Low Frequency Transducer Design for Methane Detection

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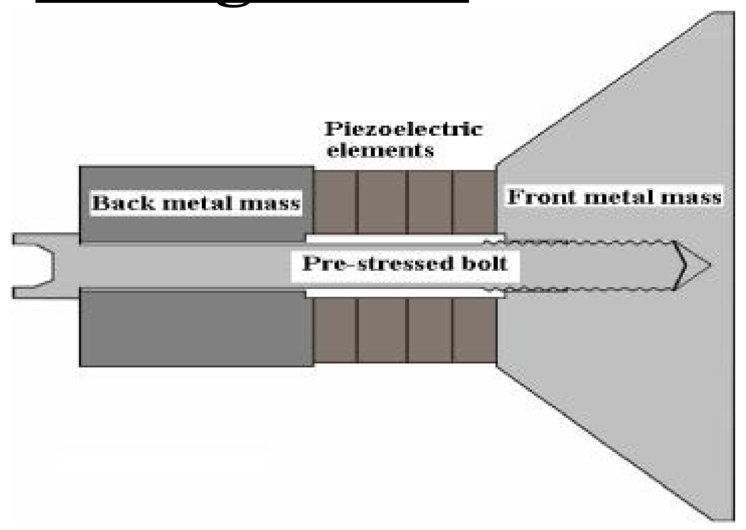
Motivation

- Methane Bubbles can cause a variety of problems. Including both environmental and buoyancy issues.
- As the environment changes, methane is being released in different quantities and locations.
- Detecting these bubbles can improve safety and analytic capacity.

Paul Zizka/Caters News

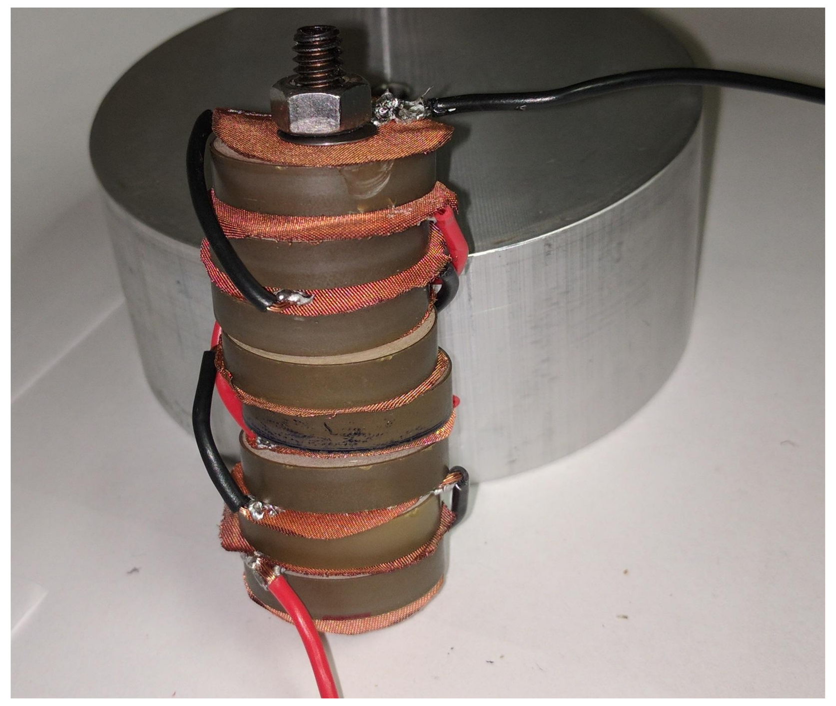
Background

Tonpilz transducers make use of piezoelectric elements to change a physical vibration into an electrical one.



-Shuyu Lin and Chunlong Xu, Analysis of a Sandwich Transducer

- An AC current is driven through several piezoelectric elements.
- When a piezoelectric is exposed to current, it expands and contracts relative to the voltage.
- Several piezoelectrics in series can cause the whole column to vibrate.



-A stack of ceramic piezoelectric elements.

-Negative and positive wires are interleaved to measure current generated by similar sides.

- The front mass of a tonpilz transducer is scaled to vibrate with the natural frequencies of different targets.
- The back mass serves as a counterweight.

Project Objective

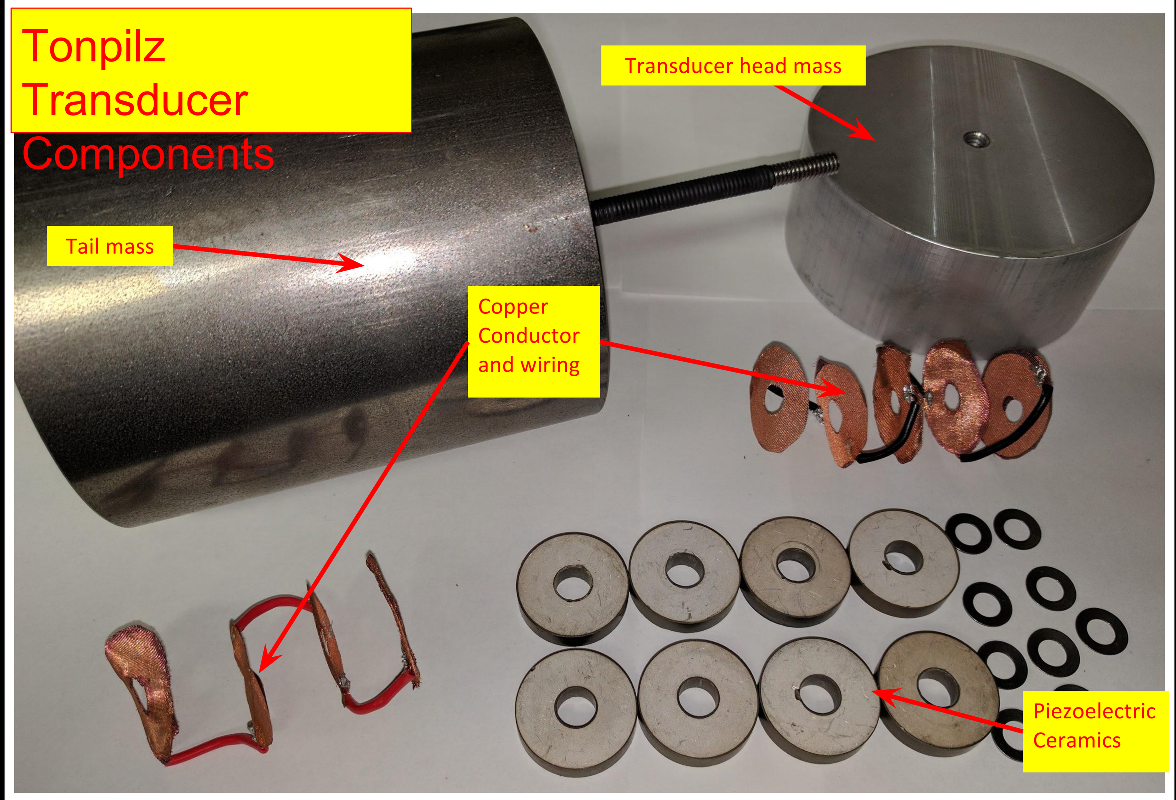
To design and build a low cost transducer with a head size matched to the natural frequency of a methane bubble.

Methods

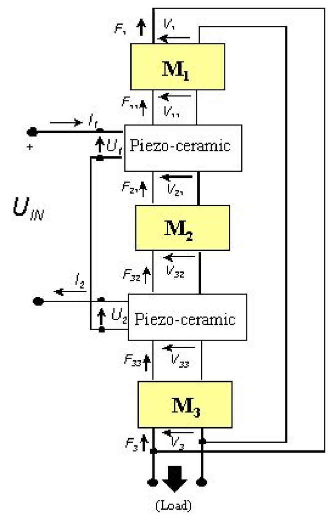
- The simple harmonic motion of an object on a spring can be used to represent on object perched on any oscillator.

  $\omega^2 = (k/m)$
  ω = natural frequency,
  k = spring constant/stiffness, m = mass

- In this case, for a frequency of 2.5 kHz, with a stack of eight piezoelectrics producing a stiffness of 6.25×10^6N/m the mass of the vibrating head can be calculated as 1 kg even. The final head mass was .732 kg after accounting for pushed water.



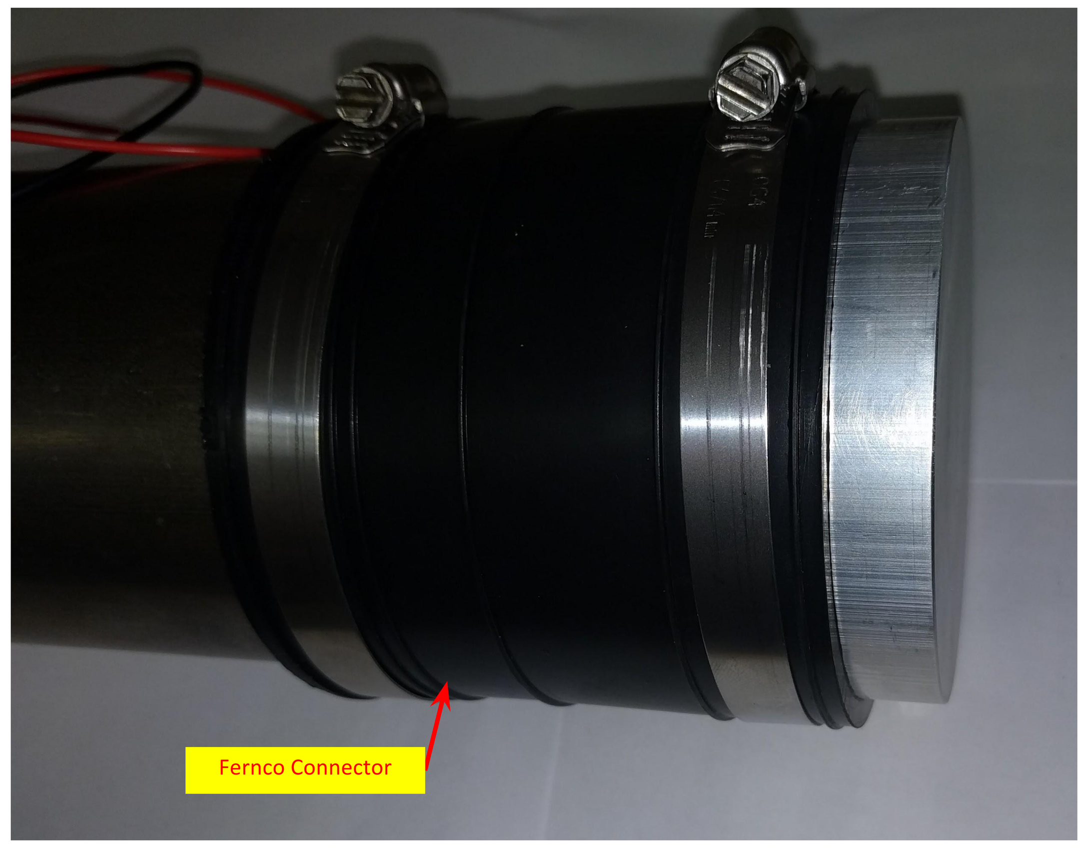
- In order to stabilize the harmonic system the tail mass needs to be at least 4 times more massive so the head vibrates 'independently' of the tail.
  - The hammer transducer is a different style of this type of transducer, it uses more complicated compound pendulum equations to deal with broader wavelengths.
  - The tonpilz is cheaper and easier to maintain.



mpi-ultrasonics hammer transducer

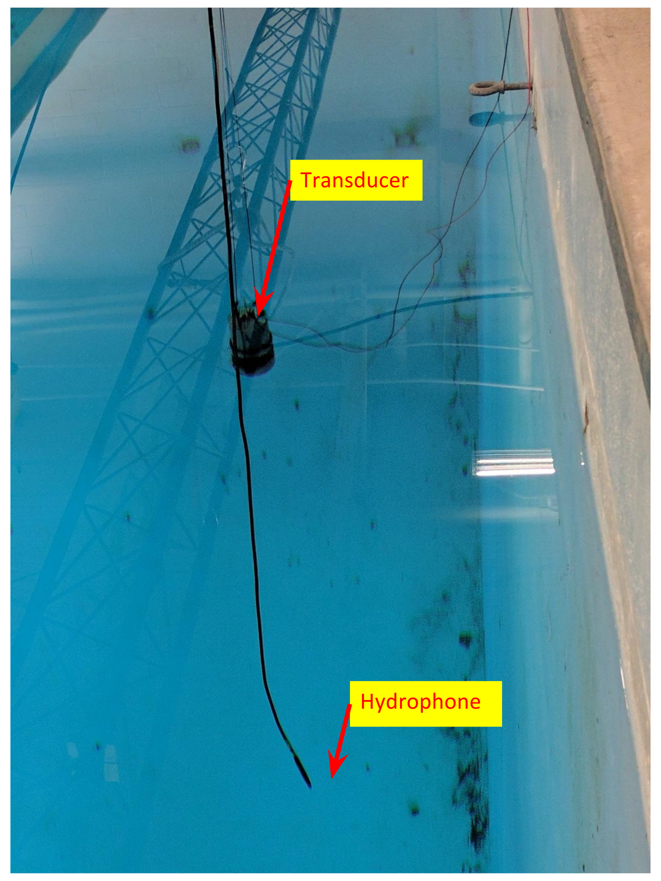
- One column of piezoelectrics was used to prevent the spring constant (k) from getting larger. A larger k would require a larger head mass to balance out the spring.

- The transducer has to be waterproofed to avoid water contacting the piezoelectrics.
- A rubber 1060-33 Fernco coupling was used to cover the space between the head and tail, this space was filled with vegetable oil.
- The bolt holding the head in place can be tightened and loosened to make small changes to the natural frequency.



- The center bolt was coated in shrink tube plastic to prevent the piezoelectrics from grounding into it.
- The insides of the aluminum and steel were coated in lacquer for the same reason.

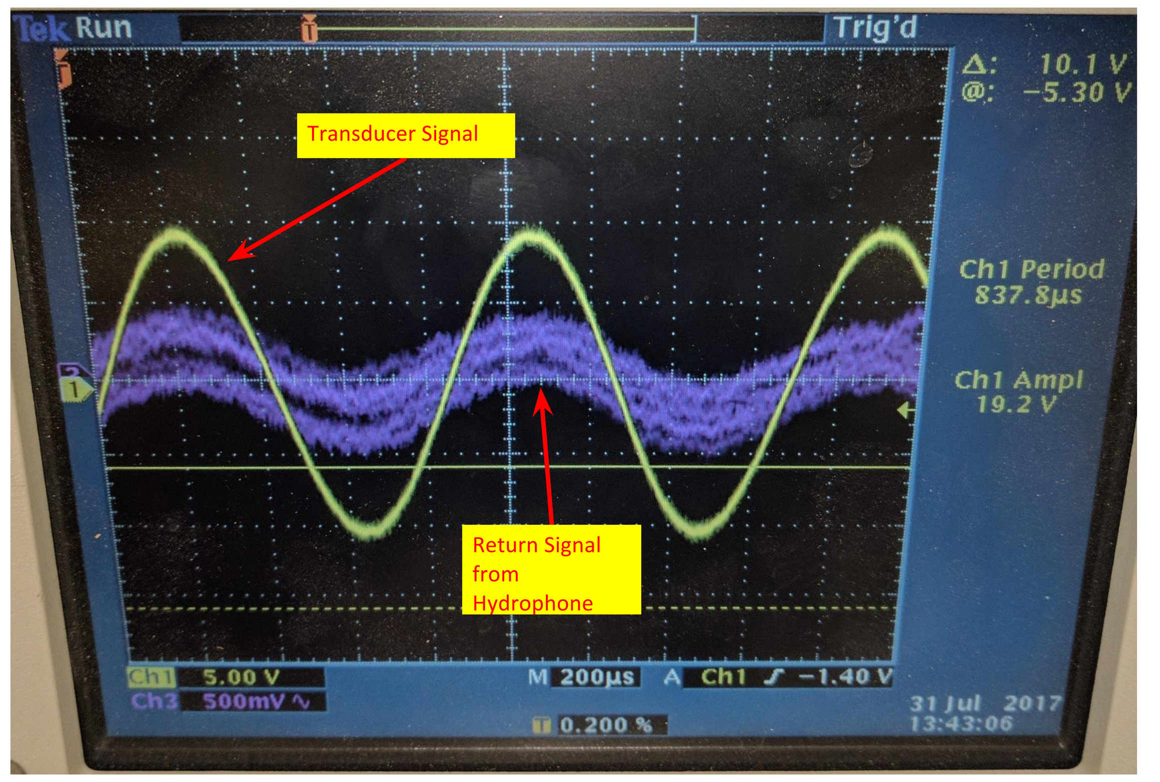
Results



-The transducer was tested in a 6 foot deep tank by sending known signals from the transducer and collecting those signals with a commercial hydrophone.

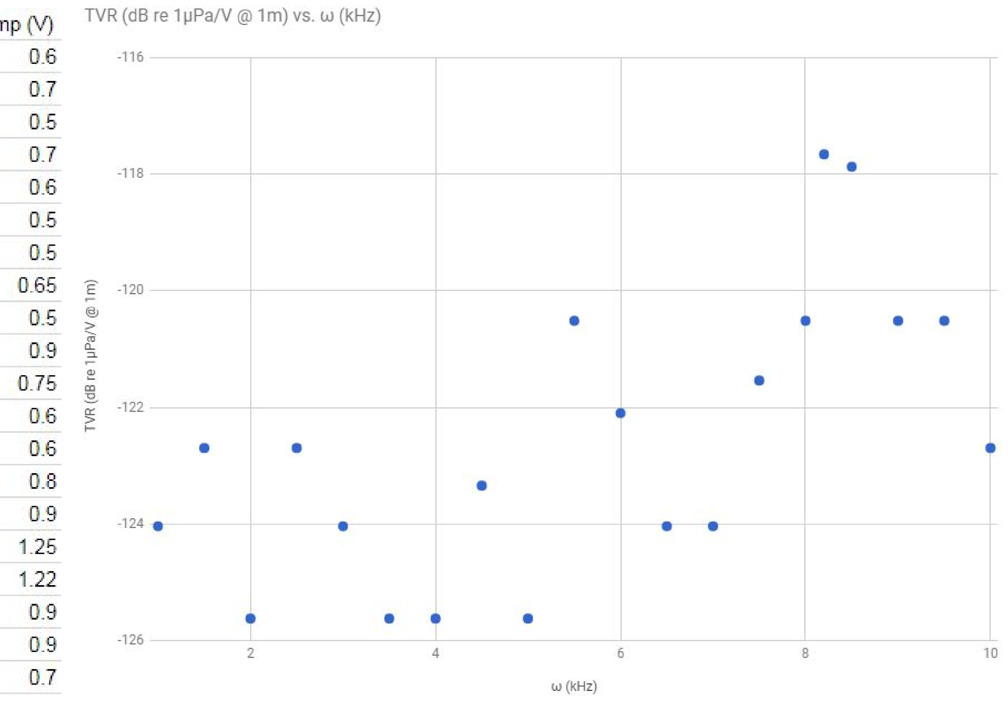
-The signal to the transducer and from the hydrophone were compared.

- The hydrophone returned AC current that was tested at .5 khz intervals between 1 and 9 khz (with some additions). V_{in} was always 19.1 V.
- The strongest frequencies were at 8.2 kHz.



- Transponders are judged by their Transmitting Voltage Response (TVR).
- Calculated by $TVR = SL - 20\log_{10}V_{drive}$
- SL is the original source level and V_{drive} is the voltage running the whole system.

ω (kHz)	Vamp (V)
1	0.6
1.5	0.7
2	0.5
2.5	0.7
3	0.6
3.5	0.5
4	0.5
4.5	0.65
5	0.5
5.5	0.9
6	0.75
6.5	0.6
7	0.6
7.5	0.8
8	0.9
8.2	1.25
8.5	1.22
9	0.9
9.5	0.9
10	0.7



Conclusions

- The transducer functioned as a signal transmitter and was able to remain underwater for several hours with no faults.
- The final cost of this transducer was around $80
- The natural frequency ended up being ~8.2kHz, which is much too high.
- There are significant electrical losses of signal to faults between the piezoelectrics and the head/tail mass.
- The natural frequency could be fixed by either decreasing the stiffness (adding more piezoelectrics) or by increasing the head mass.
- The electrical loss may require a thicker enamel or shellac.

References

Langdon Tarbell, Alec Clemons, Graham Pirie, Mary Beth Sareault, Naomi Clark, Paul Gesel, Peter Abdu
"The Poseidon Project"

Shuyu Lin. Chunlong Xu
"Analysis of a Sandwich Transducer"

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