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WHOI 260Hz Sound Source -
Tuning and Assembly

BY

James R. Valdes, Heather H. Furey

April 2021

TECHINCAL REPORT

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Woods Hole, Massachusetts 02543

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Amy Bower, Chair

Department of Physical Oceanography

WHOI 260Hz Sound Source – Tuning and Assembly

Furey/Valdes

Table of Contents:

Page	Contents
2	Introduction
5	(1) Test equipment and supplies
7	(2) Resonator tuning
14	(3) Evaluation of in-situ properties and resonator length
18	(4) Matlab scripts *
27	(5) Electronics test and assembly
34	(6) Pictures *
36	(7) Manual *
50	(8) Electrical Mechanical Documentation
62	(9) Acknowledgements

* These and other items may be downloaded from:

<https://www2.who.edu/site/bower-lab/rafosfloats-soundsources/>

WHOI Sound Source Testing and Fabrication Notes

Introduction:

Sound sources are designed to provide subsea tracking and re-location of RAFOS floats and other Lagrangian drifters listening at 260Hz. More recently sweeps have been added to support FishChip tracking at 262Hz. These sources must be tuned to the water properties where they are to be deployed as they have a fairly narrow bandwidth. The high-Q resonator's bandwidth is about 4Hz. This report documents the tuning, and provides an overview of the sound source assembly.

There are a number of (260Hz) sound source designs available (as of 3/24/2021).

- Teledyne Webb Research [TWR] – Reproduces updated Sound Sources based upon an earlier WHOI (WRC) design.
- URI – Pioneered the spherical transducer resonator and a dedicated (now unavailable) controller.
- WHOI – Utilized the URI style resonator with a set of electronics available from SeaScan. The mechanical design and system integration was performed at WHOI. This is the current WHOI design.
- Develogic Subsea Systems – tunable / fixed frequency source, 200 to 300 Hz.

Those who are interested in a bit of 'Float History' should read the Gould (2005) paper which describes the early float work through the present day Argos program, or a paper by Rossby (2007) which provides a similar historical overview. Another interesting paper by Richardson (2005) details some of the early Gulf Stream work which includes floats.

WHOI Sound source fabrication is comprised of three distinct phases:

1. Ordering the long lead time items in the electronics bill of materials list, and acquiring the other parts and hardware to assemble the source. Many of these parts are custom made to the drawings in the Electrical / Mechanical files.
2. Mechanical resonator - characterization and tuning of the individual magnetics used in the resonator assembly.

3. Assembly and testing of the sound source electronics, and overall integration.

Detailed examples for each step are provided in an orderly manner.

The mechanical parts for the electronics need to be fabricated to the drawing files in the Electrical / Mechanical section of the report. Note that several drawings in the Source.pdf file have been updated. Please work from the most recent drawing. In particular, note that the end caps have been modified to use jacking screws which aid in the disassembly of the pressure housing.

The initial run of sound source electronics was a two board set; a controller and a signal generator sub-assembly. In the most recent design SeaScan has integrated these two assemblies onto a single PC board. They are functionally identical, testing and mechanical differences are minimal.

There are a number of photos, these may be helpful in identifying components. These and other items may be downloaded from:
<https://www2.whoi.edu/site/bower-lab/rafosfloats-soundsources/>

***** CAUTION * CAUTION * CAUTION *****
* * * * *
* Sound Sources produce low frequency AC voltages which can *
* exceed 1000 volts. You may be injured or killed. DO NOT attempt *
* to test or tune the sound source assemblies if you DO NOT have a *
* thorough understanding of the circuitry, generation techniques, *
* and precautions necessary for personnel safety. *
* * * * *
***** CAUTION * CAUTION * CAUTION *****

And finally, this report would not be complete without acknowledging the contributions of Dr. Thomas Rossby. Tom has been the driving force behind RAFOS and Sound Sources for many years. The resonator described here was developed by Tom and URI engineer George Schwartz at URI.

References:

Gould, W.J., 2005. From swallow floats to Argo—The development of neutrally buoyant floats. *Deep Sea Research Part II: Topical Studies in Oceanography*, 52(3-4), pp.529-543. DOI: [10.1016/j.dsr2.2004.12.005](https://doi.org/10.1016/j.dsr2.2004.12.005)

Rossby, T. “Evolution of Lagrangian methods in Oceanography.” Chapter 1 in *Lagrangian Analysis and Prediction in Coastal and Ocean Processes*. Cambridge University Press. 2007

Richardson, P.L., 2005. WHOI and the Gulf Stream. Published in book: Cullen, V., 2005. *Down to the sea for science: 75 years of ocean research, education, and exploration at the Woods Hole Oceanographic Institution*. Woods Hole Oceanographic Institution. <https://webarchives.whoi.edu/75th-archive/book/whoi-richardson.pdf>

Section 1: Test Equipment and Supplies

Pic. 1 – Test Equipment (A)



Shown here are:

- Multi-channel Oscilloscope, 2 to 4 channel
- Variable power supply, 15 to 20v @ 1A minimum
- Synthesized Function Generator – Stanford Research Systems Model DS345
- LCR meter – Wayne Kerr 4234 LCR meter, not essential but useful.

Not shown – Variable power supply, 9 to 15v adjustable, hydrophone and isolated power supply (battery), miscellaneous wiring, jumpers, and connectors, transducer dummy load, resonator extension cable.

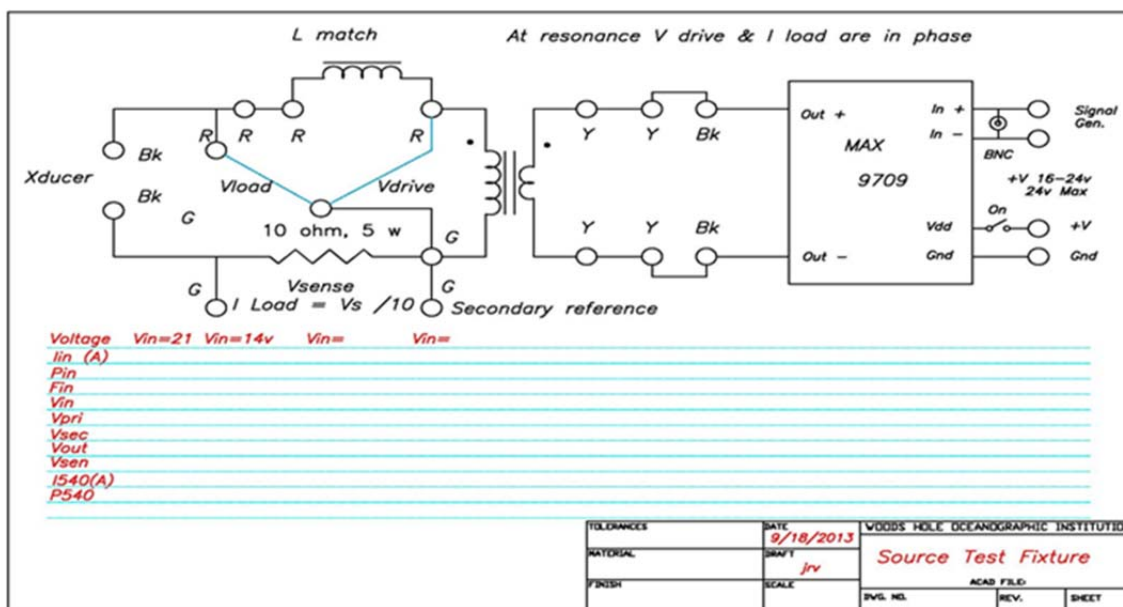
Pic. 2 – Test equipment (B)



Shown are:

1000v Digital Volt Meters and the custom Test Fixture.

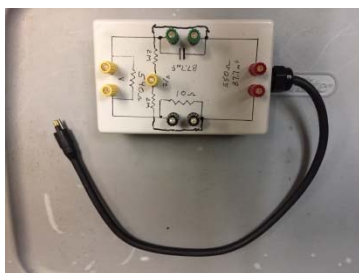
Fig.1 – Test Fixture



The fixture utilizes a Maxim – MAX9709 Evaluation kit, this is the same device used in the Sea Scan class D amplifier assembly. The 9709 is driven externally from the signal generator. The output of the amplifier is applied to the 9:1 Transformer (Gowanda 70-0750) and the 1H inductor (Pulse X-1149) to drive the resonator at terminals Bk-Bk. These are the actual components to be used for each individual Power Amplifier (PA) assembly.

USE CAUTION when working with the fixture as the excitation to the resonator can exceed 1Kv.

Pic. 3 (a, b, c) – additional test equipment



a. Dummy Load



b. YSI, Temperature / Salinity readout



c. Reson hydrophone w/interface & power supply

Section 2: Resonator Tuning

The resonator pipe should be prepared as detailed in the RESONATOR drawing. All unused holes must be PLUGGED with suitable hardware prior to tuning. The ITC-1007 should be made ready for installation as shown in Pic. 3. Keep the pins on the transducer / extension cable shorted at all times when not in use, as high voltages can be induced by the sphere.

Pic. 3 Assembled Transducer, ready for mounting in the resonator.



The transducer assembly must be spliced and made watertight with a urethane (*) potted connection. See the transducer drawing for details.

The transducer is secured in the STRUT ASSEMBLY with 3/16 inch parachute cord. It is important that the sphere not be held captive. Initially, the sphere was secured in place with small turnbuckles – I found that the resonator would not always oscillate when power was applied. The parachute cord was the initial approach taken by URI, I have found it to function reliably and to not degrade over the term of deployment. Tip: when the cord is cut, melt the end to prevent fraying.

It is assumed that the tuning will be at a facility similar to the WHOI outboard dock well in approximately 60 feet (~20m) of water. The assembled resonator with an extension cable will be lowered in the dock well to 10m; Take care: if shallower, the assembly is likely to cavitate when excited at full power.

(*) Urethane – 3M Scotchcast Kit 82-F1

Pic. 5 Resonator support rope (white right) and hydrophone cable (black left) in the dock well.



Care should be taken to minimize bubbles on the surface of the resonator prior to tuning.

- The assembly may be misted - sprayed with a dilute solution of dish soap from a spray bottle, prior to lowering into the water. (Not the most effective.)
- Soaked for a few hours (overnight) prior to tuning. (Most effective.)
- Excited at resonance prior to characterization.

Nominal Resonator Impedance:

LCR check (air) $C \sim 84\text{nF}$, $R \sim 10\ \text{ohm}$, (wet) 83nF , $13\ \text{ohm}$ [initial values]

Sweep the transducer with the LCR meter to determine the resonate frequency ($X=0$). Note the Frequency and the (X) and (R) terms. [Note Freq vs R, i.e., 247.5Hz $555\ \text{ohm}$]

Lower the hydrophone in the dock well to 10m, about 2m from the suspended resonator.

Ready the resonator test fixture for the initial excitation (see Sect.1, Fig.1, Pic 2), set the signal generator at the {determined} frequency with low drive to minimize output power. Connect the resonator and observe the power supply current and the resonator output on the scope. Adjust the drive to limit the current to .5A or less, sweep the generator and note the frequency at which the 'sound in the water' is at a maximum. Sweep the generator to maximize the observed sound pressure level (SPL). The frequency will likely change as the temperature of the resonator reaches equilibrium with the water, and the coupling with the water improves as the bubbles are reduced due to the excitation. When stable, briefly increase the power until the drive current reaches .9A. Cycle the drive on & off a few times to confirm the reliability of the transducer at power. Observe the sound in the water with the hydrophone and scope.

NOTE – This is the most likely scenario for a transducer failure, be ready to quickly remove drive should a failure be observed.

Allow several hours' time [overnight is best] for the resonator to stabilize. In the morning again, check the X & R terms with the LCR meter. R should be ~500 – 600 ohms. The source is tuned in a 'broadband' mode, utilizing the fixture in Section 1, Fig.1, with no inductor and the inductor terminals shorted. Vref below is the voltage on the transformer secondary.

Following is a transcription from my notebook [Valdes, Sound Source 2013/2014, pg. 88]
Date 4/24/14, Tube #82, Xducer #334, Tube length 73.875"

Time	Freq	S	T	Vref	Notes
1155	247.9	32.92	8.3	157.4	data point was deleted, not entered into Excel
1202	248.1	32.88	8.4	157.4	
1210	248.4	32.93	8.3	157.4	
1215	248.3	32.95	8.3	157.3	
1242	248.8	33.02	8.4	157.3	

LCR 97.9nF, 590 ohm [Reference check]
97.0nF, 600 Ohm

See Section 4 for a description of the Matlab Scripts.

This data is entered into an excel file (data_file_all.xls) and processed using Matlab scripts to characterize the pipe and to determine the scale factor (SF) for the pipe. With the data stored in the Excel file run the tune_pipe_v1 Matlab script, use a 1.000 scale factor for your initial guess. See Dr. Rossby's description and instructions in Section 4.

Repeat with different scale factors until you have a (relatively) equal distribution of positive and negative numbers in the f-diff column.

Output from Matlab tune_pipe_v1 script:

```
>> tune_pipe_v1
Enter pipe #82

Enter scale factor: 1.0
ans =

scale factor = 1.0000

year mon day pipe lngh f-obs f-exp f-diff s-vel
2014 4 24 82 73.9 248.1 251.3 -3.2 1481.4
2014 4 24 82 73.9 248.4 251.2 -2.8 1481.1
2014 4 24 82 73.9 248.3 251.2 -2.9 1481.2
2014 4 24 82 73.9 248.8 251.3 -2.5 1481.6
```

Note : SF yields all negative f-diff results

```
>> tune_pipe_v1
Enter pipe #82
Enter scale factor: 1.01
```

ans =

scale factor = 1.0100

year	mon	day	pipe	lngh	f-obs	f-exp	f-diff	s-vel
2014	4	24	82	73.9	248.1	248.8	-0.7	1481.4
2014	4	24	82	73.9	248.4	248.7	-0.3	1481.1
2014	4	24	82	73.9	248.3	248.7	-0.4	1481.2
2014	4	24	82	73.9	248.8	248.8	0.0	1481.6

Note: non-even f-diff distribution with the given SF

```
>> tune_pipe_v1
Enter pipe #82
Enter scale factor: 1.02
```

ans =

scale factor = 1.0200

year	mon	day	pipe	lngh	f-obs	f-exp	f-diff	s-vel
2014	4	24	82	73.9	248.1	246.3	1.8	1481.4
2014	4	24	82	73.9	248.4	246.3	2.1	1481.1
2014	4	24	82	73.9	248.3	246.3	2.0	1481.2
2014	4	24	82	73.9	248.8	246.3	2.5	1481.6

Note: SF yields all positive f-diff values

```
>> tune_pipe_v1
Enter pipe #82
Enter scale factor: 1.015
```

ans =

scale factor = 1.0150

year	mon	day	pipe	lngh	f-obs	f-exp	f-diff	s-vel
2014	4	24	82	73.9	248.1	247.6	0.5	1481.4
2014	4	24	82	73.9	248.4	247.5	0.9	1481.1
2014	4	24	82	73.9	248.3	247.5	0.8	1481.2
2014	4	24	82	73.9	248.8	247.6	1.2	1481.6

Note: f-diff still all positive

```
>> tune_pipe_v1
Enter pipe #82
Enter scale factor: 1.012
```

ans =

scale factor = 1.0120

year	mon	day	pipe	lngh	f-obs	f-exp	f-diff	s-vel
2014	4	24	82	73.9	248.1	248.3	-0.2	1481.4
2014	4	24	82	73.9	248.4	248.3	0.1	1481.1

2014	4	24	82	73.9	248.3	248.3	0.0	1481.2
2014	4	24	82	73.9	248.8	248.3	0.5	1481.6

Note: Much better distribution

```
>> tune_pipe_v1
Enter pipe #82
Enter scale factor: 1.011
```

ans =

scale factor = 1.0110

year	mon	day	pipe	lngh	f-obs	f-exp	f-diff	s-vel
2014	4	24	82	73.9	248.1	248.5	-0.4	1481.4
2014	4	24	82	73.9	248.4	248.5	-0.1	1481.1
2014	4	24	82	73.9	248.3	248.5	-0.2	1481.2
2014	4	24	82	73.9	248.8	248.5	0.3	1481.6

>>

After reviewing the results a SF = 1.012 was chosen.

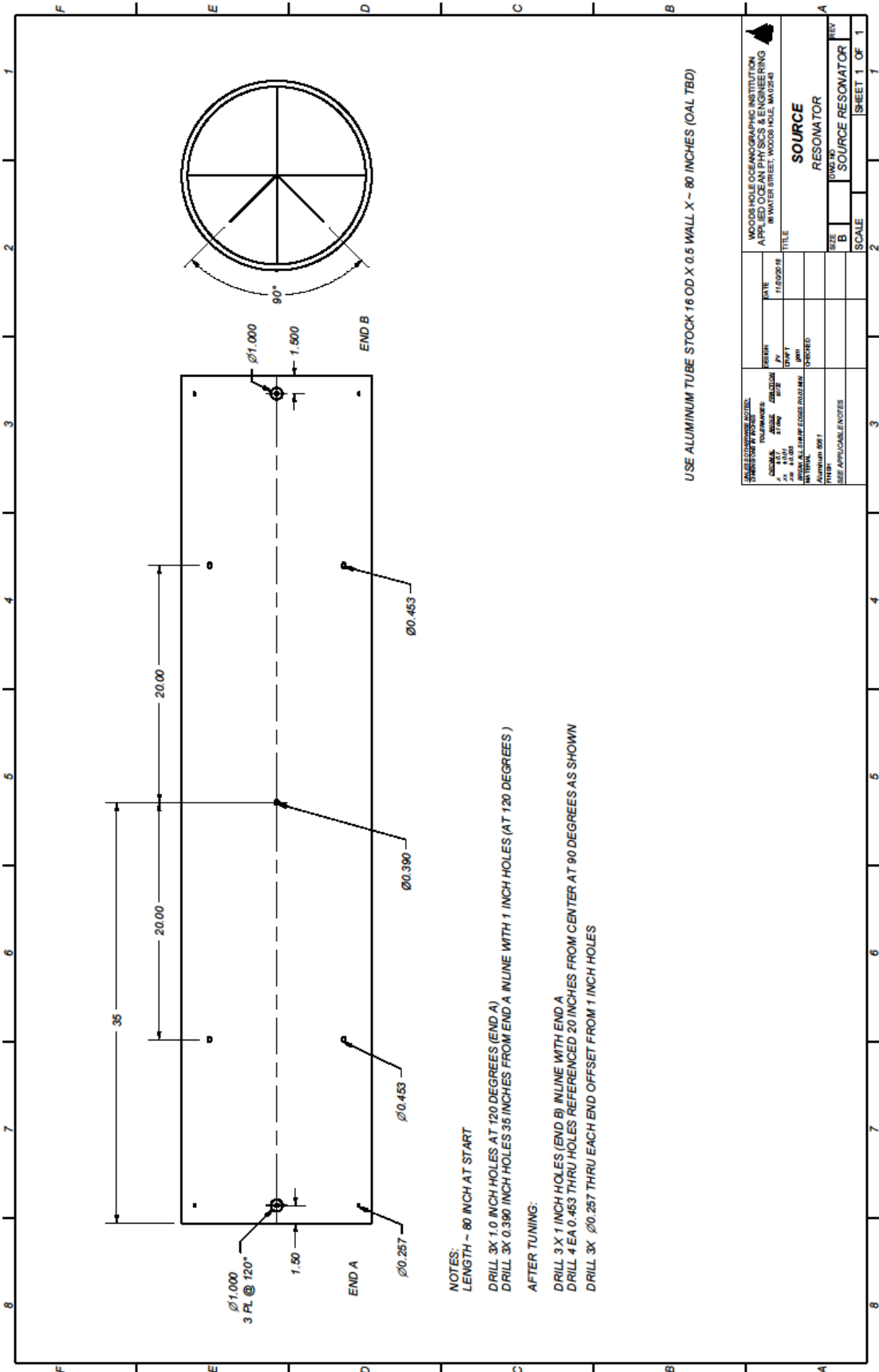
Note, I have not observed a SF less than 1 to date.

Once the tube has been characterized, it can be tuned to the specific water mass, or retuned to a different set of in-situ values.

Adding the tuning parameters under notes is helpful for future reference.

Excel – data_file_all example:

Data_file_all.xls															
Pipe #	Metal	Year	Month	Day	Length(in)	Inner dia(in)	Wall thkns	salinity(PSt)	temperatu	depth(m)	snd vel	res.(Hz)	method	where	notes
80	Al	2014	4	21	74	15	0.5	31.84	7.2	10		245.9	0	whoi	SF 1.015
80	AL	2014	4	22	74	15	0.5	32.72	7.9	10		244.9	0	whoi	34.91 3.6 1200
80	Al	2014	4	22	74	15	0.5	32.72	7.9	10		246.2	0	whoi	L 70.0
80	Al	2014	4	22	74	15	0.5	32.41	7.9	10		247.1	0	whoi	
80	Al	2014	4	22	74	15	0.5	30.05	8	10		247.3	0	whoi	
80	Al	2014	5	13	70	15	0.5	34.5	11.7	10		262.2	0	whoi	
80	Al	2014	5	13	70	15	0.5	35.96	11.8	10		261.8	0	whoi	
80	Al	2014	5	13	70	15	0.5	36.01	11.8	10		262	0	whoi	
81	Al	2014	4	22	78	15	0.5	32.36	7.7	10		234.3	0	whoi	SF 1.013
81	AL	2014	4	22	78	15	0.5	32.44	7.7	10		235.9	0	whoi	34.91 3.6 1200
81	Al	2014	4	22	78	15	0.5	32.66	7.9	10		236.1	0	whoi	L 70.2
81	Al	2014	5	6	70.2	15	0.5	34.59	10.3	10		259.2	0	whoi	
81	Al	2014	5	6	70.2	15	0.5	34.61	10.3	10		260.3	0	whoi	
81	Al	2014	5	6	70.2	15	0.5	34.6	10.3	10		260.6	0	whoi	
82	Al	2014	4	24	73.87	15	0.5	32.88	8.4	10		248.1	0	whoi	SF 1.012
82	Al	2014	4	24	73.87	15	0.5	32.93	8.3	10		248.4	0	whoi	34.91 3.6 1200
82	Al	2014	4	24	73.87	15	0.5	32.95	8.3	10		248.3	0	whoi	L 70.3
82	Al	2014	4	24	73.87	15	0.5	33.02	8.4	10		248.4	0	whoi	
82	Al	2014	5	2	70.3	15	0.5	33.2	8.8	10		264.3	0	whoi	open ...
82	Al	2014	5	2	70.3	15	0.5	33.3	8.8	10		265.1	0	whoi
82	Al	2014	5	2	70.3	15	0.5	33.34	8.9	10		265.5	0	whoi	...holes
82	Al	2014	5	2	70.3	15	0.5	33.38	8.9	10		257.4	0	whoi	plugged —
82	Al	2014	5	2	70.3	15	0.5	33.45	8.9	10		259.6	0	whoi
82	Al	2014	5	2	70.3	15	0.5	33.45	8.9	10		260.1	0	whoi Holes
83	Al	2014	4	24	74.06	15	0.5	33.28	9	10		247.3	0	whoi	SF 1.013
83	Al	2014	4	24	74.06	15	0.5	33.34	9	10		247.5	0	whoi	34.91 3.6 1200
83	Al	2014	4	24	74.06	15	0.5	33.34	9	10		248	0	whoi	L 70.2
83	Al	2014	4	24	74.06	15	0.5	33.36	9.1	10		247.9	0	whoi	
83	Al	2014	5	11	70.2	15	0.5	36.13	11.8	10		262.2	0	whoi	
83	Al	2014	5	11	70.2	15	0.5	35.8	11.8	10		262	0	whoi	
83	Al	2014	5	11	70.2	15	0.5	34.38	11.8	10		262.2	0	whoi	



USE ALUMINUM TUBE STOCK 16 OD X 0.5 WALL X ~ 80 INCHES (OAL TBD)

- NOTES:**
 LENGTH ~ 80 INCH AT START
 DRILL 3X 1.0 INCH HOLES AT 120 DEGREES (END A)
 DRILL 3X 0.390 INCH HOLES 35 INCHES FROM END A INLINE WITH 1 INCH HOLES (AT 120 DEGREES)
AFTER TUNING:
 DRILL 3 X 1 INCH HOLES (END B) INLINE WITH END A
 DRILL 4 EA 0.463 THRU HOLES REFERENCED 20 INCHES FROM CENTER AT 90 DEGREES AS SHOWN
 DRILL 3X $\phi 0.257$ THRU EACH END OFFSET FROM 1 INCH HOLES

WOODS HOLE SCIENCE CENTER APPLIED OCEAN PHYSICS & ENGINEERING 80 WATER STREET, WOODS HOLE, MA 02545		DATE: 7/26/2018 DRAWN BY: [blank] CHECKED BY: [blank] SCALE: [blank]	
PROJECT: SOURCE RESONATOR TITLE: SOURCE RESONATOR		SHEET 1 OF 1	

Section 3: Evaluation of In-Situ Properties & Resonator Length

Example file : OSNAP_SoundSource Tuning-1A.xlsx [OSNAP experiment]

Note: For Tuning purposes we are only interested in the data contained in columns C thru J in Table 1, as these describe the In-Situ water properties where the sources will be deployed. Columns K and L were added to the original spreadsheet, after reviewing and grouping the data.

From the OSNAP report, 4/30/2014.

Sound source tuning parameters – reference OSNAP_SoundSourceTuning-1A.xls

Group (ABC) sound sources by in-situ parameters (T), for SS1 evaluate effect on calculated tube length for the variations in T & S. [Example tube #82 is used for all calculations / evaluations.]

Source	Sal	Temp	Press	Length (tube #82)
1,2,3	34.870	3.500	1200	70.284
1A1	34.830	3.300	1200	70.246
1A2	34.830	3.700	1200	70.316
1A3	34.900	3.300	1200	70.258
1A4	34.900	3.700	1200	70.306
4B	34.91	3.600	1200	70.303
5B	34.91	3.700	1200	70.308
6B	34.92	3.900	1200	70.328
7C	34.93	4.200	1200	70.375
8,9B	34.90	3.700	1200	70.303
10B	34.89	6.600	1200	70.283

Other useful constants ... ~3.33 Hz/inch of tube, assume the tube trim is accurate to .1 inch.

Length (limits) = 70.284 – 70.375, Average length = 70.305

Suggests we might use the in-situ values for Source 4 and the individual Scale Factors for each tube as the basis for tuning. The evaluation summary is shown in columns K & L.

Using Tube 82 as an example, from

The raw date is entered into the excel file [data_file_all.xls]

Pipe #	Met al	Year	Month	Day	Length(in)	Inner dia(in)	Wall thkns (in)	salinity(PS U)	temper ature(° C)	depth (m)	snd vel	resonanc e(Hz)	meth od	where	
82	Al	2014	4	24	73.87	15	0.5	32.88	8.4	10		248.1	0	whoi	
82	Al	2014	4	24	73.87	15	0.5	32.93	8.3	10		248.4	0	whoi	
82	Al	2014	4	24	73.87	15	0.5	32.95	8.3	10		248.3	0	whoi	SF 1.012
82	Al	2014	4	24	73.87	15	0.5	33.02	8.4	10		248.4	0	whoi	
82	Al	2014	5	2	70.3	15	0.5	33.2	8.8	10		264.3	0	whoi	open ...
82	Al	2014	5	2	70.3	15	0.5	33.3	8.8	10		265.1	0	whoi
82	Al	2014	5	2	70.3	15	0.5	33.34	8.9	10		265.5	0	whoi	.holes plugged
82	Al	2014	5	2	70.3	15	0.5	33.38	8.9	10		257.4	0	whoi	---
82	Al	2014	5	2	70.3	15	0.5	33.45	8.9	10		259.6	0	whoi
82	Al	2014	5	2	70.3	15	0.5	33.45	8.9	10		260.1	0	whoi holes

Data in RED used for tuning. Blue lines were after trimming with mounting holes open, results were inconsistent – frequency much higher than expected. Black data is with holes plugged.

Output from tune_pipe_v1.m after adjusting the scale factor for the empirical fit.

```

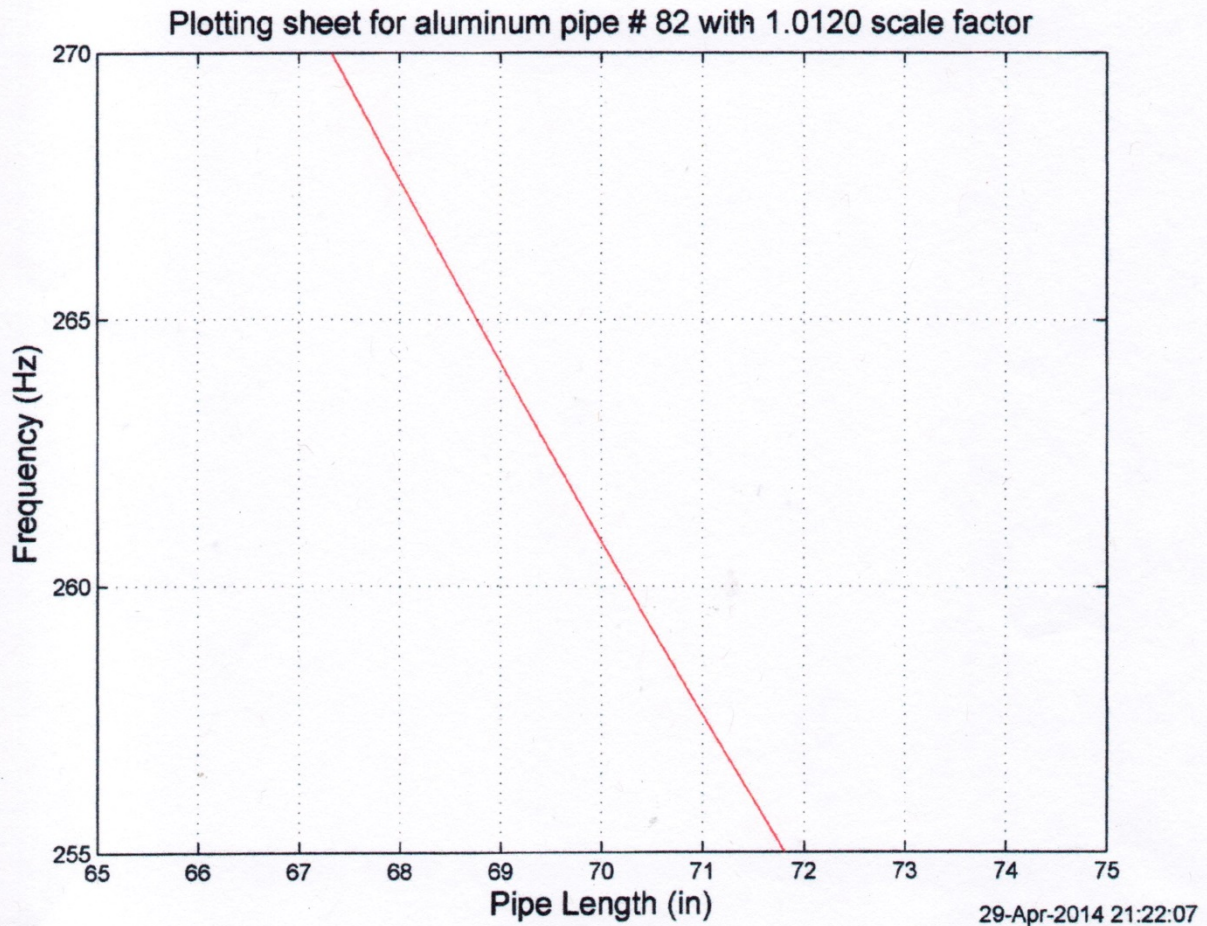
-----
>> tune_pipe_v1
Enter pipe #82
Enter scale factor: 1.012

ans = scale factor = 1.0120

year mon day pipe lngh f-obs f-exp f-diff s-vel
2014 4 24 82 73.9 248.1 248.3 -0.2 1481.4
2014 4 24 82 73.9 248.4 248.3 0.1 1481.1
2014 4 24 82 73.9 248.3 248.3 0.0 1481.2
2014 4 24 82 73.9 248.4 248.3 0.1 1481.6
-----

```

The tune_pipe_v1.m script is only used to determine the scale factor (SF) to be applied to the pipe. The actual length in-situ is determined from resonance_fcnof_length.m script, the resulting plot is used to determine the length of the pipe. Actual length from the plot at 260Hz was determined using a set of dividers to be 70.2 in.



The final OSNAP results obtained after tuning is summarized below.

All resonators are tuned to 4B parameters; S=34.91, T=3.6, P=1200.

Tube	S.F	Length	Tube	S.F	Length
80	1.015	70.0	86	1.0135	70.25
81	1.013	70.2	87	1.015	70.0
82	1.012	70.2	88	1.009	70.5
83	1.013	70.2	21	1.012	70.3
84	1.016	70.0	24	1.012	70.3
85	1.012	70.3			

Table 1: OSNAP_SoundSource Tuning-1A.xlsx

	C	D	E	F	G	H	I	J	K	L	
	Sound Source Tuning Parameters										
Sound Source #	source location		water depth (i)	sound source depth (m)	pr (dbar): mean / range		in situ properties ps (psu): mean / range		te (°C): mean / range	Group	Length typ #82
1	55	-49.5	-3634	1200	1214.5	1214.5 - 1215.1	34.87	34.83 - 34.90	3.5	A	70.284
2	57.5	-54	-3359	1200	1214.7	1214.7 - 1215.0	34.86	34.83 - 34.88	3.5	A	70.284
3	59	-47.5	-3082	1200	1214.9	1214.9 - 1215.2	34.88	34.82 - 34.93	3.5	A	70.284
4	59.7	-40.5	-2656	1200	1214.9	1214.9 - 1215.2	34.91	34.87 - 34.94	3.6	A	70.303
5	59	-34	-2633	1200	1214.9	1214.9 - 1215.2	34.91	34.89 - 34.00	3.7	A	70.308
6	58	-28.0	-2326	1200	1214.8	1214.8 - 1215.7	34.92	34.89 - 35.02	3.9	B	70.328
7	58	-23.0	-3087	1200	1214.8	1214.8 - 1215.1	34.93	34.91 - 35.01	4.2	C	70.375
8	53	-30	-3190	1200	1214.3	1214.2 - 1214.8	34.90	34.88 - 34.92	3.7	A	70.303
9	50.5	-38.5	-3959	1200	1214.0	1214.0 - 1214.2	34.90	34.84 - 34.94	3.7	A	70.303
10	52.5	-43.0	-4341	1200	1214.2	1214.2 - 1214.5	34.89	34.87 - 34.91	3.6	A	70.283
soso1 te: 3.2884 - 3.746 C			soso4 te: 3.3453 - 3.8643 C			soso7 te: 3.8318 - 5.0804 C					
soso1 sa: 34.8312 - 34.9033 psu			soso4 sa: 34.8729 - 34.9392 psu			soso7 sa: 34.9069 - 35.0107 psu					
soso1 pr: 1214.4511 - 1215.0902 dbar			soso4 pr: 1214.931 - 1215.1938 dbar			soso7 pr: 1214.7616 - 1215.094 dbar					
soso1 ss: 1483.5532 - 1485.5871 cm/s			soso4 ss: 1483.885 - 1486.1471 cm/s			soso7 ss: 1485.9806 - 1491.3182 cm/s					
soso2 te: 3.2317 - 3.6853 C			soso5 te: 3.374 - 6.3008 C**			soso8 te: 3.4957 - 4.507 C					
soso2 sa: 34.8296 - 34.882 psu			soso5 sa: 34.8583 - 34.9641 psu			soso8 sa: 34.8798 - 34.92 psu					
soso2 pr: 1214.7109 - 1214.9924 dbar			soso5 pr: 1214.8619 - 1215.1938 dbar			soso8 pr: 1214.2373 - 1214.7842 dbar					
soso2 ss: 1483.3166 - 1485.3138 cm/s			soso5 ss: 1484.0033 - 1486.8157 cm/s			soso8 ss: 1484.5332 - 1488.8133 cm/s					
soso3 te: 3.2298 - 3.8977 C			soso6 te: 3.5194 - 4.4637 C			soso9 te: 3.3609 - 4.1944 C					
soso3 sa: 34.8193 - 34.9299 psu			soso6 sa: 34.8877 - 35.0153 psu			soso9 sa: 34.8428 - 34.9394 psu					
soso3 pr: 1214.8619 - 1215.1938 dbar			soso6 pr: 1214.7616 - 1215.7379 dbar			soso9 pr: 1213.9641 - 1214.2423 dbar					
soso3 ss: 1483.3147 - 1486.2856 cm/s			soso6 ss: 1484.6355 - 1488.7329 cm/s			soso9 ss: 1483.8711 - 1487.5339 cm/s					
						soso10 te: 3.41 - 3.8973 C					
						soso10 sa: 34.8658 - 34.9112 psu					
						soso10 pr: 1214.1832 - 1214.4623 dbar					
						soso10 ss: 1484.1444 - 1486.2401 cm/s					
**bad data point, real upper limit is 4.0°C											
Added GROUP - A,B,C											
Used to evaluate the effect of in-situ properties on length of resonator.											

Table 1: In situ properties derived from historical Argo data for locations where sound sources will be moored. Tuning for each sound source is specific to the water properties at the site of deployment.

Section 4: URI Matlab Scripts (Dr. T. Rossby)

A note on the use of the pipe tuning programs,

October 10, 2005.

(minor update May 25, 2011)

(delete all earlier notes on pipe tuning)

The program **tune_pipe_v1.m** is an evolution of earlier programs. It combines the steel and aluminum versions into one, and it requires that all information be supplied in an excel -file called **data_file_all.xls**. These steps greatly simplify use and increase robustness. Above all, the use of excel to enter the data removes a number of earlier headaches reading ascii files. Use of the program **tune_pipe_v1.m** is an iterative process that might be automated at a future time, but for now I think it best to examine closely the numbers before making a decision.

The objective of **tune_pipe_v1.m** is one and one only, namely to determine how this pipe deviates from the ideal pipe of the same dimensions. These deviations can occur because of non-uniformities in pipe dimensions or properties. The program requires for this purpose tuning data, that is a determination of frequency of resonance in water of known properties. The data from each tuning are entered into the above excel file. Because each measurement has some error or uncertainty associated with it (we still need to better understand how to reduce this measurement uncertainty), it is important to determine resonance more than once, preferably three times in case the results differ.

Operation of **tune_pipe_v1.m** is very simple. After entering pipe number, you enter a first guess for the scale factor (start with 1.0 if nothing else). The program will show a table of observed and expected resonance frequencies. (I have kept the plot for historical reasons, but it serves no useful purpose now.) If the expected frequencies are too low (differences are negative), increase the scale factor somewhat (try increasing by 1% to 1.01) and rerun with the new value. When you have obtained a result where the differences scatter comparably to positive and negative values you can decide this is the best estimate for the scale factor. By doing this manually, you can inspect the results as you go along. Very importantly, you can decide to ignore outliers and focus on data that cluster tightly (kind of like choosing the median value). In summary, the key result of the first program is making a best estimate of the scale factor. It is a number close to one, but the significance lies in the third decimal. This number essentially encapsulates the particular properties of the pipe. It matters because the mechanical q-factor of the pipes that resonance must be determined for each pipe separately. But once this scale factor has been determined, it can be used to predict the frequency of resonance in situ, i.e. in waters where it is to be used. This is what the second program, **resonance_fcnof_length.m** is used for.

This program, **resonance_length.m**, is used to predict the frequency of resonance as a function of pipe length given the in-situ water properties and the previously determined scale factor. The output is a plot of resonance as a function of pipe length. When operating **resonance_fcnof_length.m** be sure to enter the numbers inside square brackets [nnn mmm] with space between entries, not commas.

The format of the excel file is self-evident, but is indicated here:

- A: pipe #
- B: material (should be Al for aluminum and Fe for steel)
- C: year
- D: month
- E: day
- F: pipe length (inches)
- G: pipe inner diameter (inches)
- H: pipe wall thickness (inches)
- I: salinity at time of this tuning (PSU)
- J: temperature at time of this tuning (°C)
- K: water depth at time of tuning (m)
- L: speed of sound (m/s); no longer needed as it is computed by program
- M: measured frequency of resonance (Hz)
- N: type of tuning (0 = voltage method expected; 1 = tuned circuit used in early days)
- O: misc info such as location or state of tide

Editor Note: Some of the scripts could use a 'tidy up'; Removing links which are no longer required, etc. The resonator count has been modified to allow greater than 100.

The M file scripts are available at:

<https://www2.who.edu/site/bower-lab/rafosfloats-soundsources/>

Matlab code courtesy of Dr. Thomas Rossby

```
% tune_pipe_v1.m
%
% Estimating pipe cavity resonance frequency.
% We consider a simple pipe of:
%
% L = length [m]
% d = inside diameter [m]
% a = inside radius [m]
% t = wall thickness [m]
% E = Young's modulus [Pa]
% K = bulk modulus of fluid [Pa]
% c = speed of sound in fluid [m/s]
%
% In the model the monopole driver is 'transparent' (no physical presence).
% The scale factor can be adjusted to fit the pipe as closely as possible
% such that the plot can be read directly, i.e. given a frequency
% and speed of sound the required pipe length can be read directly.
%
% This package evolves from earlier pipe_tune code. This version estimates
% K as a function of target water properties.
% -----
clear all
mpi = 0.0254 ; % meters per inch (inches to meters).
K = 2.28e9 ; % bulk modulus of seawater - used only
% to set up plot; it is **NOT** used
% for pipe tune calculations
% -----
-
% -- read in pipe information

% -- Note that the data_file.txt columns are:
% Pipe metal YYYY MM DD pipe_length pipe_ID wall_thickness
% Sal Temp Press Svel Freq driver Comment/location

% Under driver enter 0 for voltage driver or 1 for tuned (coil) driver

[A,B] = xlsread('data_file_all.xls');

% delete top row in B (don't know how to rid it in EXCEL had header info
% now moved to bottom)
B = B(2:end,:);
Pnbr = A(:,1); Mtl = B(:,2); year = A(:,3); month = A(:,4); day = A(:,5);
pipelen = A(:,6);
ID = A(:,7); TK = A(:,8); S = A(:,9); T = A(:,10); Pr = A(:,11); svel =
A(:,12);
freq = A(:,13); Drvr = A(:,14); whre = B(:,15);

% Enter which pipe to analyse:
% specify pipe # - for consistency assumes voltage drive mode (Drvr == 0).
P = input('Enter pipe #');
J = find(Pnbr == P & Drvr == 0);

% determine properties of pipe (must be Al or Fe at present):
```

```

mtrl = Mtl(J(1));

if strcmp(mtrl,'Al')
    E = 7.0e10; % -- Young's modulus (aluminum)
    mtrl = 'aluminum';
elseif strcmp(mtrl,'Fe')
    E = 1.95e11; % -- Young's modulus (304SS)
    mtrl = 'steel';
else
    disp('check material type')
    return
end

% get radius and wall thickness:
id = ID(J); tk = TK(J);
id = unique(id(~isnan(id))); % get ID from list (need only scalar
since always the same)
tk = unique(tk(~isnan(tk))); % likewise for wall thickness
d = id*mpi; % inner diameter of pipe (units are
metric here)
a = d/2; % inner radius of pipe
t = tk*mpi; % wall thickness

% Now determine resonant frequency as a function of
% sound velocity and pipelength

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% This section is highlighted because this
% is where the scale factor is tweaked to
% minimize the difference between expected and
% measured frequency (Hz). Typically a couple
% of % less than unity. If differences > 0,
% reduce scf slightly.
% Set scf = 1 if no empirical adjustment wanted

% Enter scale factor:
scf = input('Enter scale factor: ');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% PLOT parameters are set here:
% Range of speeds of sound in m/s for plot (x-axis):
sv = sw_sspd(S(J),T(J),Pr(J));
xmin = min(sv); % min sound velocity
xmax = max(sv); % max sound velocity

sl = 1400:10:1550;
L = sl < xmin;
xmin = max(sl(L)); % have lower plot limit given sound
velocities
L = sl > xmax;
xmax = min(sl(L)); % have upper plot limit given sound
velocities

% Range of pipe lengths in inches for plot (y-axis):
ymin = min(pipelen(J)); % min pipe length

```

```

ymax = max(pipelen(J));           % max pipe length
pl = 40:5:90;
L = pl < ymin;
ymin = max(pl(L));               % have lower plot limit given pipelengths
L = pl > ymax;
ymax = min(pl(L));               % have upper plot limit given pipelengths
ystep = 2;
L = ymin:ymax ;                  % range of pipe length in inches

LE = (L/2)*mpi + 0.6*a ;         % effective length (includes end-effect)
LE = LE*scf ;

C = xmin:xmax ;
CE = C / sqrt( 1+K*d/(E*t) ) ;   % -- effective speed of sound in pipe

[Xe,Ye] = meshgrid(CE,LE) ;
F = ( 1*Xe )./( 4*Ye ) ;
[X,Y] = meshgrid(C,L) ;

% -----
% Set up plot
figure(1)
clf
orient portrait
plotdef
axes( 'Position', [ 0.15 0.4 0.75 0.5] )

% plot isopleths of resonant frequencies based on a mean seawater bulk
modulus:
[ cont, hc ] = contour( C, L, F, [190:1:290], 'k' ) ;
set( hc, LW, [0.01] )
hold on
[ cont, hc ] = contour( C, L, F, [200:5:300], 'k' ) ;
set( hc, LW, [2.0] )
clabel( cont, hc )
axis([xmin xmax ymin ymax])      % set plot limits

% get data lines. Allow for several entries with same pipe length.
lines = pipelen(J);
nlines = length(lines) ;
colors = 'brcmk' ;                % colors for different pipe lengths

for j = 1:nlines
    k = J(j);
    len = pipelen(k);
    sv = sw_sspd(S(k),T(k),Pr(k)); % speed of sound for this case (m/s)
    plot( [ xmin xmax ], [ len len ], colors(rem(j,5)+1) ) ;
    plot( sv, len, 'w.', MS, [48] ) ;

    bm = sw_seck(S(k),T(k),Pr(k))*1e5; % bulk modulus for this case (Pa)
    Fres(j) = (sv/(sqrt(1 + bm*d/(E*t))))/((len/2*mpi + 0.6*a)*scf)/4;
    df(j) = freq(k) - Fres(j);

    index = min(find( lines == len ));
    plot( sv, len, sprintf( '%so', colors(rem(index,5)+1) ), MS, [16] ) ;
    text( sv, len, sprintf( '%2d\n%5.1f', Pnbr(k), freq(k) ), ...
          FS, 5, HA, 'center' )

```



```

        str(j,1:66) = sprintf(' %2d   %2d   %2d   %2d   %4.1f   %5.1f   %5.1f
%5.1f   %5.1f', ...
        year(k), month(k), day(k), Pnbr(k), len, freq(k), Fres(j), df(j),
sv);

end
hold off

xlabel( 'Sound Velocity (m/s)', FS, [14], VA, 'top' )
ylabel( 'Pipe Length (in)',      FS, [14], VA, 'bottom' )
title(sprintf('Plotting sheet for %s pipe # %d with %5.3f scale factor',
matr1, P, scf), FS, [14] )
grid on

% -----
% Tabulate results below figure:
hdr = sprintf(' year  mon  day  pipe  lngh      f-obs    f-exp    f-diff    s-
vel');
axes( 'Position', [ 0.15 0.05 0.75 0.3] )
axis off
warning = 'PLOT FOR DISPLAY ONLY, DO NOT USE TO ESTIMATE PIPE LENGTH';
text(0.1,0.9,warning, FS, 10, HA, 'left')
text(0.0,0.8,hdr, FS, 10, HA, 'left',FN, 'monaco')
text(0.0,0.6,str, FS, 10, HA, 'left',FN, 'monaco')
sprintf('scale factor = %6.4f',scf)
disp(hdr)
disp(str)
putdate

HA = 'HorizontalAlignment' ;
VA = 'VerticalAlignment' ;
IP = 'Interpreter' ;
FS = 'FontSize' ;
MS = 'MarkerSize' ;
LW = 'LineWidth' ;
FN = 'FontName' ;

```

Matlab code courtesy of Dr. Thomas Rossby

```
% resonance_fcnof_length

% This program plots frequency of resonance for a given pipe type as a
% function of pipe length and for desired or expected water
properties.
% After entering pipe #, it will ask for water properties.
% This program will probably get appended into the pipe-tune program.

% read in excel file of pipe data.
clear all
clf

[A,B] = xlsread('data_file_all.xls');
B = B(2:end,:);
Pnbr = A(:,1); Mtl = B(:,2); year = A(:,3); month = A(:,4); day =
A(:,5); pipelen = A(:,6);
ID = A(:,7); TK = A(:,8); S = A(:,9); T = A(:,10); Pr = A(:,11); svel
= A(:,12);
freq = A(:,13); Drvr = A(:,14); whre = B(:,15);

% Enter which pipe to analyse:
% specify pipe # - for consistency assumes voltage drive mode (Drvr ==
0).
NN = input('Enter pipe # and scale factor in brackets [n1 n2]:');
P = NN(1)
scf = NN(2)
J = find(Pnbr == P & Drvr == 0);

% determine properties of pipe (must be Al or Fe at present):
mtrl = Mtl(J(1));
if strcmp(mtrl,'Al')
    E = 7.0e10; % -- Young's modulus (aluminum)
    mtrl = 'aluminum';
elseif strcmp(mtrl,'Fe')
    E = 1.95e11; % -- Young's modulus (304SS)
    mtrl = 'steel';
else
    disp('check material type')
    return
end

% get radius and wall thickness:
mpi = 0.0254; % meters per inch (inches to
meters)
id = ID(J); tk = TK(J);
id = unique(id(~isnan(id))); % get ID from list (need only
scalar since always the same)
tk = unique(tk(~isnan(tk))); % likewise for wall thickness
```

```

d = id*mpi; % inner diameter of pipe (units
are metric here)
a = d/2; % inner radius of pipe
t = tk*mpi; % wall thickness

disp('Next, enter the properties of water where the pipe will
operate')
disp('in the format [S T P]')
wtr = input('>');
S = wtr(1);
T = wtr(2);
Pr = wtr(3);
C = sw_sspd(S,T,Pr); % speed of sound in m/s for this
water
K = sw_seck(S,T,Pr)*1e5; % bulk modulus in Pa for this
water

ymin = 60; ymax = 80;
L = ymin:ymax ; % set a range of pipe lengths in
inches

LE = (L/2)*mpi + 0.6*a ; % effective length (includes end-
effect)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% The scale factor must be entered here. It is determined by
minimizing the
% scatter between observed and estimated resonance frequencies in
program
% tune_pipe_v?.m The value of scf so obtained is entered here
(eventually)
% it will be entered at the command line.

% scf = .992;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
LE = LE*scf ;

CE = C / sqrt( 1+K*d/(E*t) ) ; % -- effective speed of sound in
pipe

F = CE./(4*LE);
K
sprintf('scale factor = %6.4f',scf)

figure(2)
clf
plot(L,F,'r')
axis([65 75 255 270])
grid
xlabel( 'Pipe Length (in)','FontSize', [14])
ylabel( 'Frequency (Hz)','FontSize', [14])
title(sprintf('Plotting sheet for %s pipe # %d with %5.4f scale
factor', matrl, P, scf),'FontSize', [14] )

```

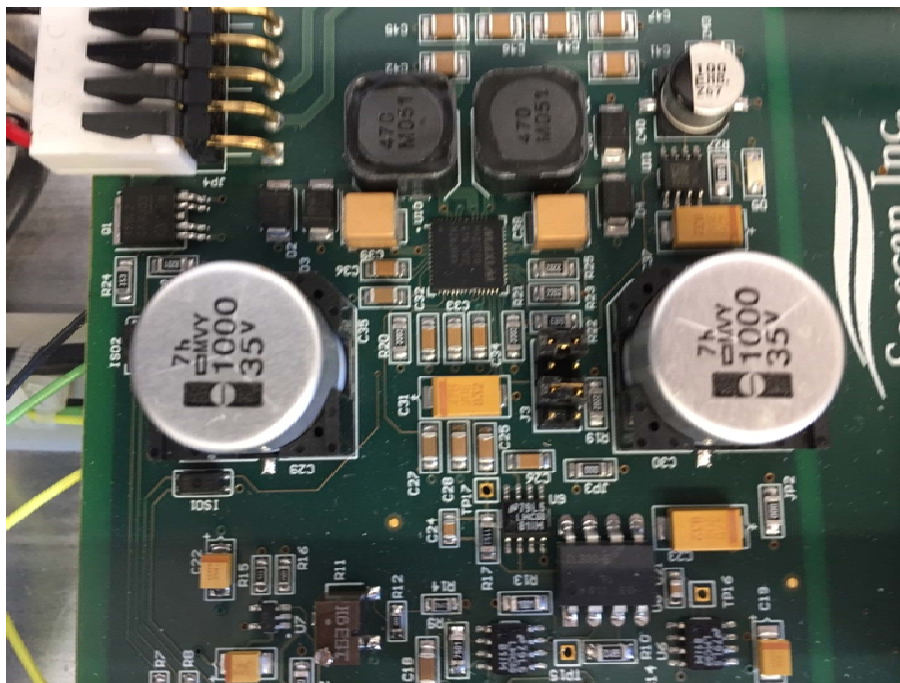
```
text(ymin+0.5,min(F)+1,sprintf('Target water properties for this plot  
are: %5.2fPSU %5.2fC %5.0fdbars',S,T,Pr))  
putdate
```

Section 5: Sound Source Electronics Test & Assembly

It is assumed that the operator has a basic understanding of the instrument and electronics. The description which follows is an overview - not a step-by-step tutorial.

Initial testing utilizes the test fixture with the internal power amplifier and the actual transformer and inductor assembled on the bench, breadboard fashion. Verify that full power can be achieved using the dummy load (Sect.1, Pic.3a) in place of the resonator (Xducer) as shown (Sect.1, Fig.1). This is the same set-up used for tuning the resonator with the addition of the 1H inductor. Again, USE CAUTION – The voltage on the output of the inductor can exceed 1000 VOLTS. If necessary the gain of the amplifier can be adjusted with the jumpers on the circuit board. They are located in a row between the two capacitors. These are generally preset by SeaScan.

The parameters of interest during testing are given on pg. 6, Fig 1 [, Source_Test].



When tuning in-water, a hydrophone placed about 20m away at 10m depth is used with an oscilloscope ('scope') to monitor the source for cavitation. The source is lowered to a depth of 10 meters and gently excited to reduce the air bubbles on the resonator tube. Given local conditions the tube may not be resonant at the desired in-situ properties. The bubbles may

also have an effect on the resonant frequency so sweeping the excitation frequency may be helpful. At this point there are two resonances; the mechanical resonance of the tube and the electrical resonance of the L/C circuit. You can check the mechanical resonance by driving the transducer in the 'Broadband' mode w/o the inductor as was done during the initial tuning. From a practical point of view, I find tuning in Woods Hole off the dock to be best in the early spring (March-May) when the local water is cold. In the cold water the resonance is close to 260Hz for the resonator. It's generally best to let the source soak at depth for a few hours to de-bubble before tuning. Always bring up power slowly - the output from the inductor can have 1000v at full output, across the cable connecting it to the resonator.

Be ready to remove the 21v supply at the first indication of a problem.

The first step is to tune the magnetics; the inductor and transducer capacitance are treated as a series tuned circuit. The inductor is a split core with .010 inch shims on each side. The number of shims is changed to increase or decrease the inductance to achieve resonance. What is resonance?

There are a number of ways to describe resonance. (Series R L C Circuit)

- * When $X_L = X_C$,
- * The frequency at which the R_s term is maximum (X_L cancels X_C),
- * The frequency at which the Voltage and Current are in phase,
- * The frequency of maximum Power Transfer (output).

Beware of 'ground loops'; I have not had a problem but you might consider using an isolation transformer with the test equipment that require AC power. Tuning is a bit subjective, it takes some time to develop a 'feel'. I'm attempting to quantify the process but it is not exact. Using the Test Fixture you can easily monitor the phase between the voltage and the current with a scope.

Scope Ch 1 – Voltage, connect a probe across the transformer secondary. (trigger here)

Ch2 – Current, connect a probe across the 10 Ohm resistor

In both cases the 'low side' of the secondary is the ground reference for the scope.

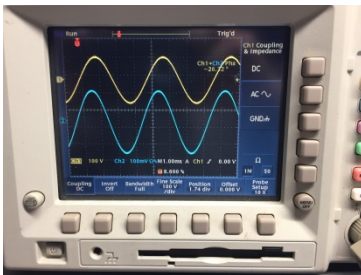
Again, gently apply excitation and observe the waveforms. I find the phase to be somewhat dynamic, it seems to vary with the power applied. Since the sweeps (RAFOS, 1.523hz, and the Fish Chip, 3 Hz) are fairly narrowband I tend to move the resonance point away from F_0 , where the phase changes. Which side doesn't matter it depends upon the available shims.

Some of us old-timers in EE may recall; “ELI the ICE” man. (From GOOGLE) ELI the ICE man is an old memory "crutch" to help one remember the A.C. current and voltage phase angle relationship in inductors and capacitors.

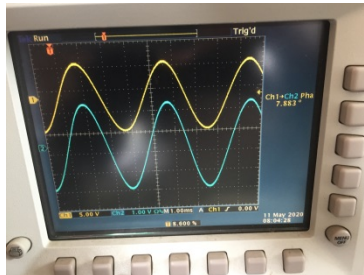
ELI tells us that the voltage (E) leads or comes before current (I) in an inductor (L).

ICE tells us the current (I) leads or comes first before voltage (E) in a capacitor (C).

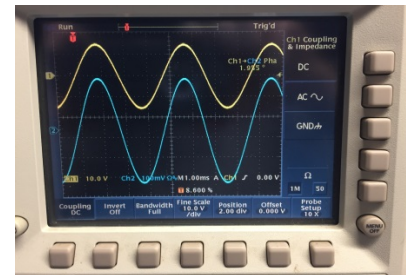
Here are a few examples for reference:



Current leading



Voltage leading



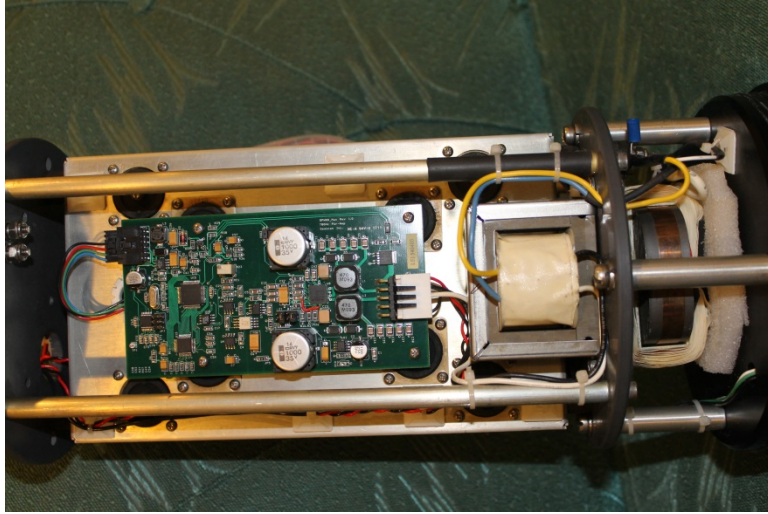
‘In Phase’, Voltage 1.9 deg leading

Adjusting the inductance is accomplished by varying the number of shims between the two half sections of the core. I generally use a band clamp to apply pressure and to keep the cores in place. Typically I grasp the cores to apply pressure when tuning. Keep in mind the working voltage and use care when handling.

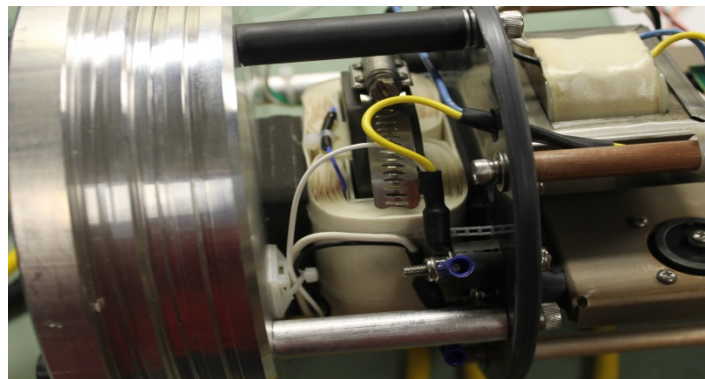
After tuning ‘serialize’ the Inductors to the resonator, as they are not interchangeable.

Electronics Mechanical assembly:

The end cap can be assembled with the external connectors and standoffs. The upper section two plates, backplane plate, and separator rods can also be assembled. Do not complete the assembly until the tuned inductors are available. Refer to the pictures folder for mounting and placement details. The electronics are mounted to the damper mounts on the plate. The transformer can now be mounted and the upper assembly wired, see the sound source interconnection diagram.



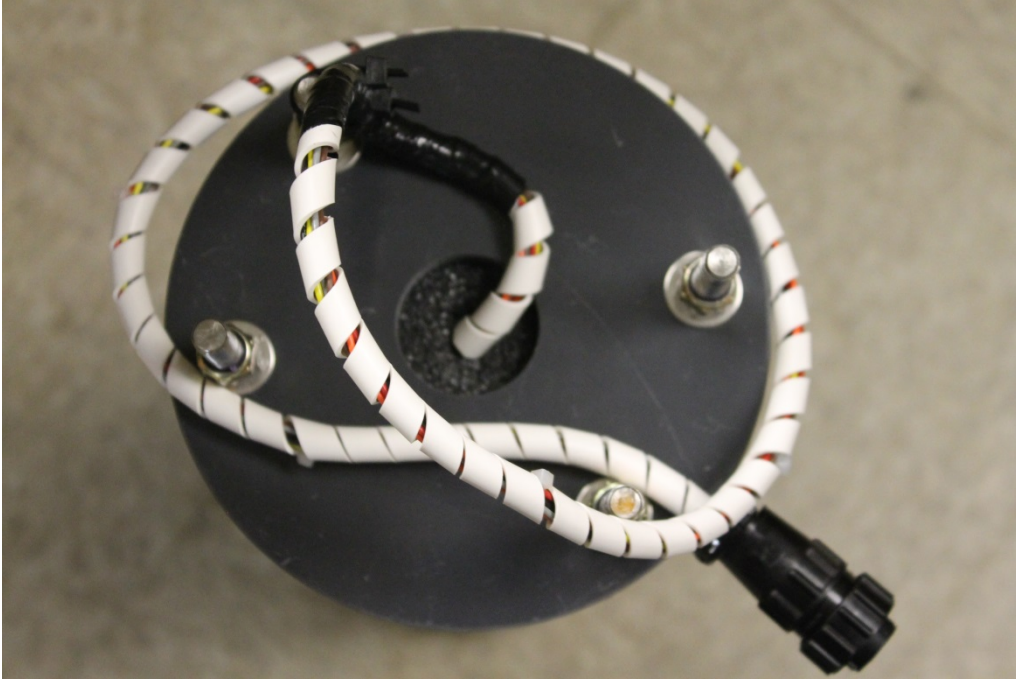
The inductor is secured to the plate with multiple sections of double sided foam adhesive. It is also secured with tie wraps.



The two sections can now be fitted together and made ready for testing. See the SS_Test file for interconnection and testing recommendations.

Battery Pack:

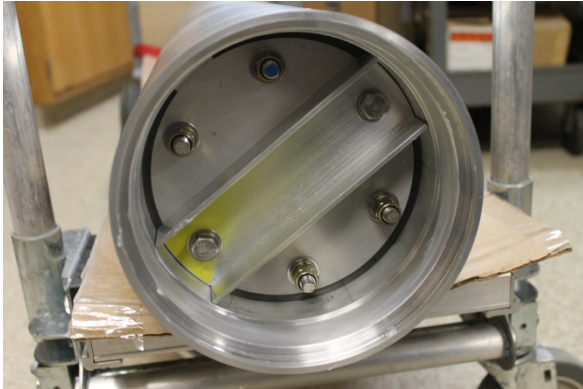
Add the spline wrap and secure the wires to one of the mounting rods to provide protection and strain relief.



The pack is assembled with tie rods, tighten to secure the pack, DO NOT OVERTIGHTEN.



The battery is assembled and secured to the snap ring.



Again, I suggest that you browse the pictures for details.

Sound Source Electronics Assembly

Number Required	Description	Part Number	Manu. P/N	Source
1	Sound Source Electronics (2 Bd set)			SeaScan
1	Transformer		70-0750	Gowanda-BTI, LLC
1	Inductor		X-1148	Pulse Systems, Inc.
4	Spacer Rod			WH
4	Spacer Bar			WH
1	Electronics Back Plane			WH
1	PCB Assembly	Source Interface PCB		Far Circuits
1	1N3817	Diode	1N3817/E3	DK
1	Electronics Plate			WH
1	Electronics Plate 2			WH
1	Transformer			
1	Inductor			
7	Vibration Damping Sandwich Mt	3823K2		McM
1	Grommet	9600K32		McM
1	Connector Shell	A1669-ND	TE 206703-5	DK
6	Pins	A23012-ND	TE 66601-2	DK
1	9v Battery Holder	36-1295-ND		DK
8	Vibration Damping Mount	6008K61		McM
4	4-40 threaded spacer x .5 in	36-2203-ND		DK
4	Machine screw 4-40 x .375			
4	Machine Screw 4-40 x .625			
4	Split Lock Washer 4-40			
8	Nylon washer 4-40 x			
				chassis mounts
4	4-40 threaded spaces x .75 in			
4	Machine Screw 4-40 x .5 in.			
4	Machine Screw 4-40 x .375 in.			
4	Split lock washer 4-40			
12	Flat washer 4-40			
				PC mount
4	Machine Screw 4-40 x .625			
8	Flat Washer 4-40			
4	Nylock Nut			
8	4-40 Flat Washer			
16	8-32 Flat Washer			
16	8-32 Nylock			
3	8-32 Split Lock Washer			
3	8-32 Nut			
4	Machine Screw 10-32x.625 SH			
4	10-32 Flat Washer			
4	10-32 Split Lock Washer			
Miscellaneous				
1	.5 x 75 in Scotch Double Sided Tape		roll	3M
1	HD tape ...			
1	Sound Source Battery - 10.5v, 21v			Adcour, Inc

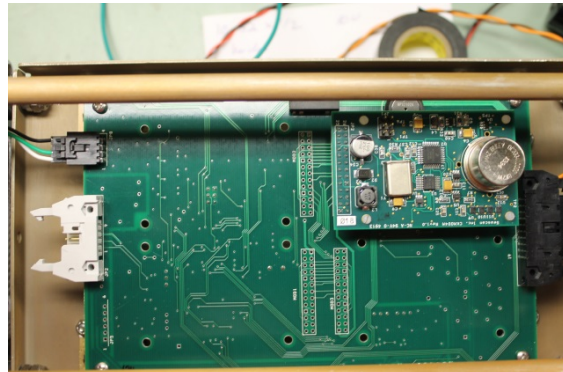
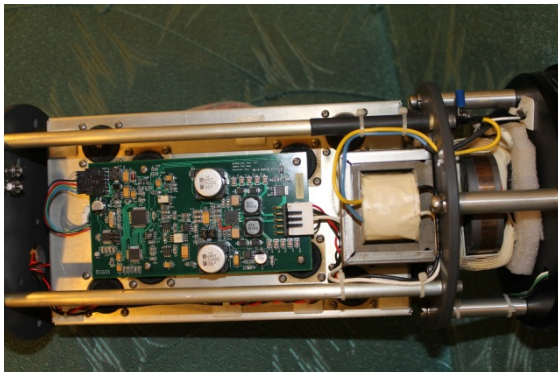
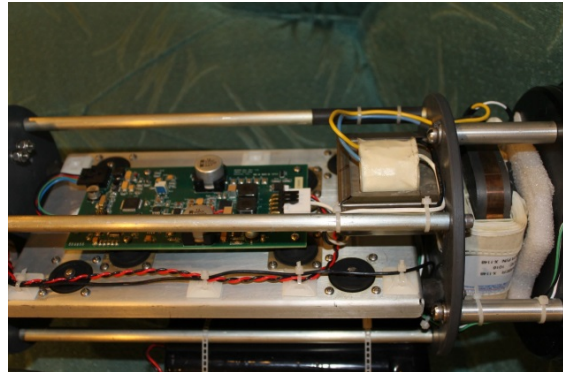
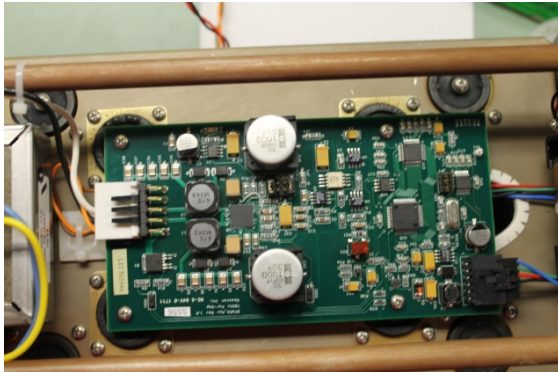
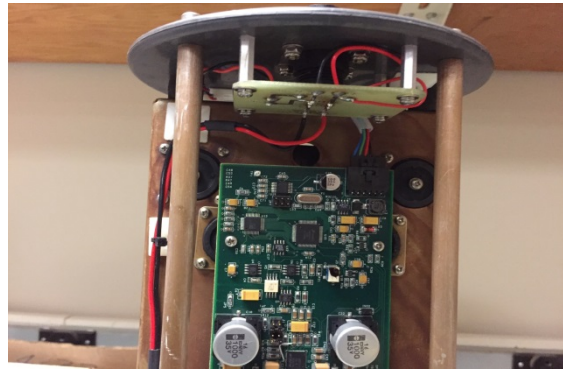
Note: small hardware should be purchased 'by the box'.

Notes:	Supplier
WH	Fabricated in WHOI or other shop
DK	Digikey, Inc.
McM	McMaster-Carr

Bill of Materials: Components needed for sound source electronics fabrication.

Section 6: Sound Source Pictures

Sound source photographs of the electronics during fabrication and assembly.



Many source photographs are available at: <https://www2.whoi.edu/site/bower-lab/rafosfloats-soundsources/>



WHOI Sound Source Manual V1.1



May 2018
J. Valdes

WHOI Sound Source Manual V1.1

Warnings:

Risk of Explosive Gas – Sound sources contain a large volume of alkaline batteries in a sealed pressure housing. Upon discharge alkaline batteries are known to release a small quantity of explosive gasses. Use care and due-diligence when handling sealed pressure housings.

High Voltage present – The output of the amplifier is on the order of 1000v RMS. Disassembly of the source is only to be undertaken by trained and qualified personnel.

To minimize these risks we recommend the following:

- Leave the interior of the case at atmospheric pressure. Install the vacuum plug on the lower end cap and evacuate prior to deployment.
- Once sealed, monitor the interior pressure (vacuum) via the external communications link.
- Remove any possible sources of ignition (sparks, flame, etc.) from the vicinity of the sound source.

Never operate the sound source without a resonator or dummy load attached. Observe the Pmax limitation and limit the source to two pongs on deck when in the Run Mode. Note; the source starts at level 02 and ramps up with each successive pong to the level of Pmax.

General Information:

In this discussion some knowledge of the RAFOS system is assumed.

The WHOI sound source is intended to facilitate acoustic tracking of subsurface instrumentation, i.e., profiling instruments, RAFOS floats, gliders, etc. The sound source emits a unique swept frequency acoustic signal referred to as a “pong”. The pong is generally at a low frequency (<2 KHz) and is generated according to a preset schedule by the source electronics which is referenced to a precision onboard Real Time Clock.

The source consists of a resonator tube which must be precisely trimmed to length to be resonant at the in-situ properties of the water at the deployment site. The electronics / power module is mounted in a pressure case ‘piggy-backed’ onto the resonator tube. When placed in the run mode the power level for the pong increments up to the Max Xmit level value set when the source is initialized. The count increments once count per transmission. Limit power to level 2 after issuing a !Run command if not in the water.

Description / Specifications:

Resonator: Aluminum

Length: 71", OD : ~ 1.8m,

Weight, ~81 Kg (air), 52 Kg (water)

Spherical Projector, Channel Technologies Group, ITC-1007

Electronics pressure case (includes end caps)

Length, ~1.3m x 2.95cm, 50" x 7.5 "

Weight, ~ 54Kg, 120 lb.

Main battery, 21v x 10 stacks (D-cells), 10.5v x 3 stacks (D-cells)

Source Electronics, Sea Scan sound source module

Source is intended to be deployed 'in-line' with the mooring. There are 3 part chain bridles (Delrin isolated) affixed to each end of the resonator tube.

Operating Instructions:

Communications with the sound source is via the three pin connector on the electronics end cap. It utilizes RS-232 (9600 baud,8 bits, N0 parity,1 stop bit, no flow control) protocol. Use capitals. Using a suitable terminal emulator connect a PC to the source, awaken the source with a magnet swipe over the pressure case where indicated and hit return.

Sound source responses are indicated in Italics.

Sound Source Rev 1.1 Apr 2014

->

Entering H will return a help menu.

->H

Help

Sound Source Controller Software Ver 1.1

C Controller Version, Apr 2014

Exclamation group:

!A<cr> Set CK Modules Address

!I<cr> Init

!R<cr> Run

!T<cr> Set Time

!P<cr> Pass-Thru Term

!X<cr> Acoustic Transmission Test

!Q<cr> Quit

Question group:

?A<cr> Query CK Modules addresses

?I<cr> Init

?T<cr> Query Time

?E<cr> Query Engineering Log

?V<cr> Query Volts and Vacuum


```
Open window at = 00 00:00:00
  Offset 00 00:44:00 Set up transmitter on waveform 2
  Offset 00 00:45:00 Trigger transmitter
  Offset 00 23:00:00 End of Window
```

```
*Initialized Max Xmit level 7
Update Mission Length and Parameters (Y/N)?N
```

Now, let's assume 2 pongs per day, spaced 12 hours apart.

->?!

SCHEDULER TASK TABLE

```
Number of windows to acquire (<10000) = 9999
Open window at = 00 00:00:00
  Offset 00 00:44:00 Set up transmitter on waveform 2
  Offset 00 00:45:00 Trigger transmitter
  Offset 00 12:44:00 Set up transmitter on waveform 2
  Offset 00 12:45:00 Trigger transmitter
  Offset 00 23:00:00 End of Window
```

```
*Initialized Max Xmit level 7
Update Mission Length and Parameters (Y/N)?N
```

Or, a single pong every other day.

SCHEDULER TASK TABLE

```
Number of windows to acquire (<10000) = 9999
Open window at = 00 00:00:00
  Offset 00 00:44:00 Set up transmitter on waveform 2
  Offset 00 00:45:00 Trigger transmitter
  Offset 01 23:00:00 End of Window
```

```
*Initialized Max Xmit level 7
Update Mission Length and Parameters (Y/N)?N
```

?T – Query the time

Displays the run time clock and the reference clock module.

```
->?T
D&T = 14-07-21 18:11:12...Å
Alarm = xx-xx-22 00:00:00

Clock Module Info
CKM_Time = 00-01-01 18:11:18...
->
```

Now onto the ! (load) group, commands are format specific.

!! Load a new initialization.

```
->!I
Task table initialization, 25 actions maximum
```

Number of windows to execute NNNN= 9999
Open window at HH:MN 0000
Cycle structure A=A
->?I

SCHEDULER TASK TABLE

Number of windows to acquire (<10000) = 9999
Open window at = 00 00:00:00
Offset 00 00:44:00 Set up transmitter on waveform 2
Offset 00 00:45:00 Trigger transmitter
Offset 00 23:00:00 End of Window

*Initialized Max Xmit level 7
Update Mission Length and Parameters (Y/N)?N

->

Note also the slight difference in the formatting between the !I and the ?I.
!I is entered as DDHHMM and ?I is displayed as DDHHMMSS.

!T – Set the time, select a reference for UTC prior to start. Enter a date and time and hit the '@' character AT the time indicated. Query the time and confirm.

->!T
Set Clock YY-MM-DD hh:mm:ss sync on @
D&T=140701 201500@

Be patient, as the two clocks need to sync after being set.
Check and confirm the time

->?T
D&T = 14-07-01 20:15:22...
Alarm = xx-xx-02 02:15:00

Clock Module Info
CKM_Time = 00-01-01 20:15:29...
->

!X – Generate a test pong

The test pong is at level 1, this is very low power. Ambient noise will likely make it difficult to hear the test sweep. A 'sounding stick' – a broom handle with rounded ends placed against the spherical transducer and your ear will conduct the sound, and make it easier to hear.

!R – Run a mission (R) or non-mission, Idle (I) mode.

If in mission awaken with a magnet swipe and continue or place back in idle mode.

See the sequence which follows... Upon a ! Run command the source will generate a test pong. Format is Max level x10, i.e. level 1 is displayed as 10. Then the source will wait until it passes the Open time programmed to start the mission.

->!R
Run or Idle (R,I)?Run... Arming Xmtr
Transmit Level= 10

*Xmtr Trigger OK
Hit any key to abort pong...
End of transmission*

Running Mission, disconnect RS232 link now

-> Mission Phase: ACTIVE_MISSION

at 14-07-02 02:15:00...

No task

Current time

at 14-07-01 20:35:11...

****Next:*

Mission Phase: ACTIVE_MISSION

Task type: NO_TASK

at 14-07-01 21:35:11...

****Running****

Swipe magnet then ?S

->?S

Sound Source Rev 1.1 Apr 2014

D&T = 14-07-01 20:37:21

Alarm = xx-xx-01 21:35:11

Vac=070 cBars VAux=087 dV VCpu=087 dV

**Initialized Running Mission Phase 1*

->

Now, back to Idle and check with ?S

->!R

Run or Idle (R,I)?Idle

->?S

Sound Source Rev 1.1 Apr 2014

D&T = 14-07-01 20:42:20

Alarm = xx-xx-01 21:35:11

Vac=070 cBars VAux=087 dV VCpu=087 dV

**Initialized Idle*

->

To place the source in the low power sleep mode use the !Q, Quit command

->!Q

->

Pre- Deployment and Case-up Testing.

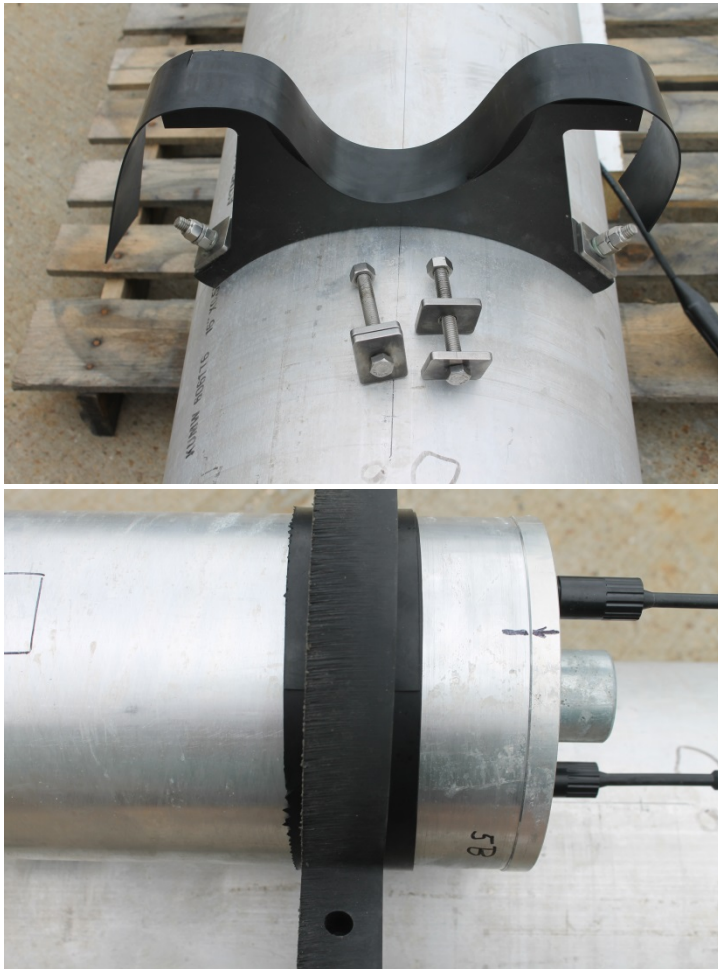
Attach electronics check out sheets here. (See Electronics Test and Assembly)

Final Deployment Preparations.

See the document which follows. Several of the high points are reiterated, these pages may be printed as a stand-alone reference for deployment operators.

WHOI 260 Hz Sound Source Launch Preparations

The sources are to be deployed with the HV cable exiting the tube in the 'up' position. The electronics is mounted with the connectors in the 'up' position. Rubber strips have been provided, place them on the brackets and center them when the tube is in position. Confirm that the electronics S/N matches the resonator S/N. They are not interchangeable.



When setting the tube place the transducer (X) connector in the up position.

Secure with the 7/16 SS hardware provided. SS will gall easily, lubricate the threads with Aqua Shield (use sparingly). If using a power driver, set the maximum torque low and tighten until the split washers are closed. Hand tighten another $\frac{1}{2}$ - $\frac{3}{4}$ turn till the urethane bracket has a slight bulge. Tighten each side equally to minimize gaps. Add the split washer and the Nylock, hand tighten to secure. Note also the large clamp washers.

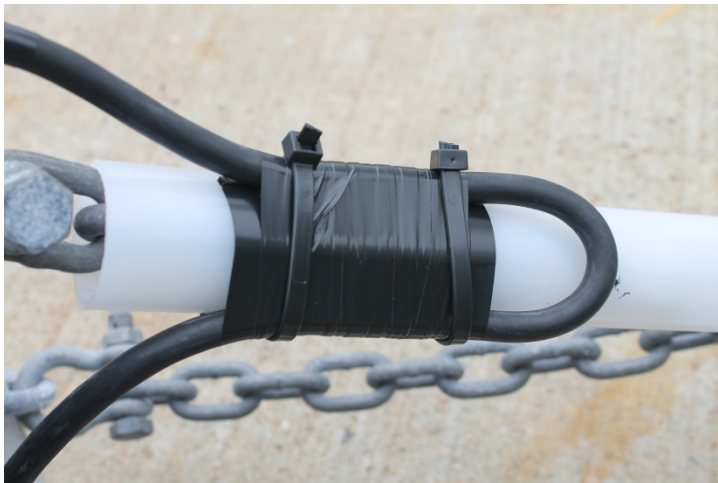


Prep the HV cable. Install the spiral wrap near the splice, and secure with tape.





Install the three point bridles, do not cross the legs. There are isolation tubes for the chain where the HV cable exits the tube. Secure the tube to the 'center' leg with tape (single wrap). Gently loop the cable back and secure with an additional wrap of tape. Do not make a sharp bend in the cable. Leave slack in the cable so it is not stressed during deployment. Secure to Shackle, tape over cotter pin, and leave slack.





All shackles must have cotter pins installed. Double bend both ends of the pin around the shackle. Secure with tape if near the HV cable. Remove the 2 pin dummy plug and plug in the resonator (X). Save the dummy plug. Do not remove the 3 pin dummy plug on the comms connector. Secure the HV cable to the comm port dummy plug.

Connect a computer running a terminal emulator (9600 baud, 8 bits, 1 stop, no protocol) to the source using the comms cable provided. Set caps on. Swipe the magnet over the tube (where indicated) and hit return, you should see a response similar to:

```
->  
Sound Source Rev 1.1 Apr 2014
```

```
->
```

Enter a ?S command to view status

```
Sound Source Rev 1.1 Apr 2014  
D&T = 14-06-18 20:33:40  
Alarm = xx-xx-19 00:00:00  
Vac=071 cBars VAux=108 dV VCpu=108 dV  
*Initialized Idle
```

```
->
```

Note the Date & Time, must be GMT.

Note the vacuum as 71 and the Vcpu as 10 volts (you cannot see the 21V pong supply).

You may check the RTC and the clock module with a ?T [time] command

```
?T
```

```
D&T = 14-06-18 21:43:22...Å  
Alarm = xx-xx-19 00:00:00
```

```
Clock Module Info
```

```
CKM_Time = 00-01-01 21:43:29...Å
```

```
->
```


Query the initialization, ?I [*sources are set 1 pong/day*]

SCHEDULER TASK TABLE

Number of windows to acquire (<10000) = 9999

Open window at = 00 00:00:00

Offset 00 00:44:00 Set up transmitter on waveform 2

Offset 00 00:45:00 Trigger transmitter

Offset 00 23:00:00 End of Window

**Initialized Max Xmit level 6*

Update Mission Length and Parameters (Y/N)?N

->

Enter "N" and continue

Note the format ... displayed as ddhhmmss, programmed [!I] as ddhhmm, a little confusing.

Armed 1 minute prior to the scheduled pong (Xmit) time. Should you desire to change the pong schedule enter a (!I) command and follow the prompts, use care!

To start a mission ... use !R and tell it R(un).

->!R

Run or Idle (R,I)?Run... Arming Xmtr

Transmit Level= 10 [this is level 1]

Xmtr Trigger OK

Hit any key to abort pong...

End of transmission

Running Mission, disconnect RS232 link now [wait for the disconnect instruction]

-> *Mission Phase: ACTIVE_MISSION*

at 14-06-19 03:32:35...

No task

Current time

at 14-06-18 21:35:27...

****Next:*

Mission Phase: ACTIVE_MISSION

Task type: NO_TASK

at 14-06-18 22:35:27...

****Running****

Wait until it has completed the pong and you see the printout before you disconnect the cable. You will not be able to hear the pong at this low level. Unlike the WRC source, the pong is almost (particularly at low power) inaudible on deck as there is no mechanical coupling to the resonator.

It's good practice to open a file to record the transactions.

Open a file, SS99_06182014.log [*SS##_mmdyyyy*]

Observe the values in the pre deployment log

Time may be adjusted with the !T command, follow the prompts.

Note:

The power level will increment from level 1 (at !Run) to Max Power with each successive pong. Maintain power less than level 3 on deck. Should the deployment be delayed, wake up the source (magnet) and enter a !R Idle command. You will need to again place the source in Run mode prior to deployment.

The sources may be interchanged as they are all tuned to the same water mass properties. The pong times will need to be adjusted with the initialization (!I) command.

Sound Source Recovery

The Sound Source acoustic generator and the controller are powered independently. A source which has failed acoustically may still be able to communicate. A battery failure can result in the batteries outgassing, remove the evacuation plug as soon as possible after recovery and allow the pressure to equilibrate. Replace the plug and use caution when handling the instrument and when removing the end cap. Do not allow anyone to stand in front of the end cap. See warnings on page [ii] in the attached manual.

Upon recovery the Sound Source acoustic transmission (pong) should be disabled as soon as possible, by placing the source in IDLE mode. The acoustic projector may be damaged if the source pongs at full power on deck. Recovery should be timed to allow for recovery and shut down prior to the next scheduled pong. We also need to determine the clock offset.

A copy of the sound source manual is attached; be aware that subtle differences in the command structure may exist. Note, [pg] refers to a page in the source manual.

Necessary supplies:

- Computer running a terminal emulator (RS-232 interface / USB to RS-232 adapter)
- Computer to 25 pin RS-232 connector for “Black Box” interface
- SAIL connector cable (Source >> Black Box)

Communication with the source: [pg4-6]

Remove the socket head bolts on the comm port cover. Connect the source to the RS-232 SAIL loop interface and the interface to the computer RS-232 / USB converter. The loop is polarity sensitive; if the source does not respond reverse the two wires on the interface converter. The overview of the procedure is: Send the address (receive response), query the status, place the source in idle mode, query the time and note the offset to Coordinated Universal Time. GPS should provide you a time reference.

Addressing: (Upper Case – interface is case sensitive) (auto fill active following bold text)

Details below:

Address source **#SSxx**, where xx is the sound source number [pg 6]

Source responds with

->

Help will return a list of acceptable commands [pg 6]

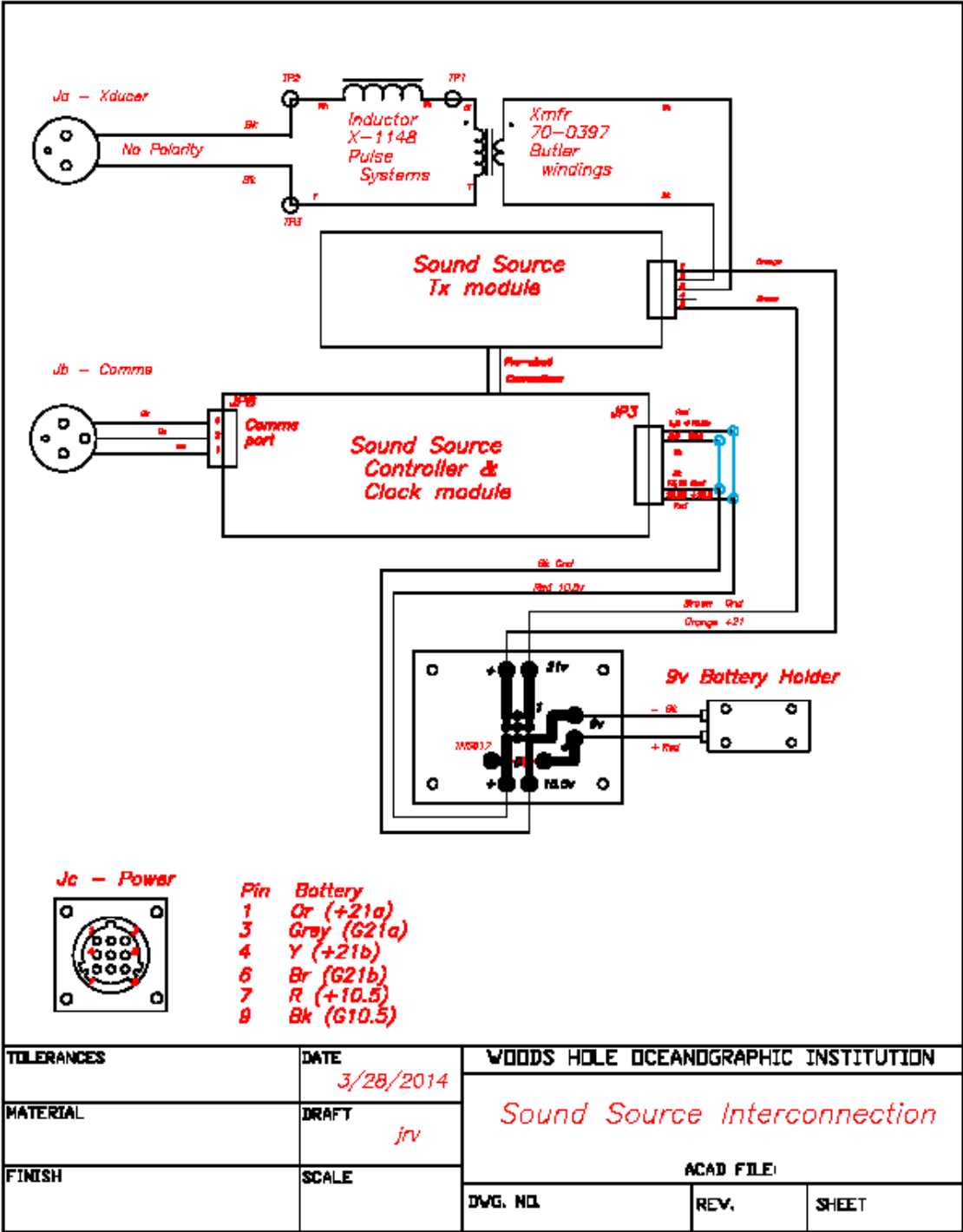
Also verifies communications with the source. Note if there is a ?Time command in the listing.

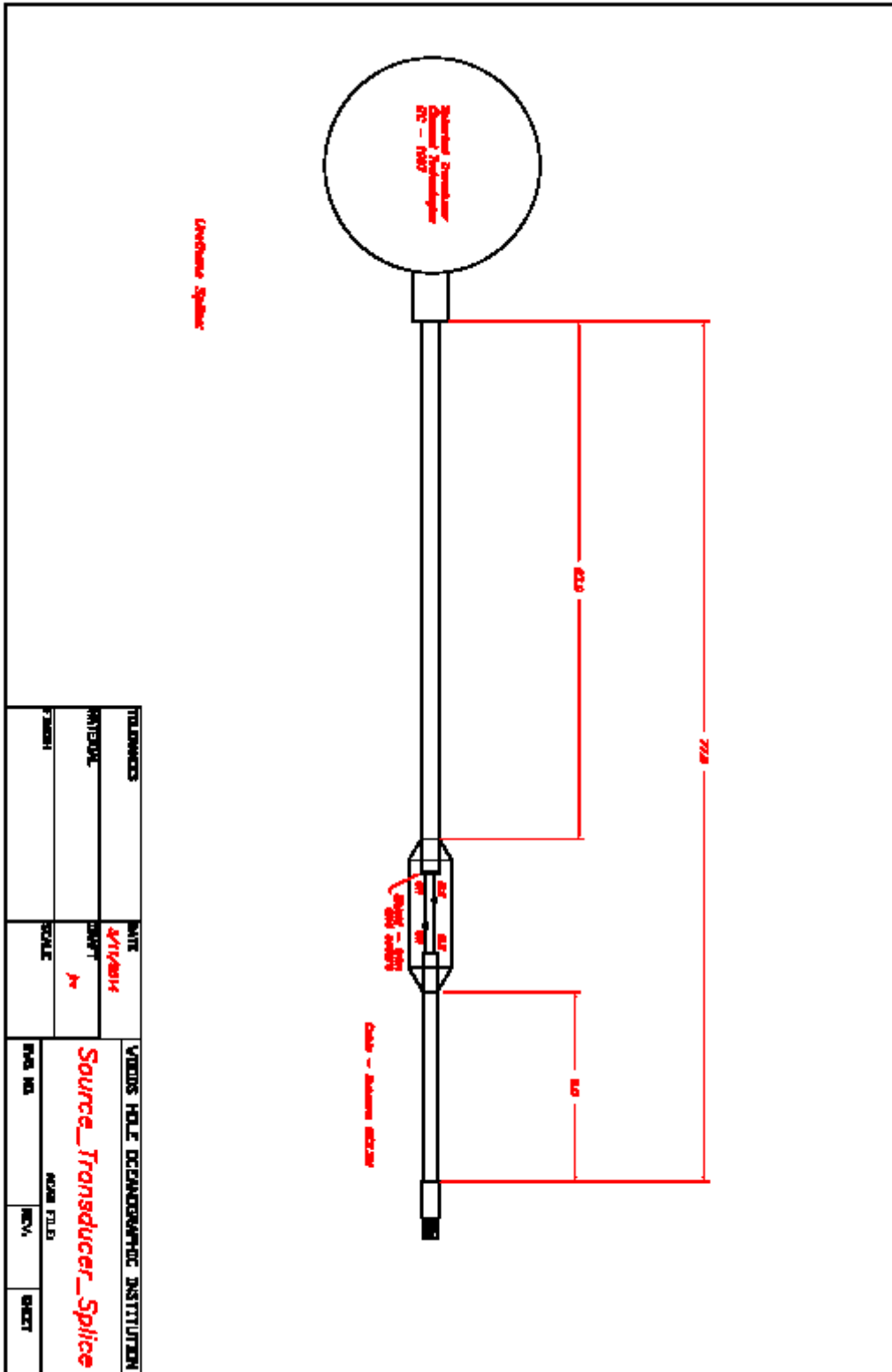
?Status, will return the present status (active mode) [pg 11]

Removal from tube:

Remove the 1/8 inch spline from the groove and the vacuum port on the bottom end. The anode is a convenient handle. The end caps have double O-ring seals and are difficult to remove, injecting a little air into the vacuum port (20 psi max) in spurts while applying and outward pressure with the anode works quite well. After assembly reset the vacuum to 70. Note: Newer Sources have 'jacking screws' on the end caps.

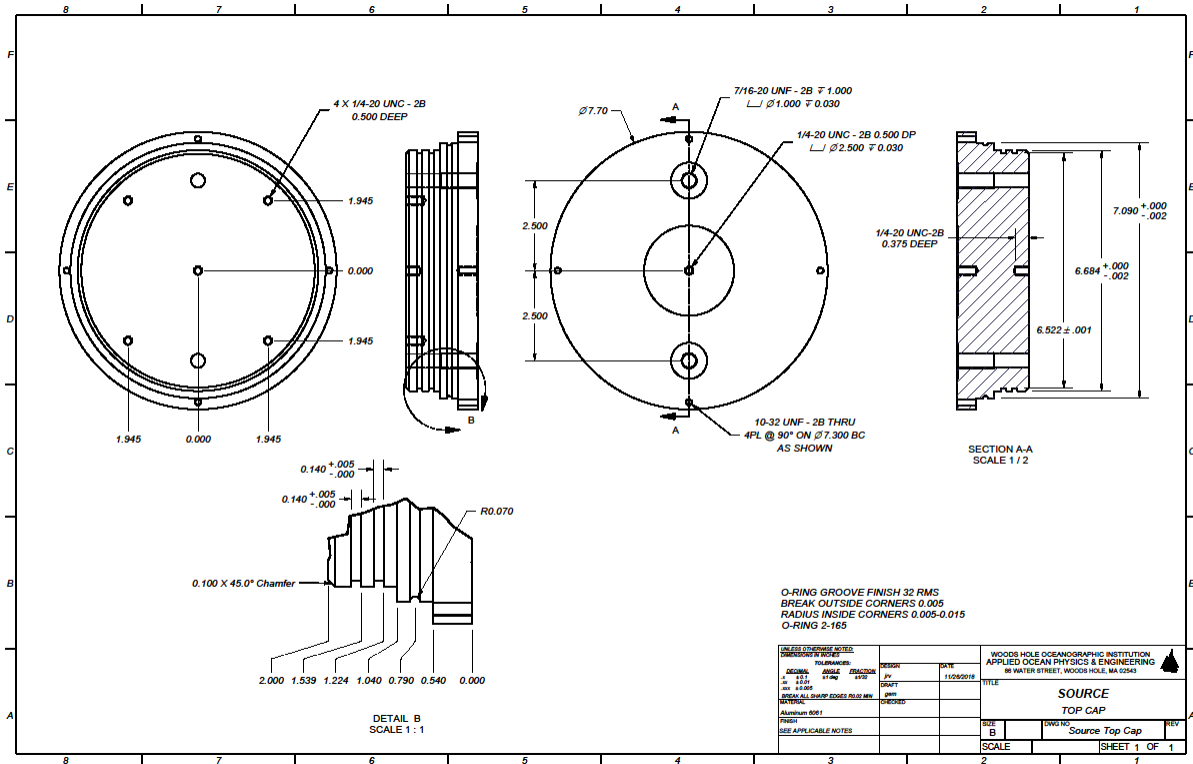
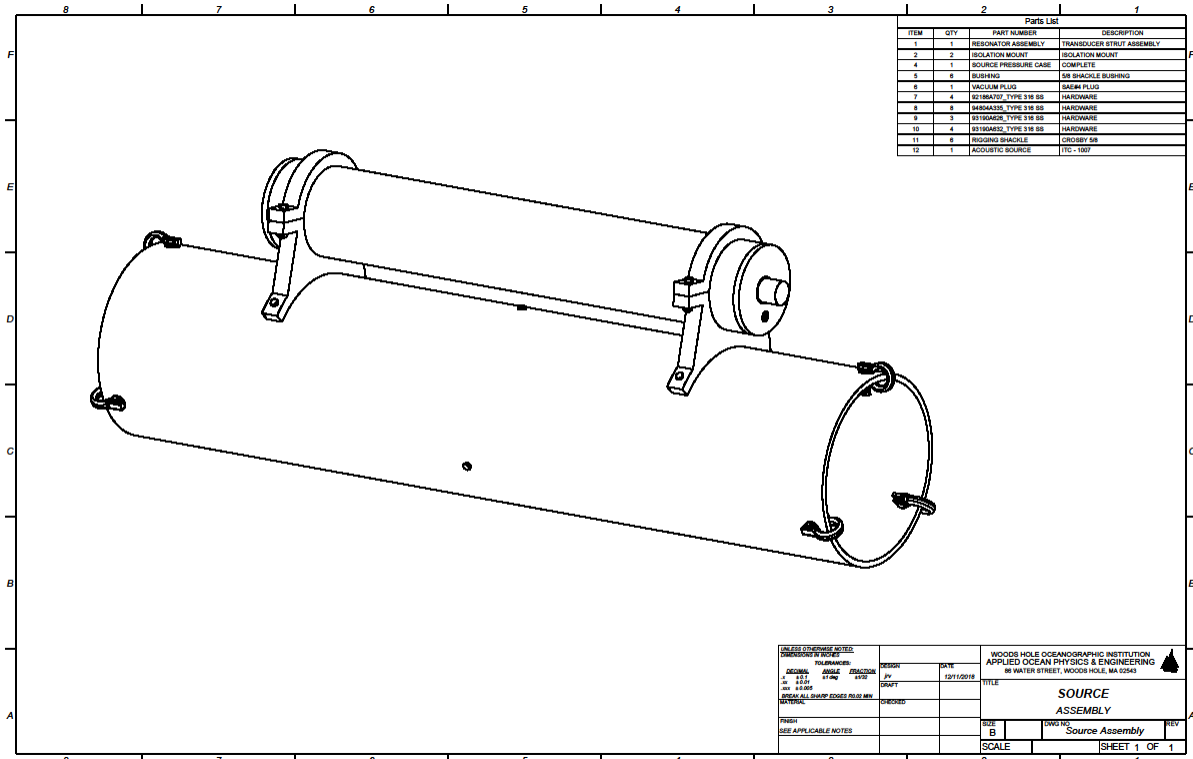
Section 8: Electrical / Mechanical Documentation

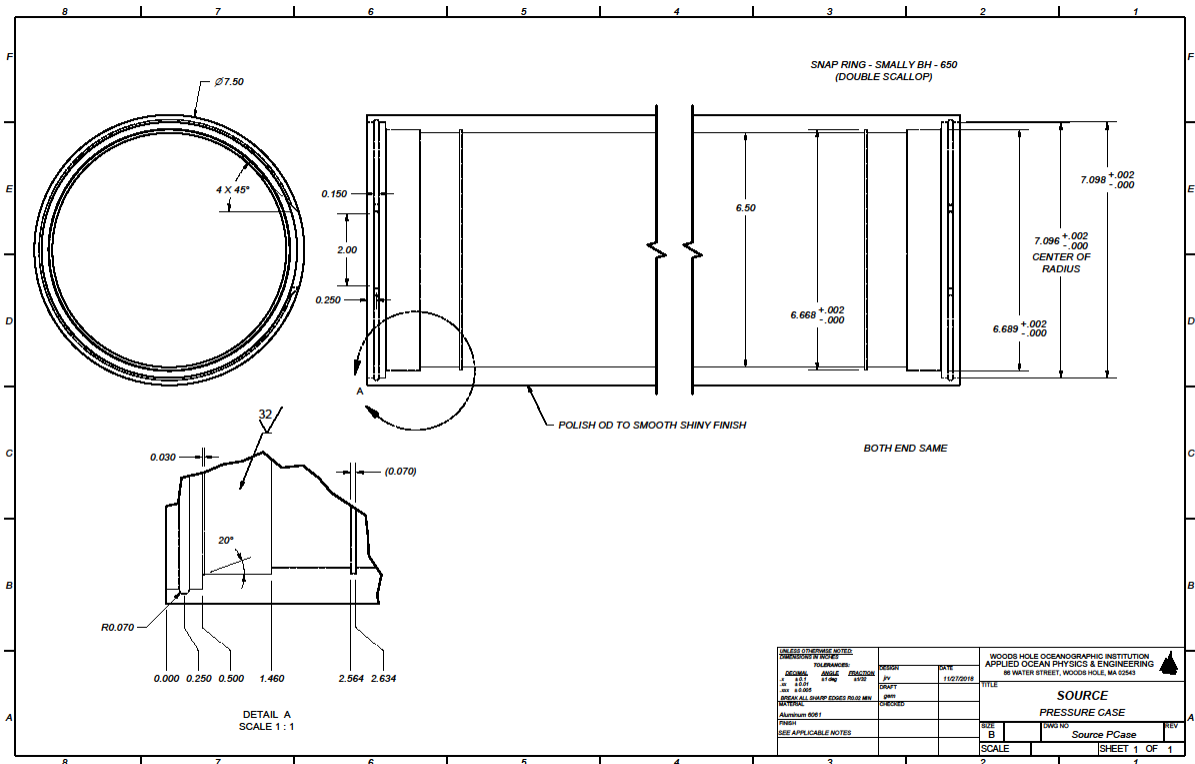
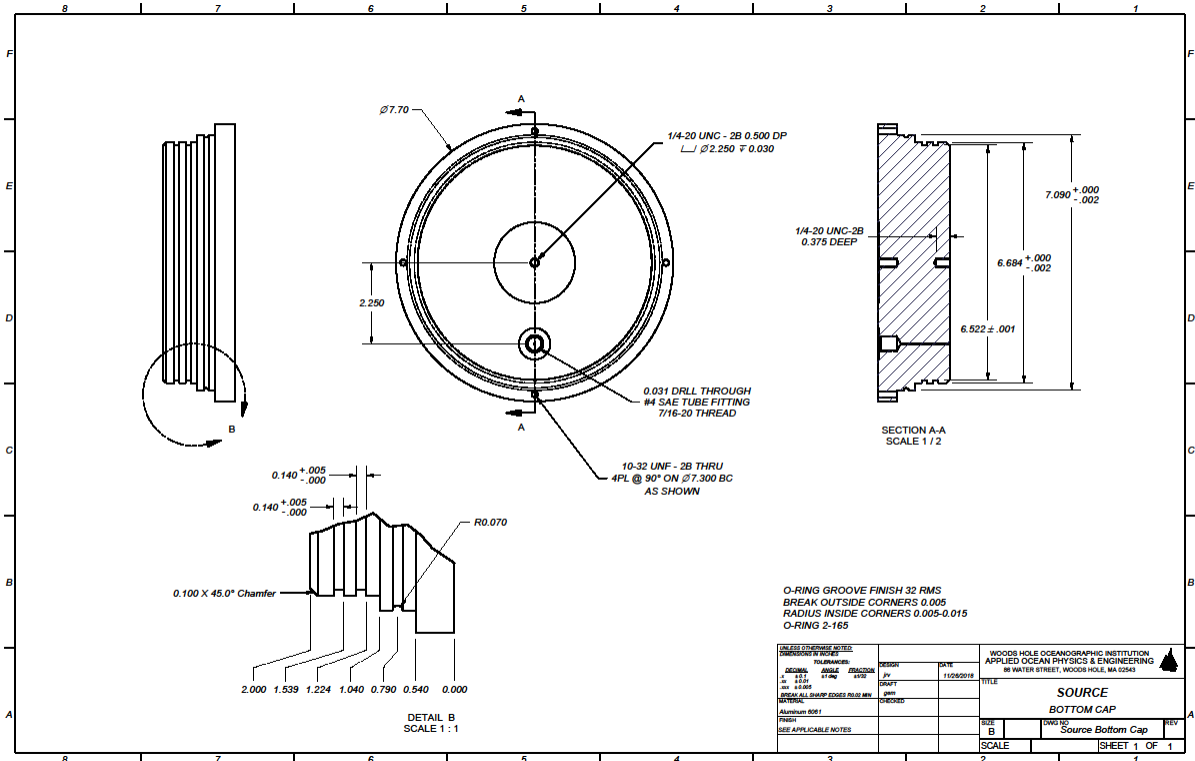


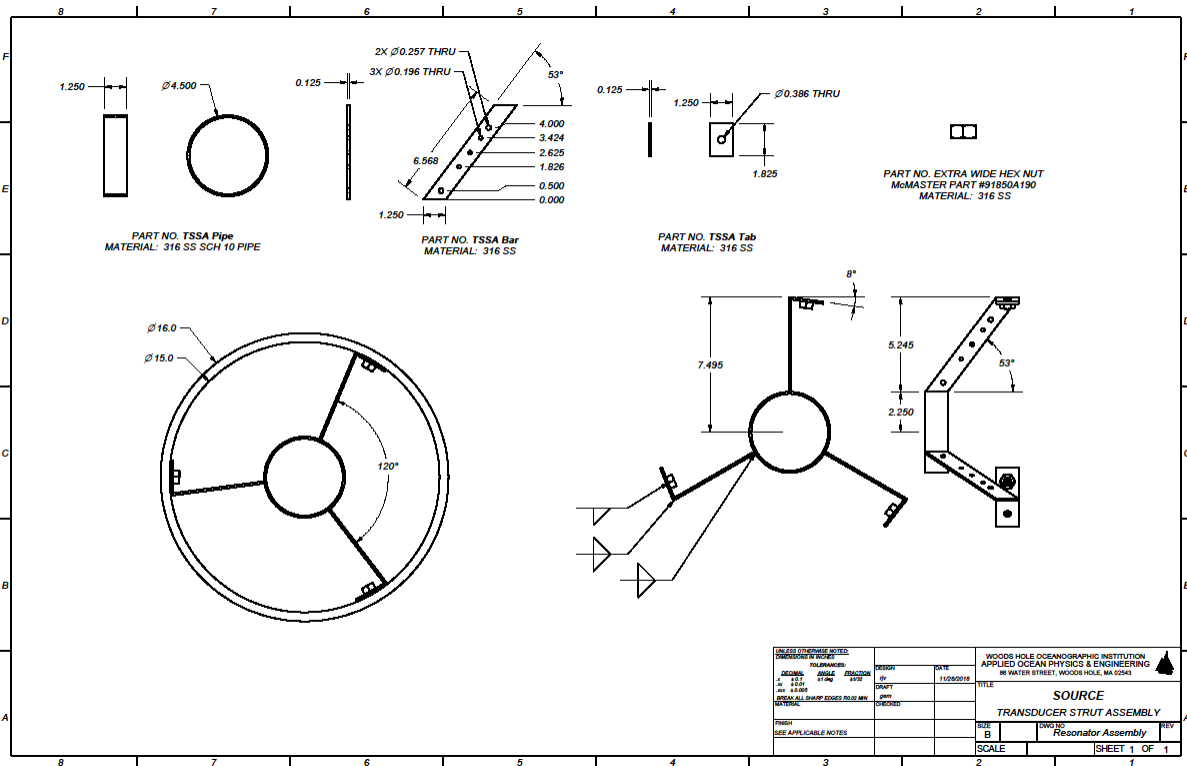
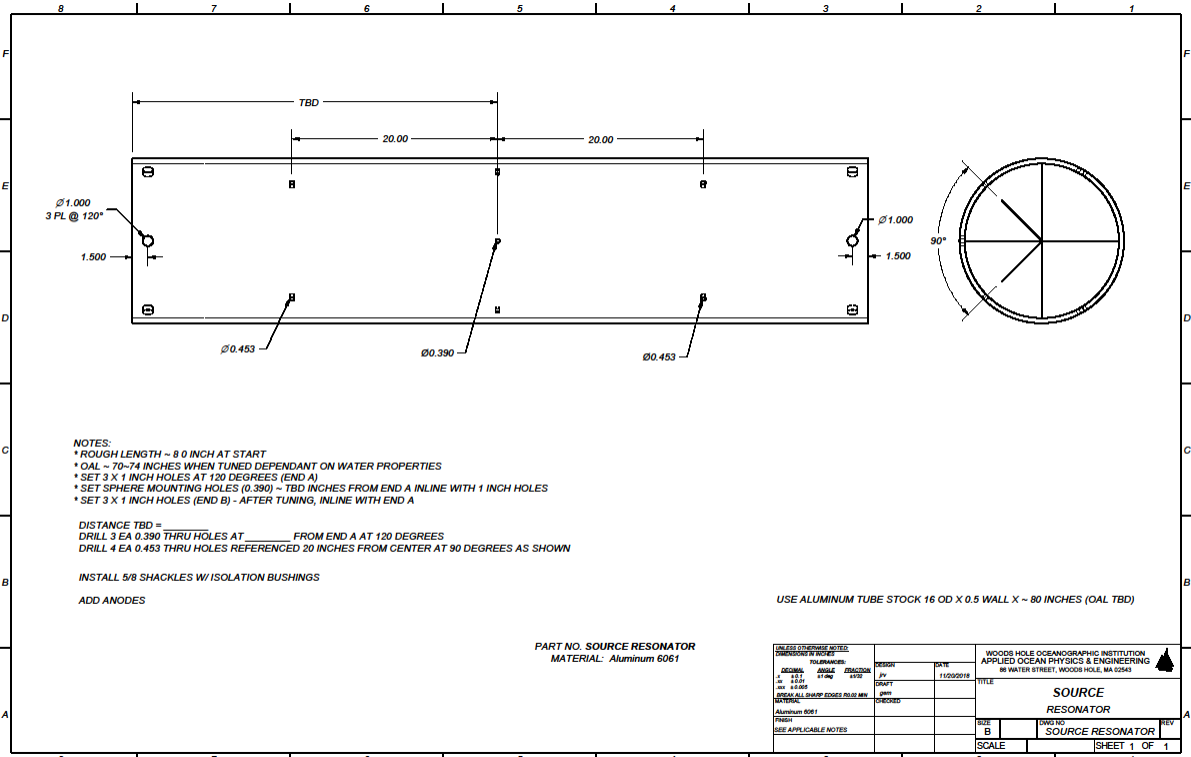


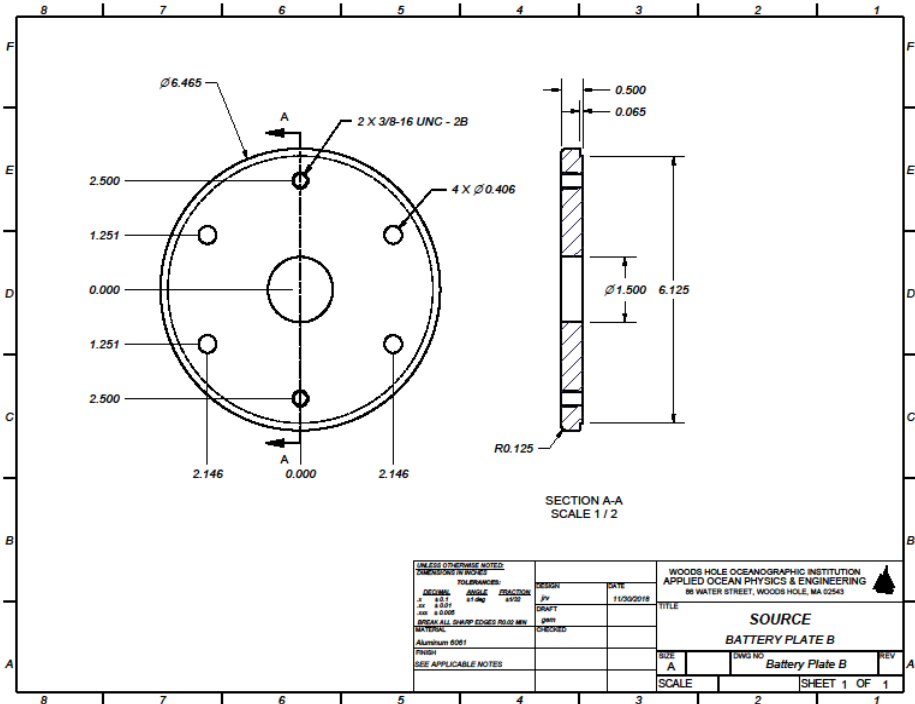
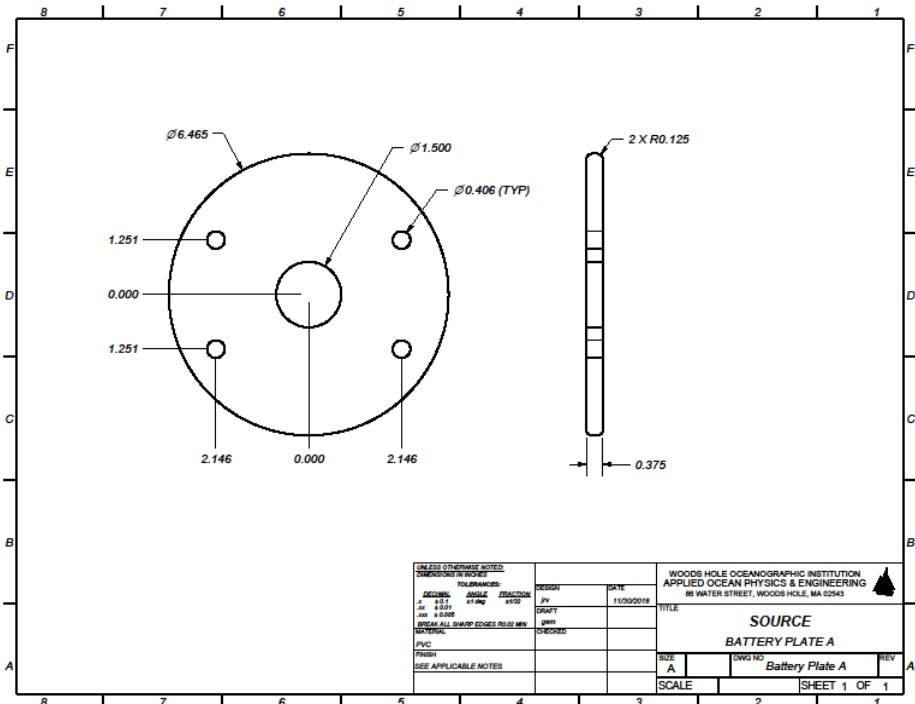
Sound Source Transducer

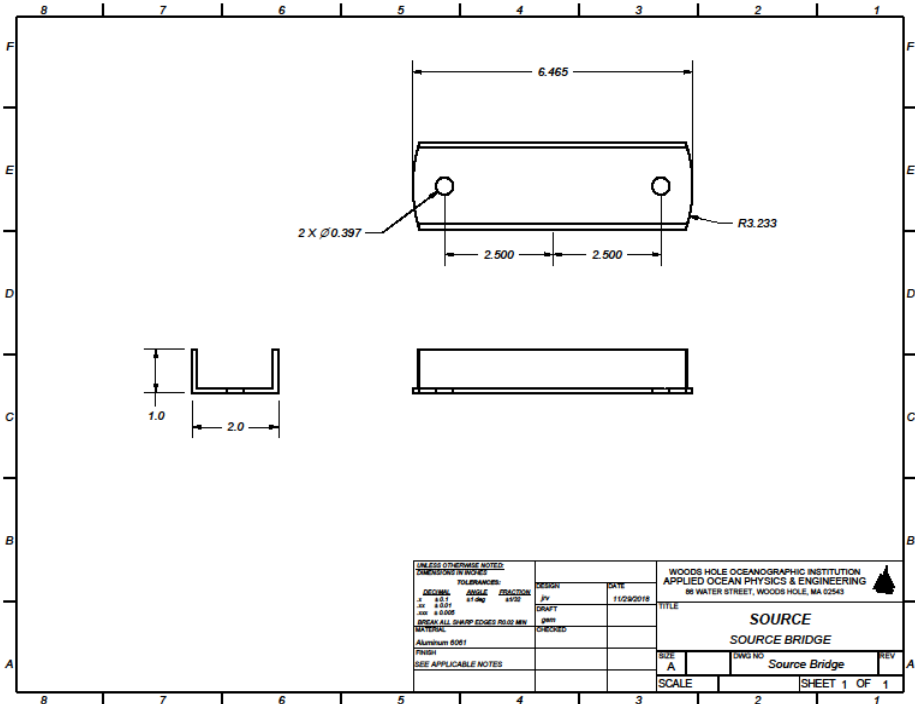
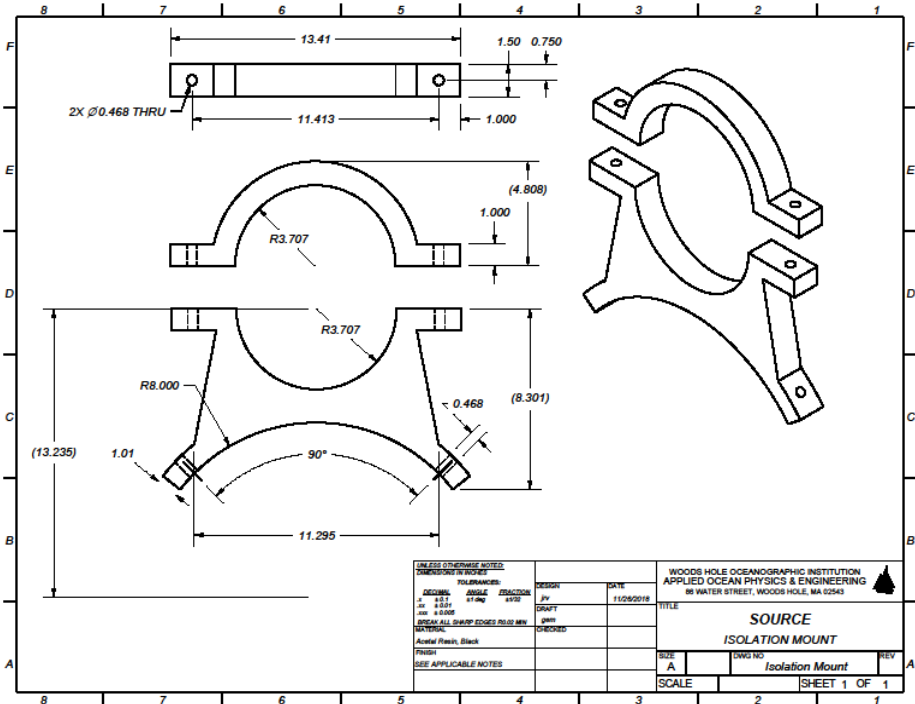
Mechanical Drawings

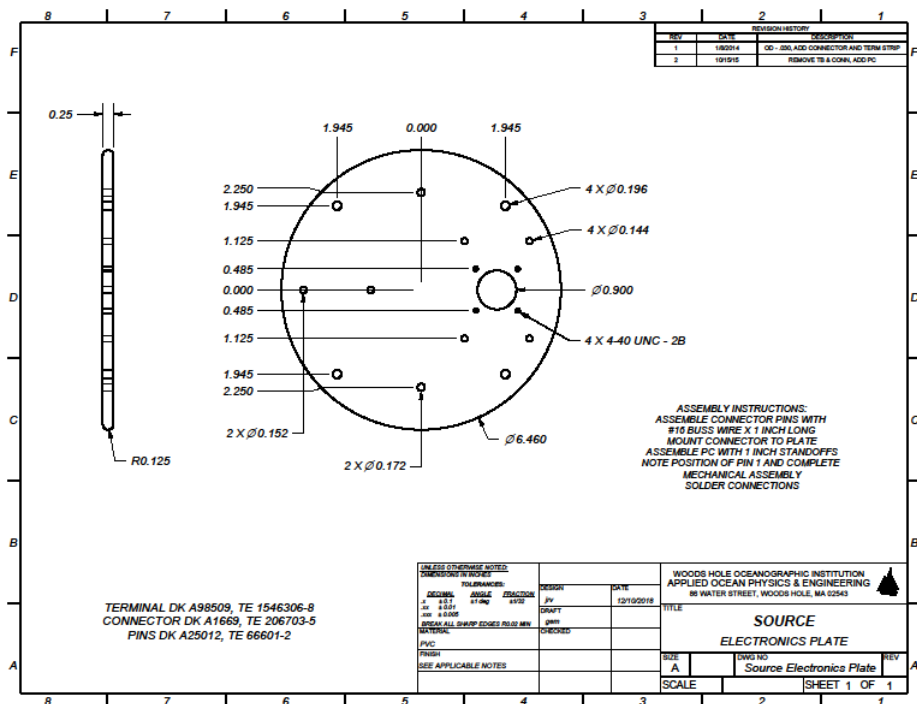
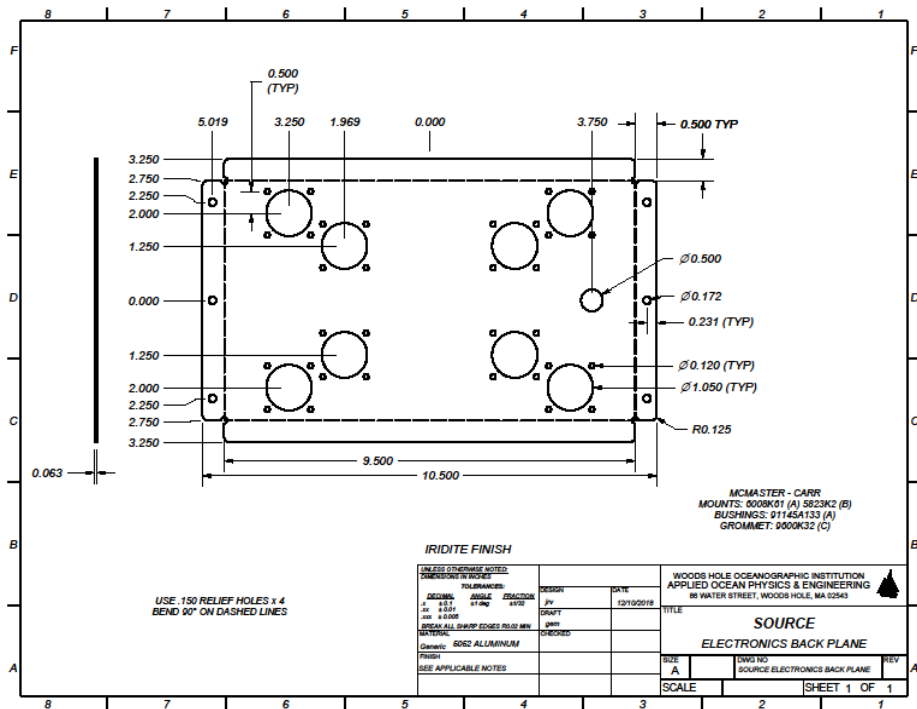


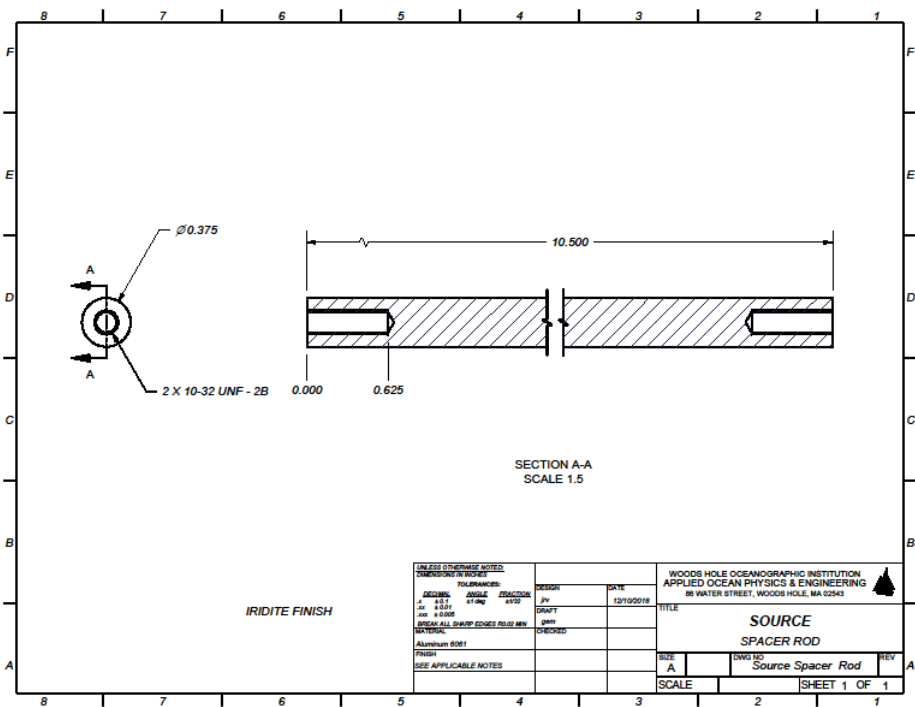
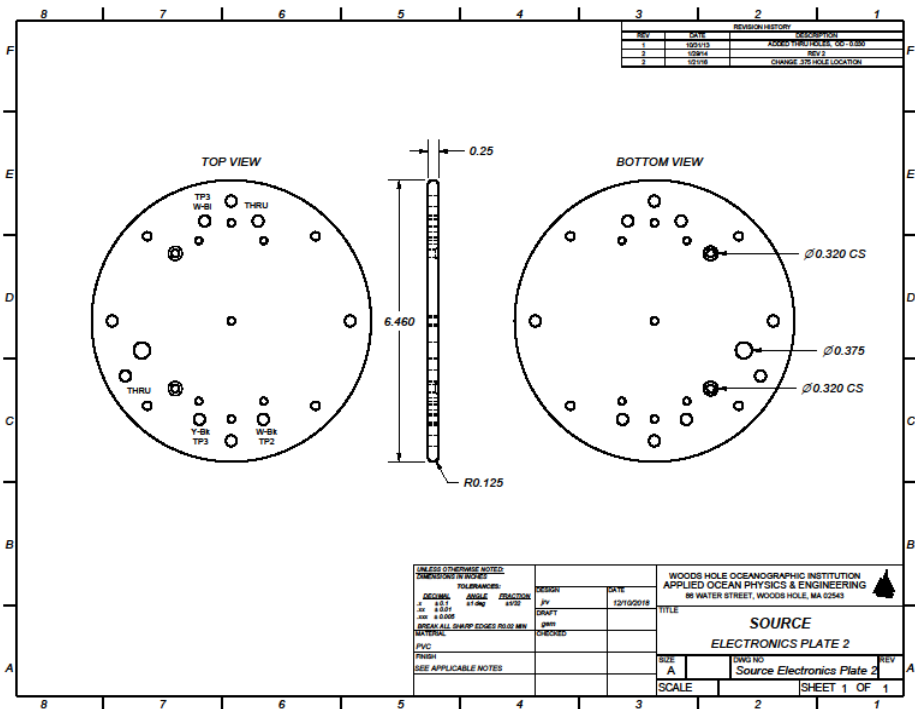


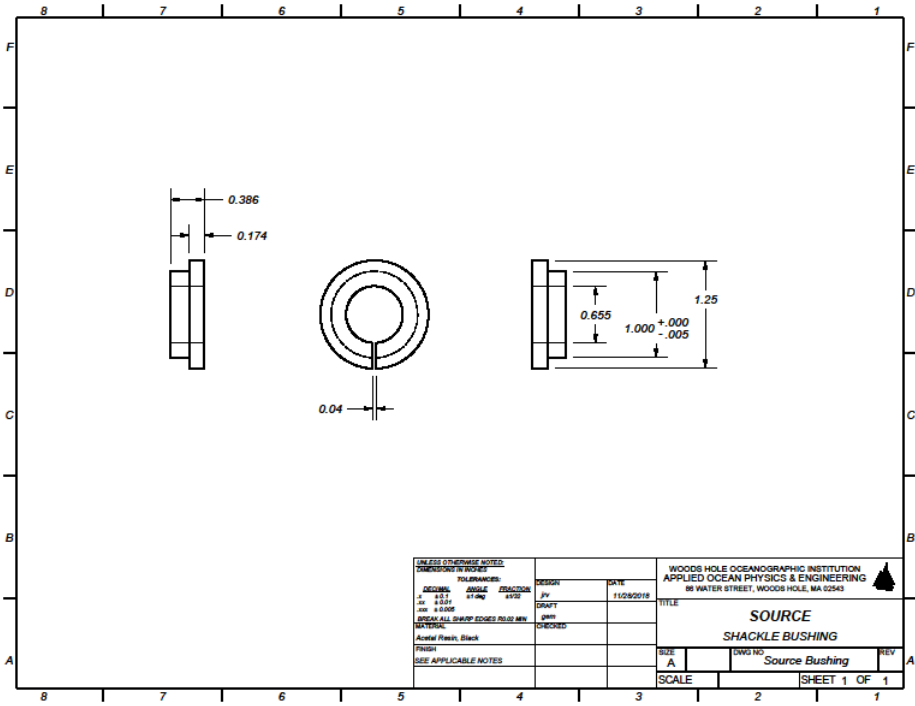
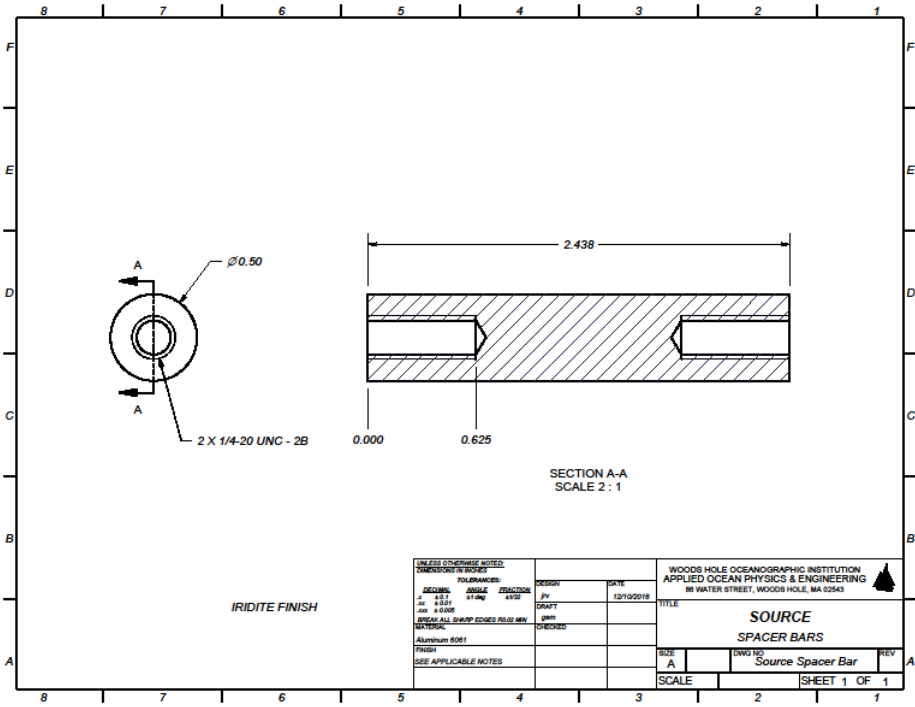


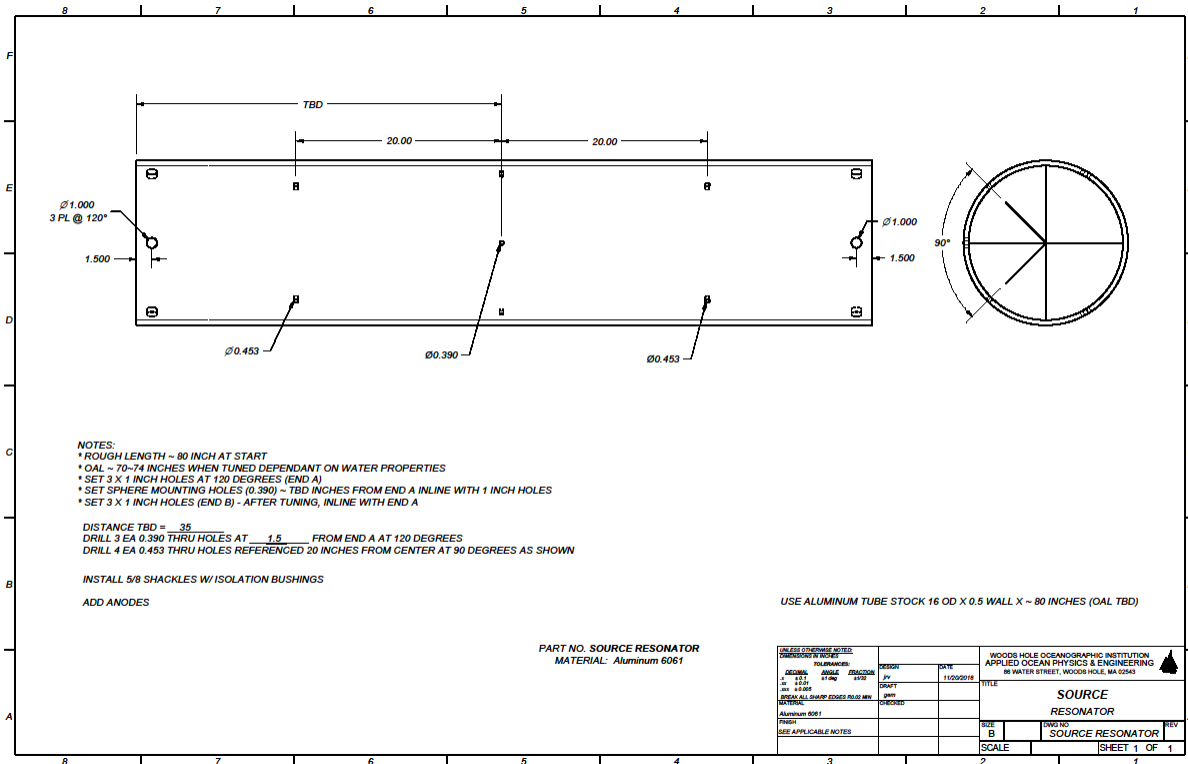
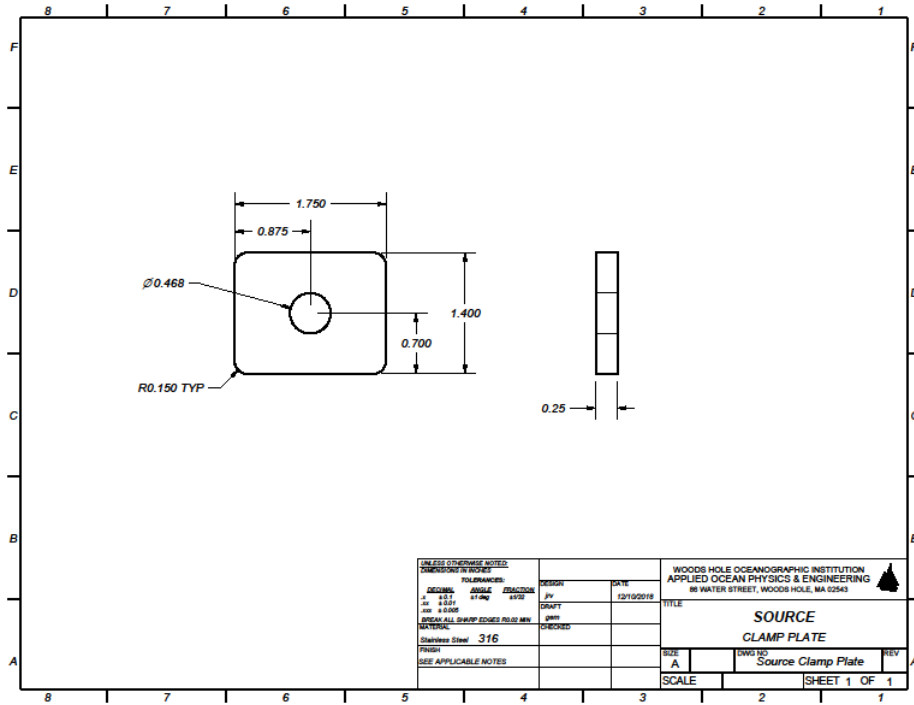


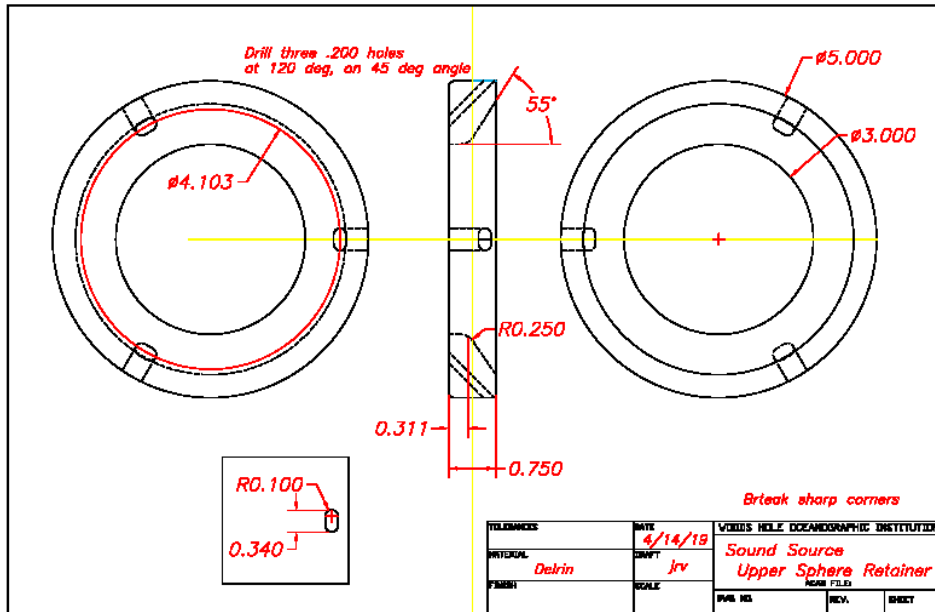
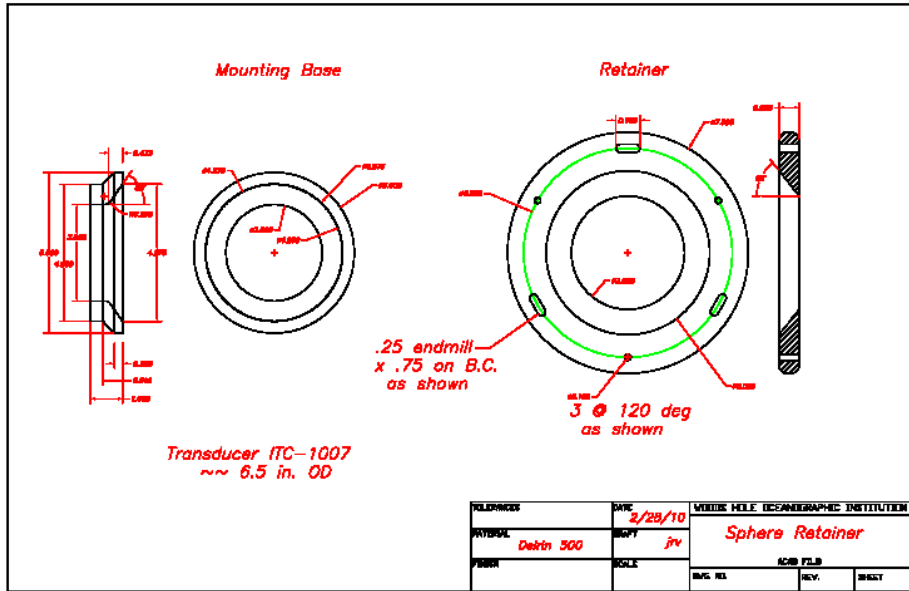












Section 9: Acknowledgements

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REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-2021-02	2.	3. Recipient's Accession No.
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7. Author(s) James R. Valdes, Heather H. Furey		6.	
9. Performing Organization Name and Address Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543		8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address National Science Foundation		10. Project/Task/Work Unit No.	
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15. Supplementary Notes This report should be cited as: Woods Hole Oceanographic Institution Technical Report, WHOI-2021-02.		13. Type of Report & Period Covered Technical Report	
		14.	
16. Abstract (Limit: 200 words) Sound sources are designed to provide subsea tracking and re-location of RAFOS floats and other Lagrangian drifters listening at 260Hz. More recently sweeps have been added to support FishChip tracking at 262Hz. These sources must be tuned to the water properties where they are to be deployed as they have a fairly narrow bandwidth. The high-Q resonator's bandwidth is about 4Hz. This report documents the tuning, and provides an overview of the sound source assembly.			
17. Document Analysis a. Descriptors Sound Source RAFOS FishChip b. Identifiers/Open-Ended Terms c. COSATI Field/Group			
18. Availability Statement Approved for public release; distribution unlimited.		19. Security Class (This Report)	21. No. of Pages 65
		20. Security Class (This Page)	22. Price