Research on Techniques for Tritium Sequestration and Removal at UNM

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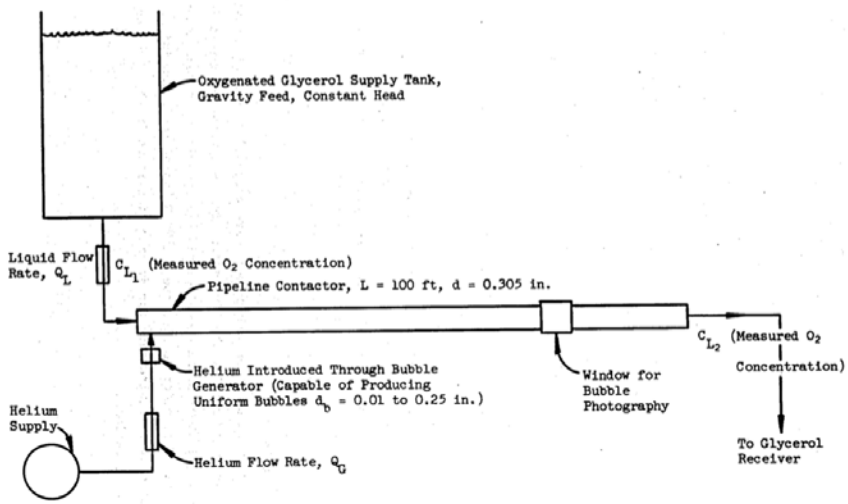
Objectives

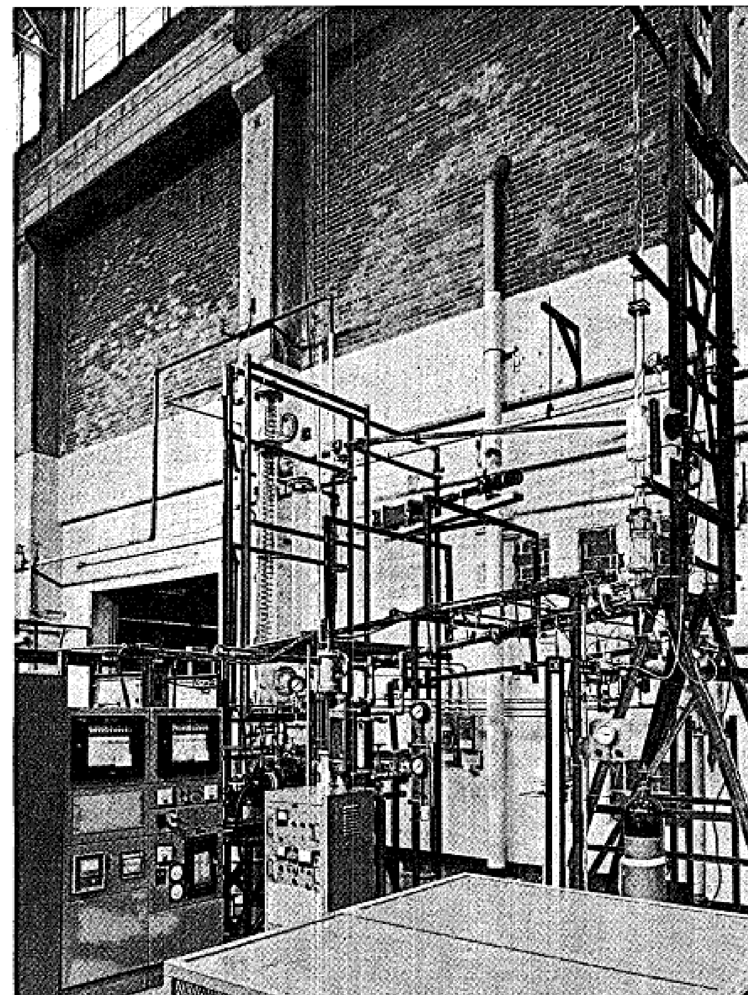
- Previous and concurrent work on inert gas sparging
- Introduction to ultrasonics
  - Theory
  - Current industrial uses
- Inert gas sparging enhancement for salt fueled and salt cooled reactors

Sparging History in the MSR

- In the past, ORNL had investigated the use of inert gas sparging for the MSR project.



Peebles, ORNL-TM-2245 1968



Kress, 1972

Focus of Sonomechanically Enhanced Sparging Research at UNM

- Use ultrasonic effects to increase the efficiency of inert gas sparging
  - Rectified diffusion to increase mass transfer of dissolved gasses into sparging bubbles.
  - Cavitation to reduce size of injected bubbles as well as take advantage of the degassing behavior.
  - Use water and dissolved oxygen as surrogates for molten salts and dissolved tritium.

Ultrasonic Theory

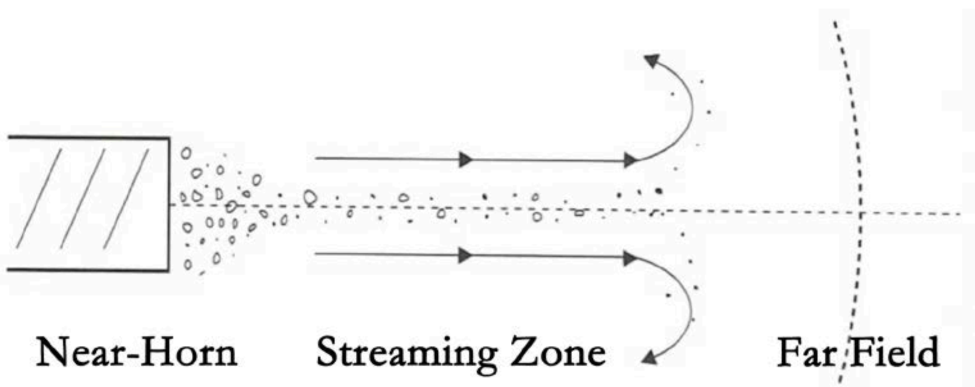
- Ultrasonic basics for process streams.
  - Sonomechanical effects
  - Sonochemical effects
- Industrial examples (non-exhaustive)
  - Metal melt degassing
  - Biological cell disruptors
  - Chemical catalysts

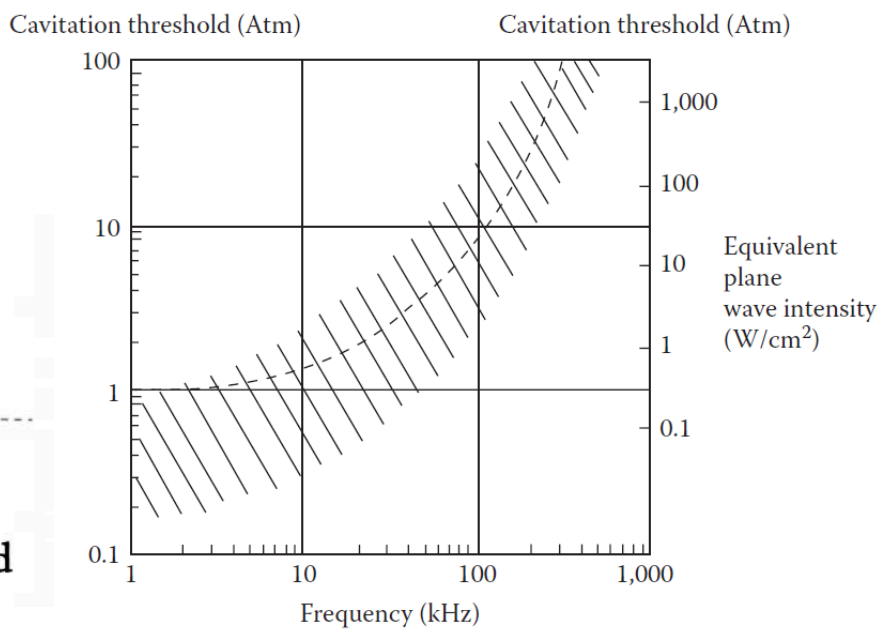
Sonomechanical Effects

- Rayleigh Plesset Equation

$$R\ddot{R} + \frac{3\dot{R}^2}{2} = \frac{1}{\rho}\left[\left(p_0 + \frac{2\sigma}{R_0} - p_v\right)\left(\frac{R_0}{R}^{3\kappa}\right) + p_v - \frac{2\sigma}{R} - \frac{2\eta\dot{R}}{R} - p_0 - p_a(t)\right]$$

  - Determines the cavitation thresholds and bubble dynamics.
  - Determines resonance frequency and size.
- Distinct regions of behavior
  - Rectified Diffusion
  - Stable Cavitation
  - Transient Cavitation
- Radiative Forces





Sonochemical Effects

- Uses high intensity ultrasonics to increase chemical activity by adding energy to the chemical system by cavitation.
  - Cavitation applies localized high temperatures (~5000 K) and pressures (~10MPa).
- General categories of processes:
  - Homogenous sonochemistry of liquids
  - Heterogenous sonochemistry of liquid-liquid systems
  - Heterogenous sonochemistry of liquid-solid systems
  - Sonocatalysis

Initial Rectified Diffusion Studies

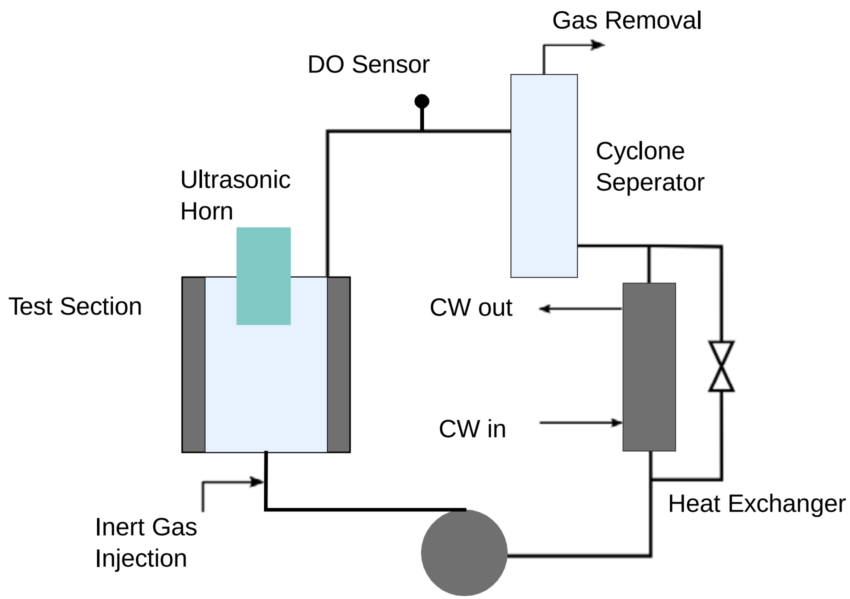
Experimental setup to capture the behavior of sparging bubbles in an ultrasonics field.

The goal is to oscillate sparging bubbles in the rectified diffusion regime.

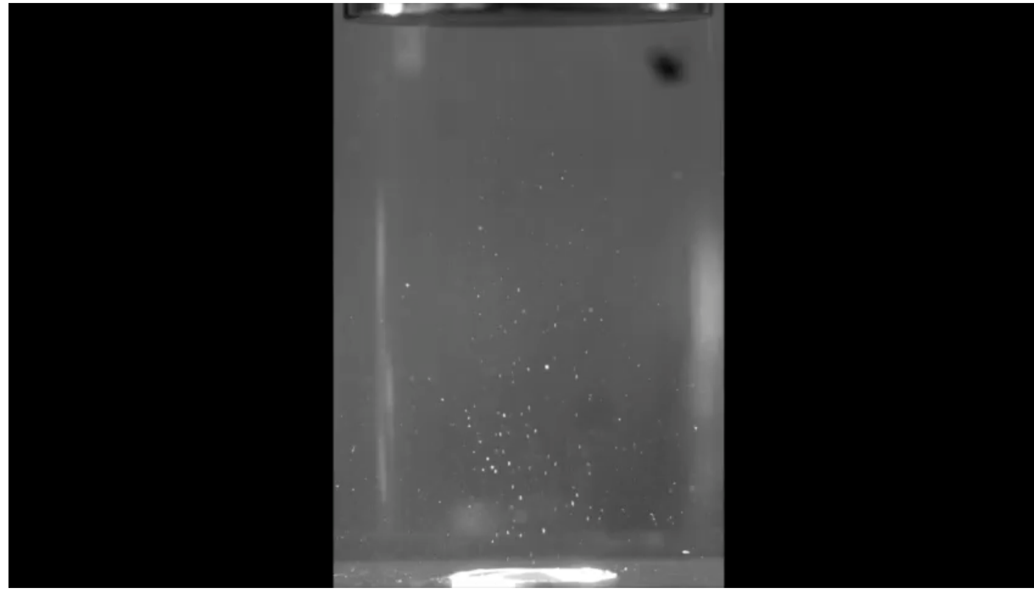
Visualizations of sparging bubbles flowing into an ultrasonic field. Bubbles were observed oscillating at around the predicted diameter.

Experimental Conditions	
Sonic Field	20 kHz, Pulsing
Intensity	~0.085 W/cm^2

Small Scale Test Loop



Small Scale Loop Test Section



Experimental Conditions	
Sonic Field	20 kHz, Pulsing
Intensity	~0.085 W/cm^2
Flow Rate	1.25 GPM
Initial DO	8.0 mg/L
Final DO	3.0 mg/L

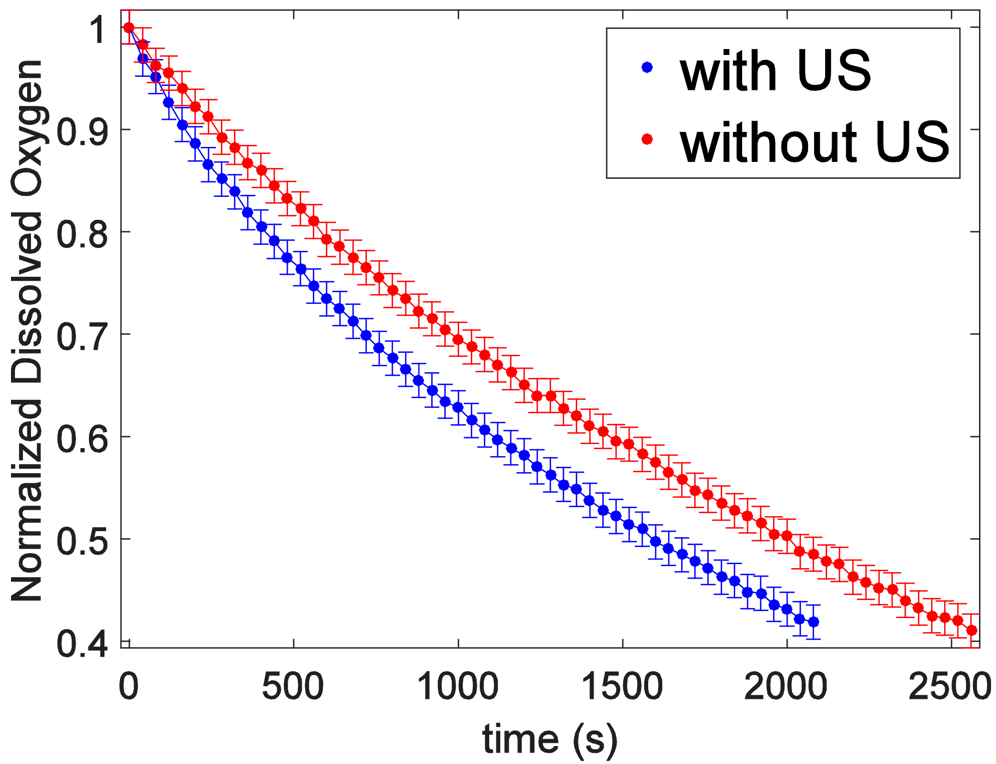
Preliminary Experimental Results for Small Scale Test Loop

Experimental Conditions	
Sonic Field	20 kHz, Pulsing
Intensity	~0.085 W/cm^2
Flow Rate	1.25 GPM
Initial DO	8.0 mg/L
Final DO	3.0 mg/L

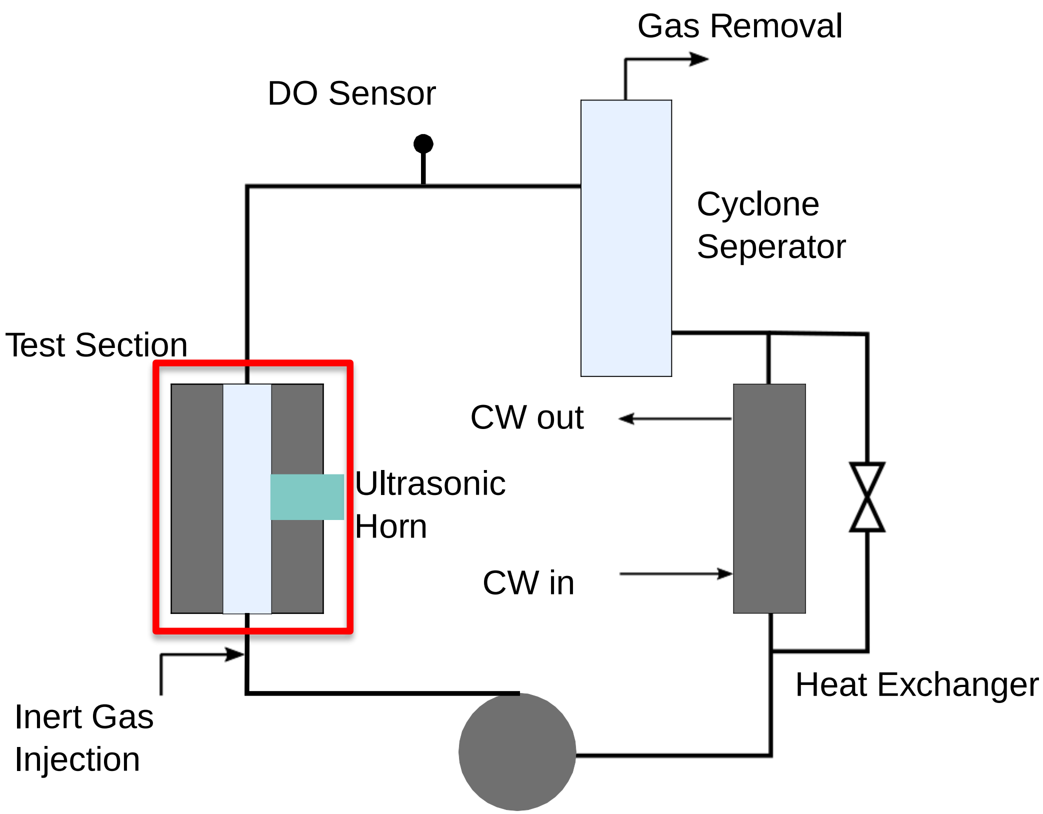
Results:

20% reduction in Degassing time.

Bubbles tend to avoid near field and oscillate in anti nodes and coalesce into bubbles of the resonant size for 20 kHz



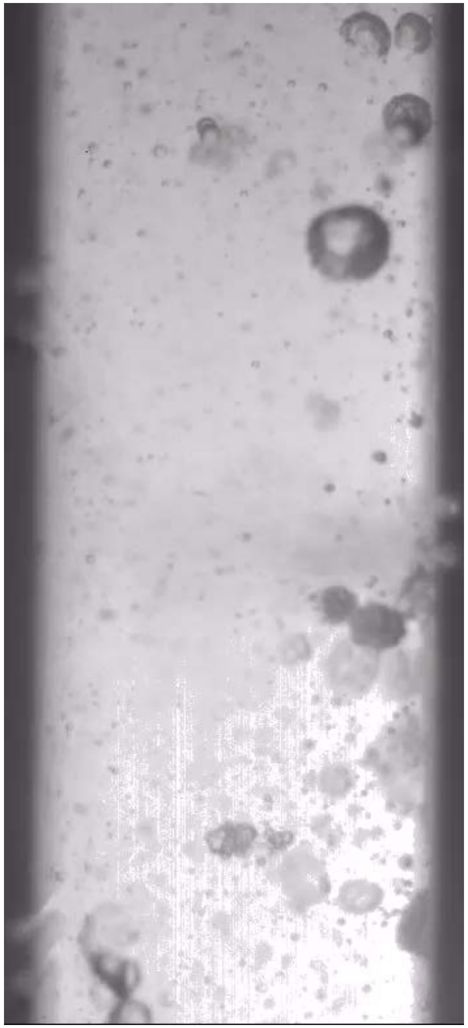
Acoustic Reflector and Cavitation Studies



Preliminary Cavitation Results

Narrow Channel Test Section

Experimental Conditions	
Sonic Field	20 kHz
Intensity	275 W/cm^2 continuous
Flow Rate	1.25 GPM
Initial DO	8.0 mg/L
Final DO	3.0 mg/L



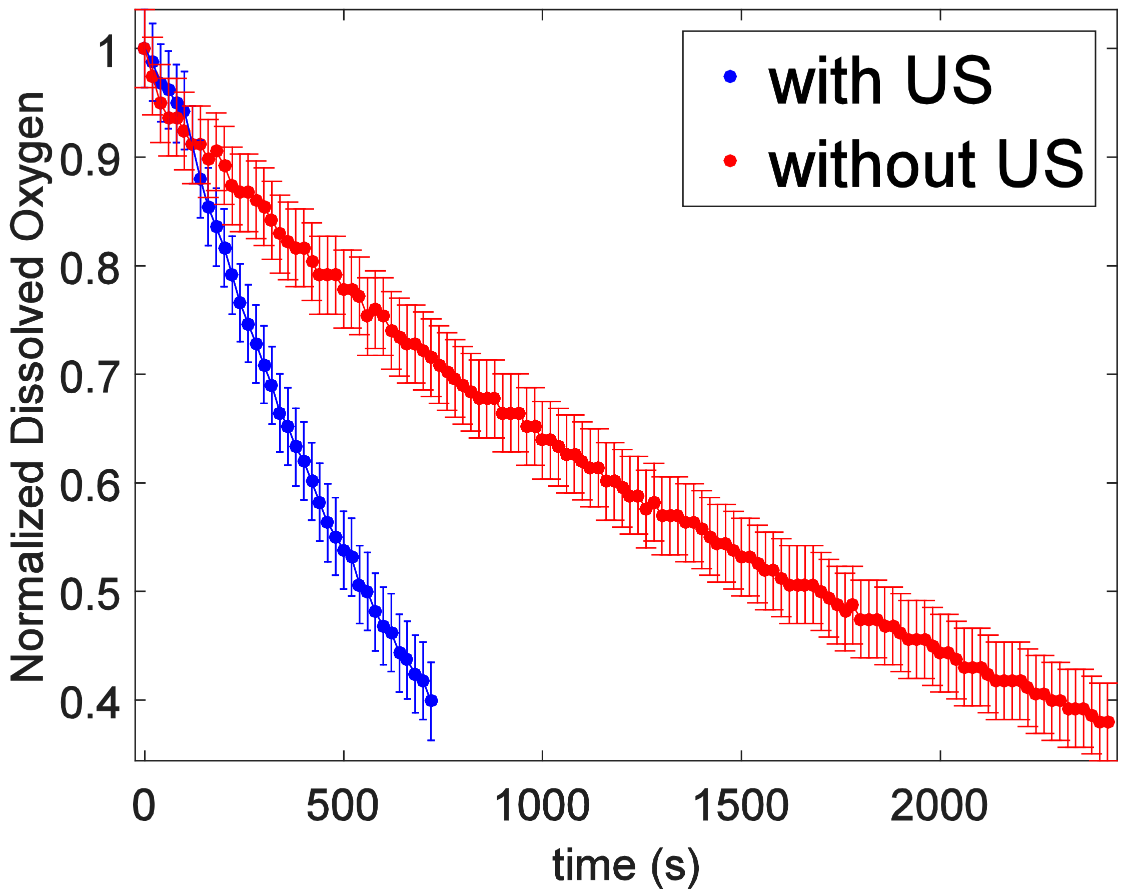
Bubbles no longer avoid near field and can start breaking up into smaller bubbles.

DO Results with Reflector and Cavitation

Result:

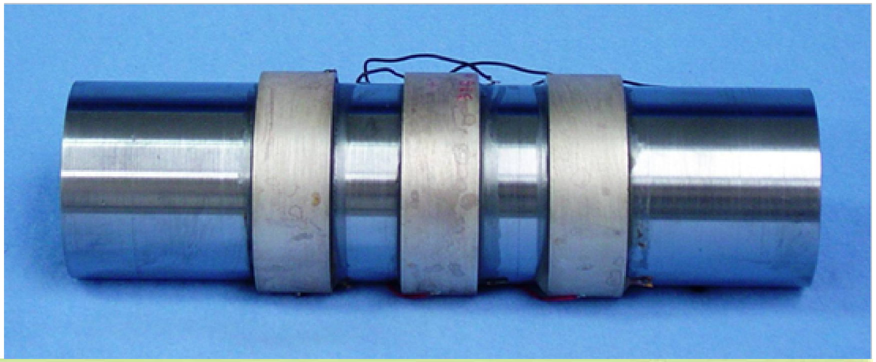
~70% reduction in time for the same DO reduction.

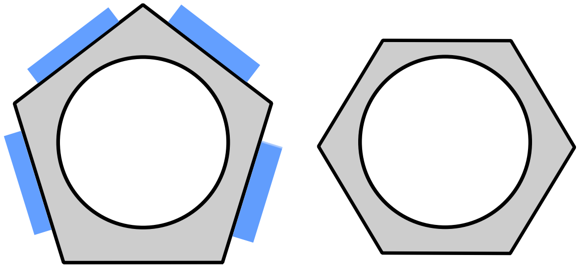
Experimental Conditions	
Sonic Field	20 kHz
Intensity	275 W/cm^2 continuous
Flow Rate	1.25 GPM
Initial DO	8.0 mg/L
Final DO	3.0 mg/L



Next Steps

- Different cell geometries
  - Ring Transducers
  - Indirect Sonication
- Scale up considerations





Challenges

- Materials challenges
  - Erosion
  - Salt Compatibility
  - Activiation
- High Temperatures
- High Radiation Doses

Conclusion

- Discussed the ultrasonic theory
- Ultrasonics has the potential of enhancing a known method of tritium removal for fluoride salt applications.
- Discussed some next steps and future challenges of ultrasonics with molten salts

Questions?