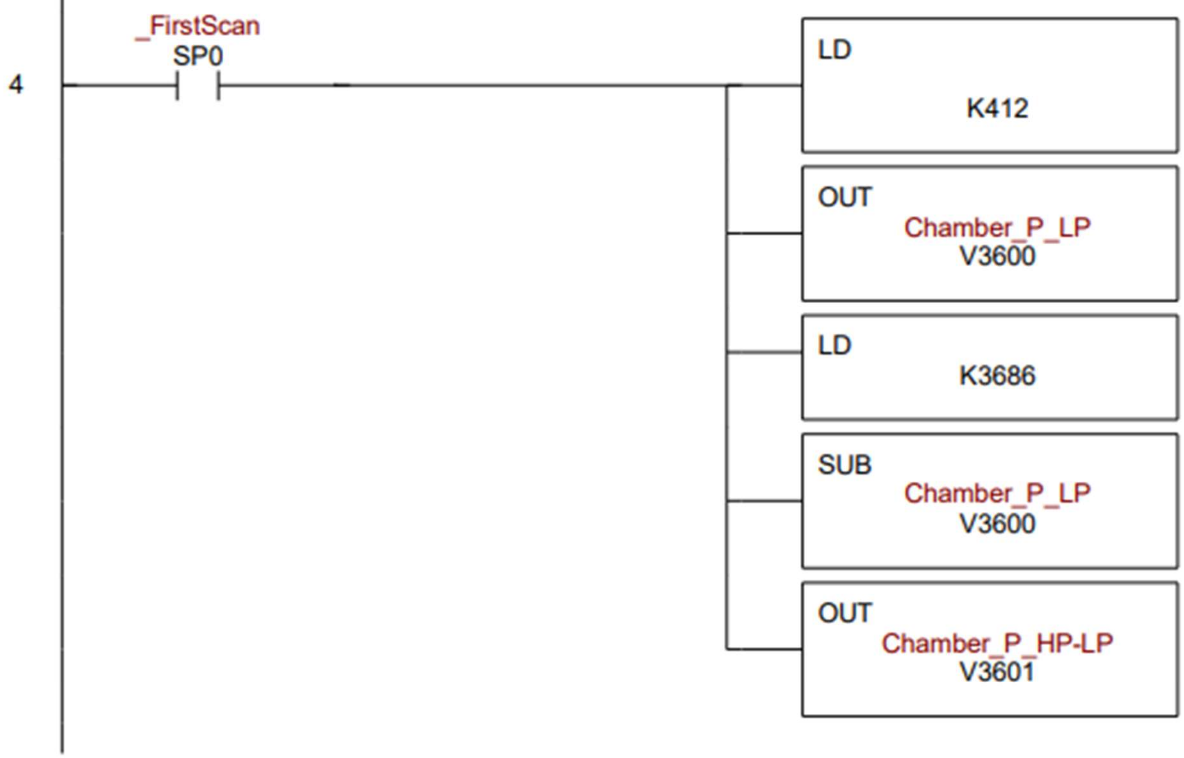
This rung specifies the number and location of V memory addresses into which the analog input signal from F2-04RTD module in slot 2 will be stored. Channels are:

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.

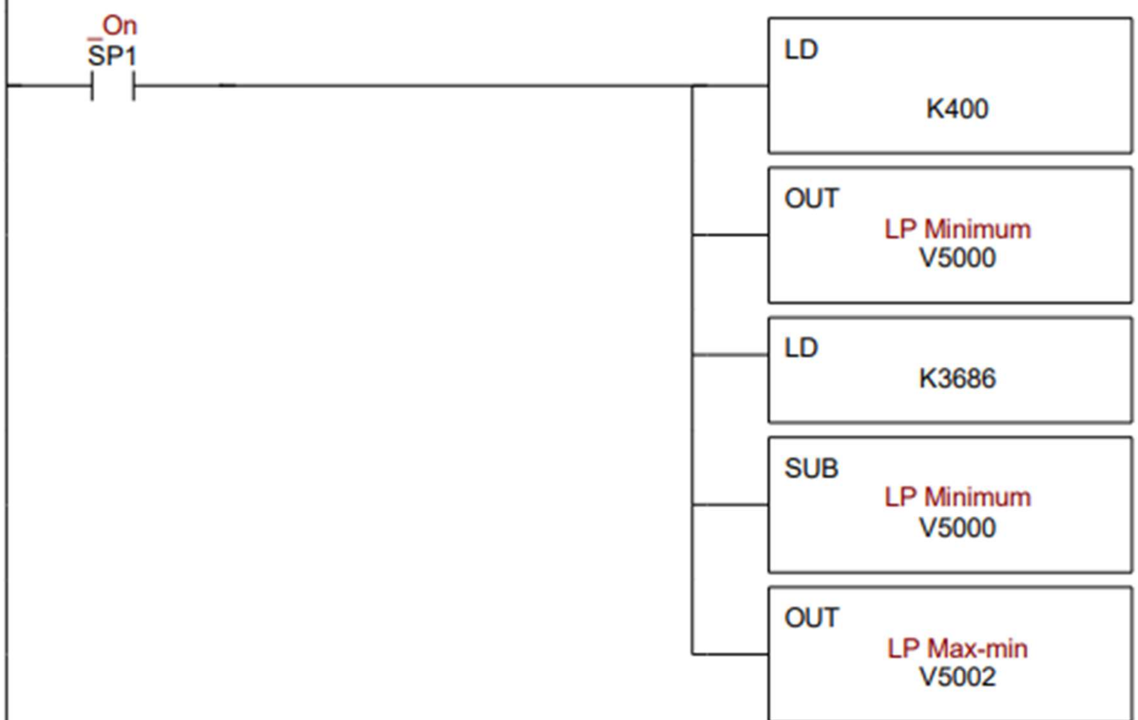
V2000 = Chamber pressure signal (0-4095)
V3600 = Pressure signal minimum value (0-4095)
V3601 = Pressure signal maximum - Pressure signal minimum (0-4095)
V3000 = Chamber pressure psig



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.

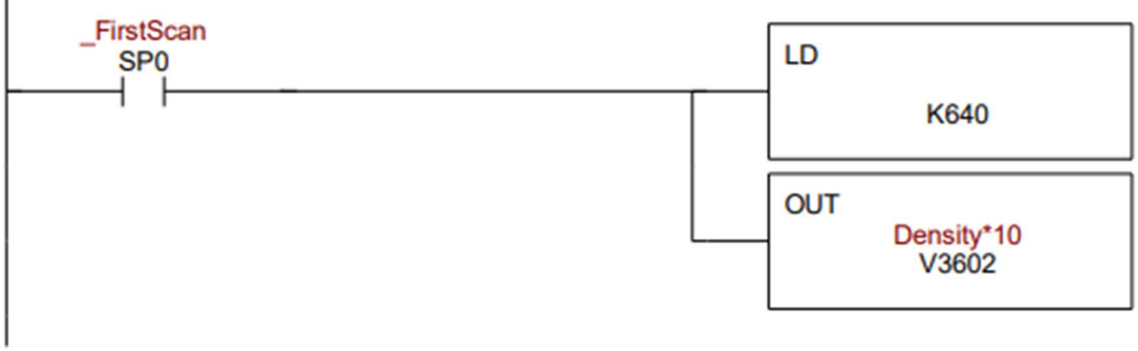
V2001 = LP Chamber pressure signal (0-4095)
V5000 = LP Pressure signal minimum value (0-4095)
V5002 = LP Pressure signal maximum - Pressure signal minimum (0-4095)
V5004 = LP Chamber pressure psig*100

5




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

6



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)*K3000/V3601

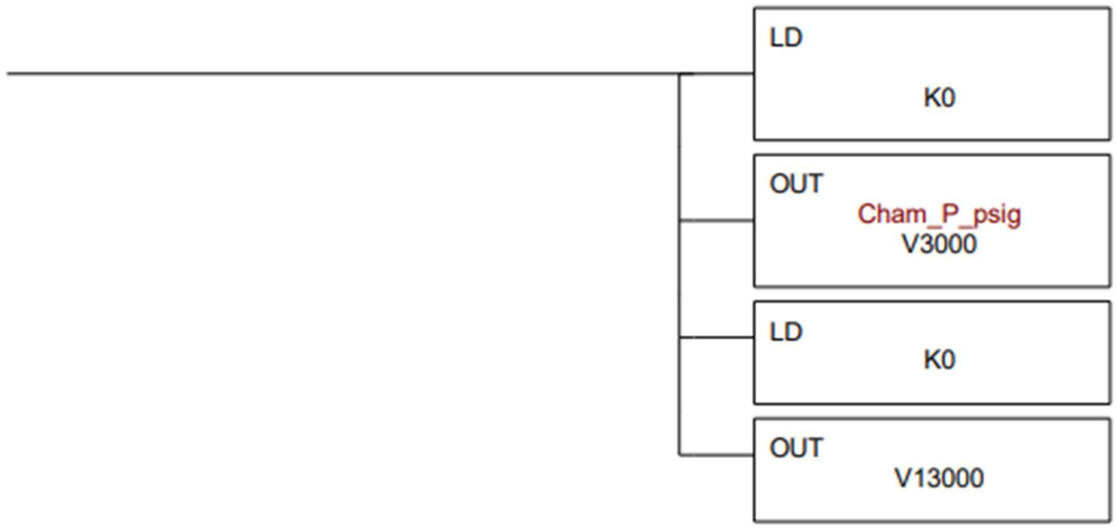
8
_On
SP1

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

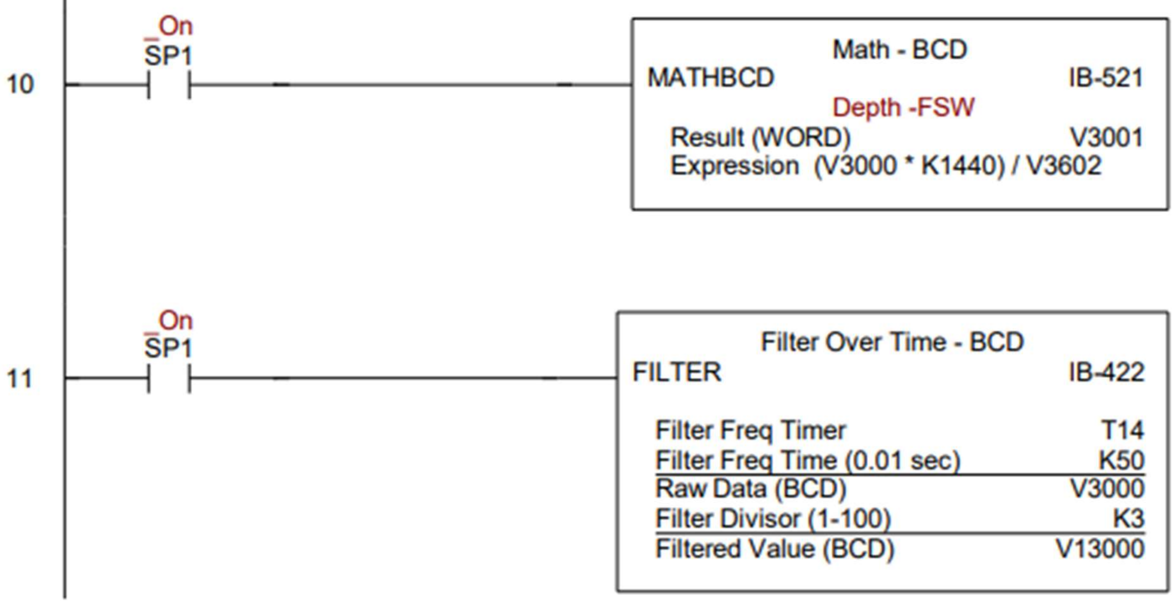
A

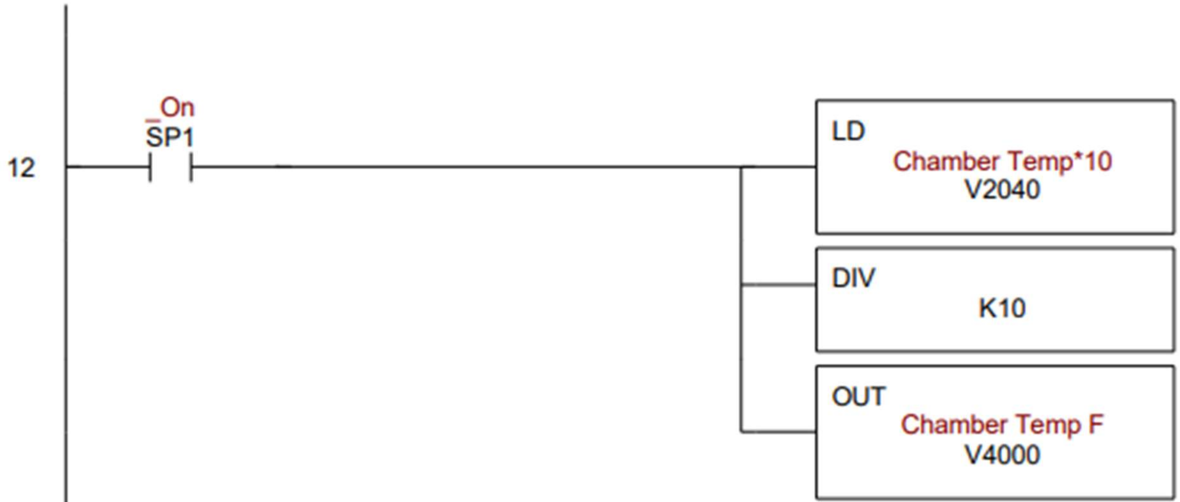



This rung calculates the equvalent water depth using the chamber pressure and the density.

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

V3001=V3000 *K14400/V3602

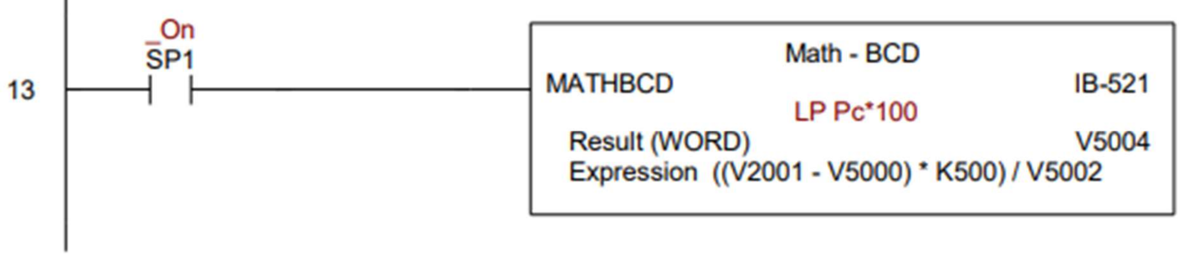


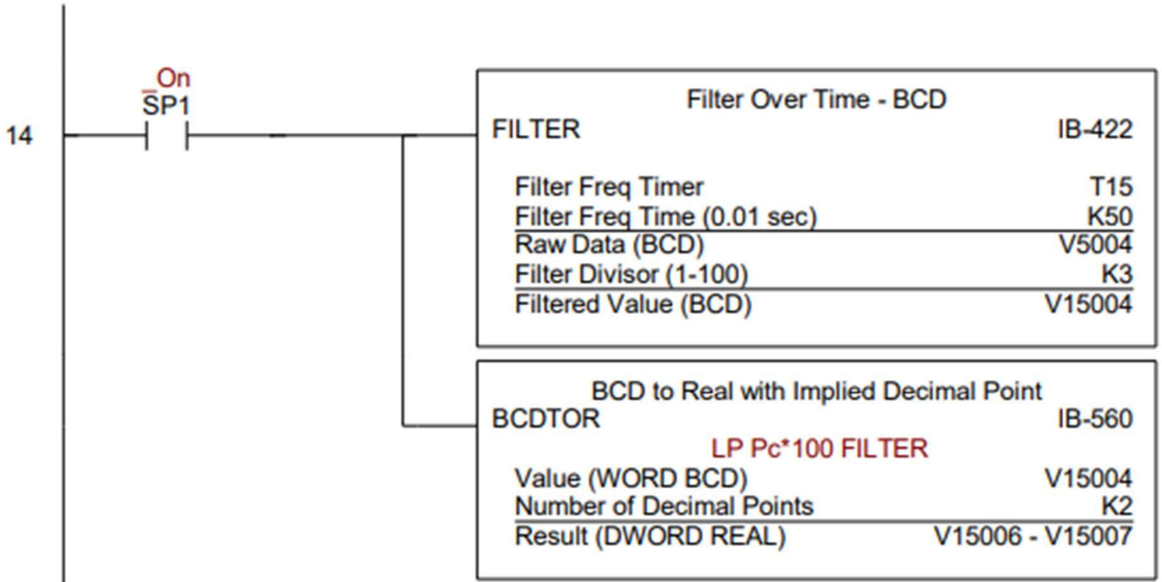



This rung converts the signal for LP chamber pressure sensor, rangeing from 0-4095, into psig*100. Sensor range is 0 to 5 psig.

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

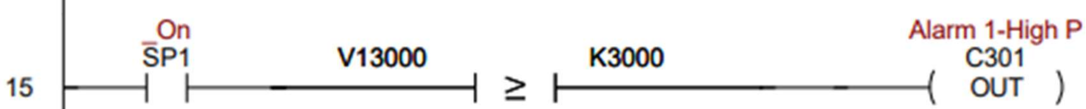
V5004=(V2002-V5000)*K500/V5002



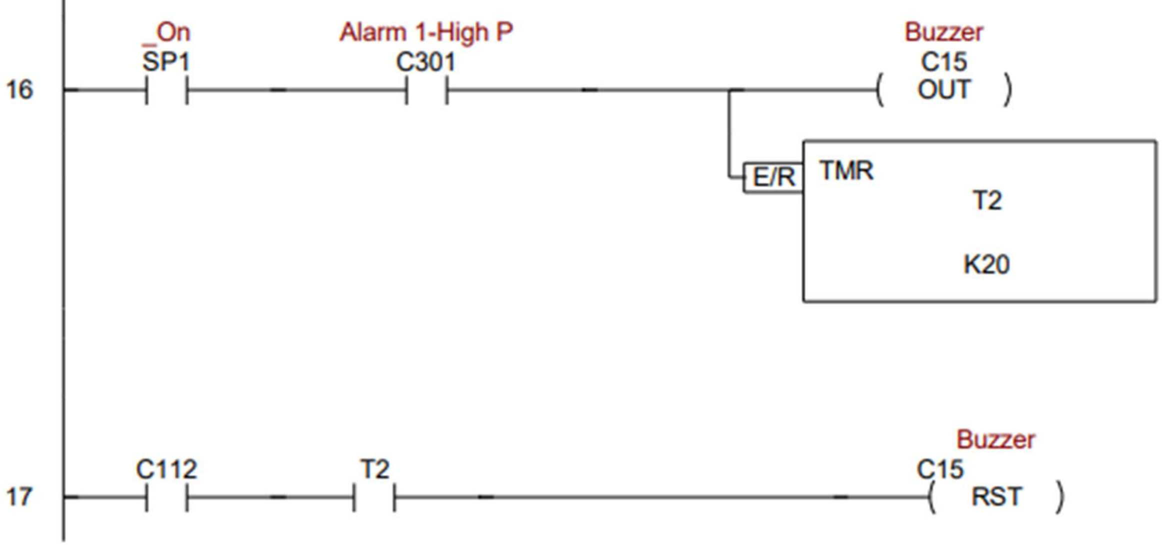



The following six rungs text for alarm conditions and set discreet flags that are used to sound an alarm buzzer.

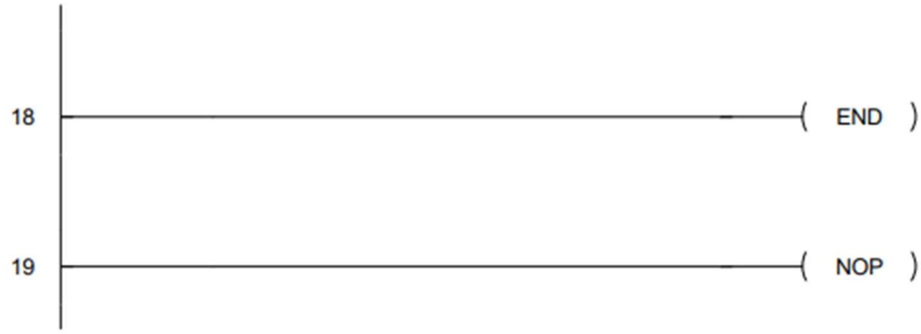
Alarm 1 - High Pressure in Test Chamber, >3000psig




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



5/1/2021 ABU120BT PROJECT 2021 260 ABU120BT

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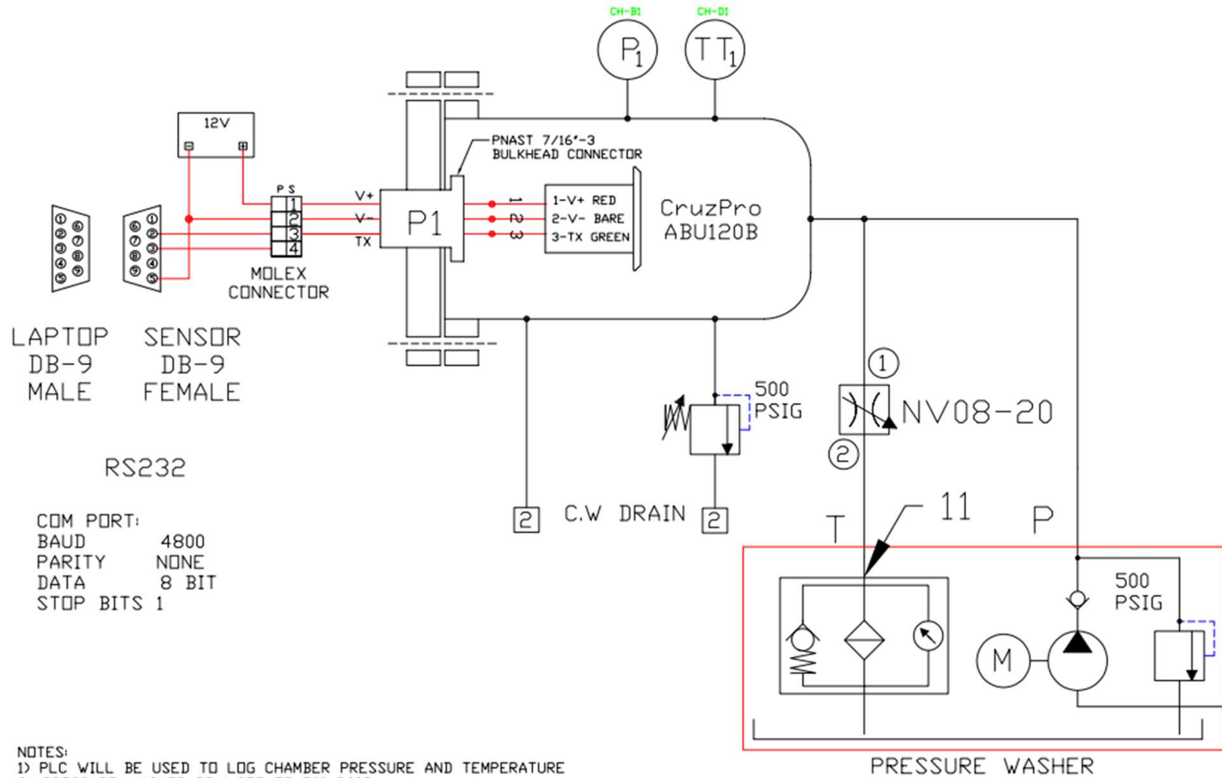
## Appendix D – Drawings

AWG 20 AS ⟨——⟩ | AWG 16 AS ⟨——⟩ | AWG 10 AS ⟨——⟩ | AWG 12 AS ⟨——⟩ | AWG 8 AS ⟨——⟩ | AWG 7 AS ⟨——⟩

| REVISIONS | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | A | INITIAL DRAWING | 4/29/21 | CLR |

CruzPro ABU120BT NEMA 0183 SENTENCES:

$SDDPT,xxx.x,*CS (Depth in Meters)
$SDDBT,xxx.x,f,xxx.x,M,xxx.x,F*CS (Depth in Fathoms, Meters & Feet)
$SDMTW,xxx.x,C*CS (Water Temperature in Deg C)




SLOT A AND B

| SLOT | CHANNEL DESCRIPTION | TAG | I/O |
|---|---|---|---|
| A | CMORE OPERATOR DISPLAY PANEL | PORT 1 | I |
| A | PROGRAMMING | PORT 2 | I |
| B | PT1 TEST CHAMBER PRESSURE (PSIG) | CH-B1 | I |
| B | CURRENTLY NOT USED | CH-B2 | I |
| B | CURRENTLY NOT USED | CH-B3 | I |
| B | VOLTAGE TO LED | CH-B4 | I |
| B | CURRENT TO LED (mA) | CH-B5 | I |
| B | CURRENTLY NOT USED | CH-B6 | I |
| B | CURRENTLY NOT USED | CH-B7 | I |
| B | CURRENTLY NOT USED | CH-B8 | I |
| B | CURRENTLY NOT USED | CH-B9 | O |
| B | CURRENTLY NOT USED | CH-B10 | O |
| B | CURRENTLY NOT USED | CH-B10 | O |
| B | CURRENTLY NOT USED | CH-B10 | O |

SLOT C

| SLOT | CHANNEL DESCRIPTION | TAG | I/O |
|---|---|---|---|
| C | CURRENTLY NOT USED | CH-C1 | I |
| C | CURRENTLY NOT USED | CH-C2 | I |
| C | CURRENTLY NOT USED | CH-C3 | I |
| C | CURRENTLY NOT USED | CH-C4 | I |
| C | S1 - COOLING WATER SOLENOID | CH-C5 | O |
| C | LED POWER RELAY | CH-C6 | O |
| C | HPU RELAY | CH-C7 | O |
| C | CURRENTLY NOT USED | CH-C8 | O |

SLOT D

| SLOT | CHANNEL DESCRIPTION | TAG | I/O |
|---|---|---|---|
| D | TT1 - CHAMBER TEMP (F) | CH-D1 | I |
| D | CURRENTLY NOT USED | CH-D2 | I |
| D | CURRENTLY NOT USED | CH-D3 | I |
| D | CURRENTLY NOT USED | CH-D4 | I |

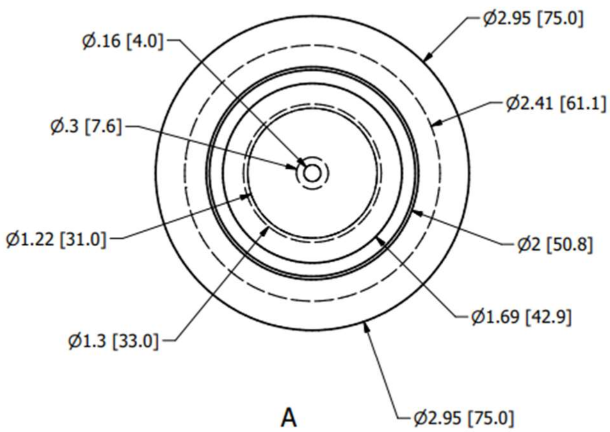
NOTES:
1) PLC WILL BE USED TO LOG CHAMBER PRESSURE AND TEMPERATURE
2) PRESSURE WASHER PRV SET TO 500 PSIG
3) A VERNIER VALVE IS USED TO ADJUST CHAMBER PRESSURE
4) THE SOUNDER IS WIRED TO LAPTOP SERIAL PORT
5) HYPERTERMINAL WILL BE USED TO MONITOR SOUNDER DURING TEST
6) SOUNDER WILL BE VISUALLY INSPECTED UP COMPLETION

REDUS ENGINEERING
612 INGRAM RD. DEVINE, TEXAS

TEST CHAMBER
CRUZPRO ABU120BT

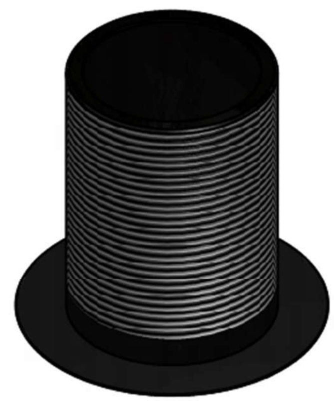
SIZE B | FSCM NO. | DWG NO. R-800-D02-009 | REV
SCALE NONE | SHEET

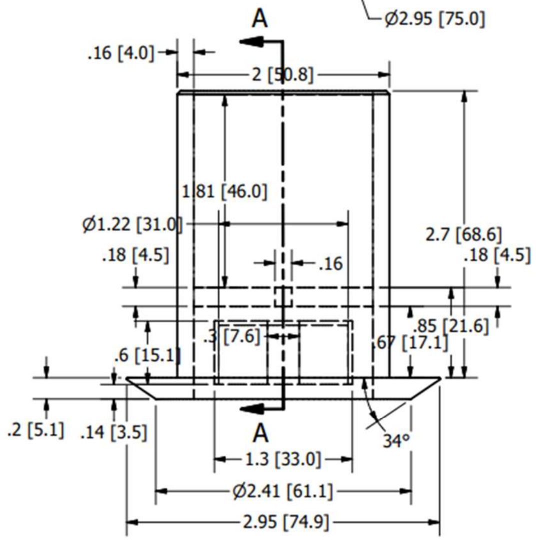
| REVISION HISTORY | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| | 1 | INITIAL | 4/15/2021 | CLR |
| | 2 | Added 4mm hole | 4/16/2021 | CLR |

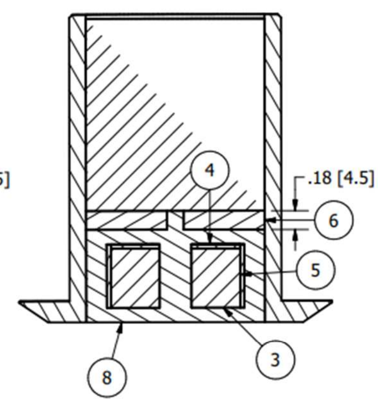



NOTES:

1) For the FEA analysis, part 1, the body of the ABU120BT was modeled as Nylon 6/6
2) The epoxy resin used was West system 105 with 209 Extra Slow Hardener
3) 4mm hole through 5mm cork pad acts like column support for epoxy above the 5mm pad






SECTION A-A
SCALE 1 : 1

| PARTS LIST | | | |
|---|---|---|---|
| ITEM | QTY | PART NUMBER | DESCRIPTION |
| 1 | 1 | ABT120BT-01 | Radarsonics 408 Plastic Housing |
| 3 | 1 | ABT120BT-03 | Piezoelectric element |
| 4 | 1 | ABT120BT-04 | CruzPRo120BT-Cork on top of element |
| 5 | 1 | ABT120BT-05 | CruzPro ABT120BT - Cork shell around element |
| 6 | 1 | ABT120BT-06 | CruzPro ATU120BT - Thick cork pad 5mm pad |
| 8 | 1 | ABT120BT-02A | West systems 105 Epoxy Resin, below the 5mm cork |
| 9 | 1 | ABT120BT-02B | WEst systems 105 Epoxy Resin, abovethe 5mm cork |

| | | |
|---|---|---|
| DRAWN CLR | 4/15/2021 | Redus Engineering |
| CHECKED CLR | 4/15/2021 | |
| QA | | TITLE |
| MFG CLR | 4/15/2021 | CrusPro ATT120BT - FEA Analysis |
| APPROVED CLR | 4/15/2021 | |
| | | SIZE B · DWG NO CruzPro ATU120BT · REV 1 |
| | | SCALE · SHEET 1 OF 1 |