A Preliminary Assessment of Mixing Techniques for Advanced Food Technology

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Background

Long duration Mission Requirements

- Transit times to Mars of at least 3 months
- Launch costs are expensive and based on payload mass

Food needs to be

- Safe
- Nutritious
- Appetizing - taste, smell, appearance, consistency

Various trade studies have examined

- Bring prepared food.
- Bring raw ingredients, process and prepare
- Grow raw ingredients, separate key ingredients, continue processing and prepare.
- Various combinations of above

Currently

- All food is prepared and packaged
- May Require Mixing (by kneading or shaking)
- May Require Heating

Purpose of Mixing

Direct:

- Promote dissolution of solids in liquids and liquids in liquids – Need to account for volume changes associated with dissolution!
- Promote chemical reactions
- Promote homogenuity/uniformity of ingredients

Indirect:

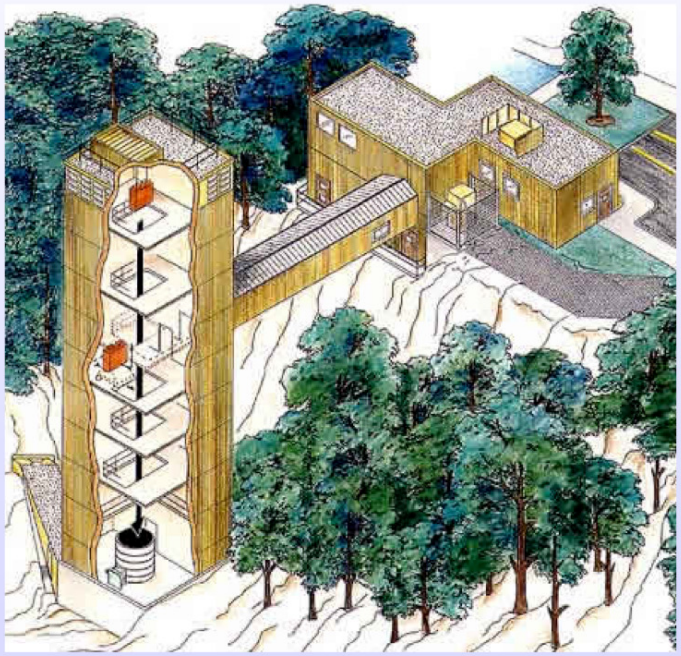
- Gas Ingestion & dissolution into ingredients
  - Atypical concern for most space system designers – try to keep the gas out.
  - Dairy industry spends considerable effort to determine best level of "overrun," ie., amount of gas bubbles trapped within Ice cream to give best flavor ("lightness" vs "heaviness)" and to increase volume per mass of product.
- Promotes convective heat transfer – Stirring the pot avoids burning the contents

Role of Gravity in Mixing

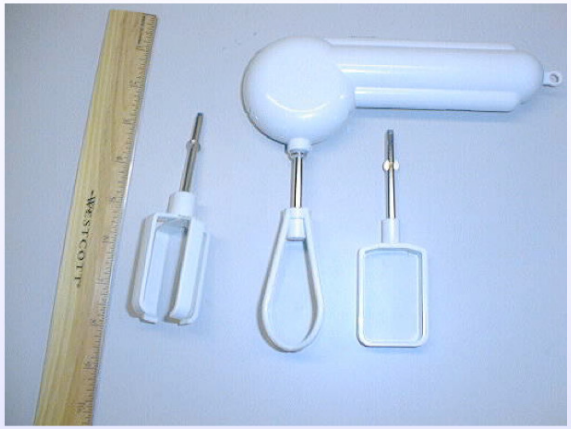
- Traditional COTS mixers "centrifugally accelerate" or "fling" ingredients towards bowl walls.
  - NASA uses centrifugal accelerations to ***separate*** not mix phases in reduced gravity
- To a small extent Gravity affects ingredient trajectories
  - Ingredients confine to bowl.
- Gravity also drains ingredients into bowl bottom where it is picked up by mixer and flung again.
  - Drainage rate of ingredients

Experiment Program

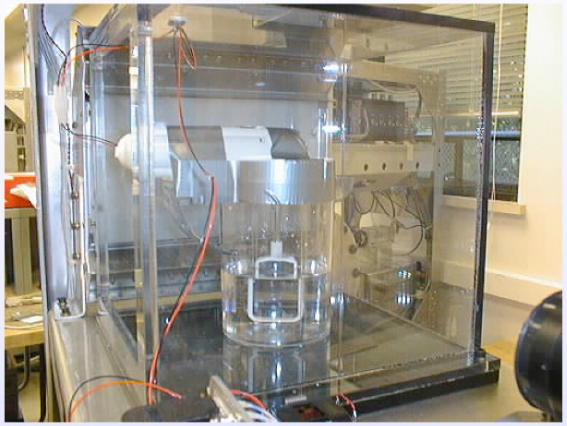
- Tests conducted in 2.2 second Drop Tower
  - Most food preparation will occur in a gravity environment, ie Mars (0.375 g's) or the Moon (0.17 g's)
  - Limiting case of G = 0 or 10^{-6}.
- Utilized Education Drop Rig
  - Fabricated polycarbonate box to provide secondary fluid containment
  - Utilized COTS mixer and bowl assembly
    - Powered by 2 "C" cells.
    - On/Off function was integrated into Drop Rig's control



Test Setup

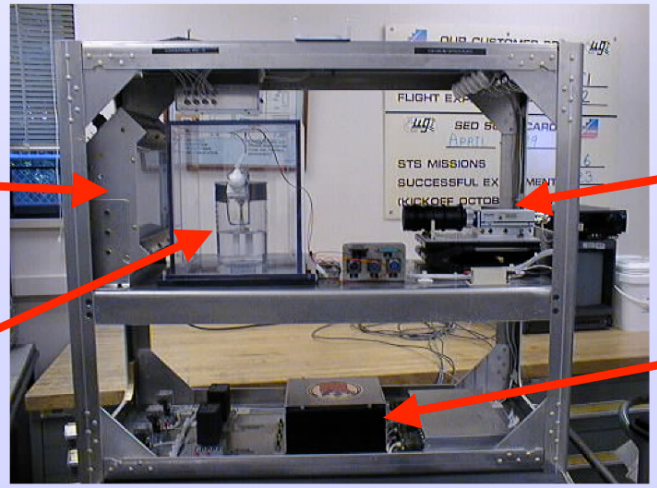


Battery Operated Mixer



Mixer in Containment Box

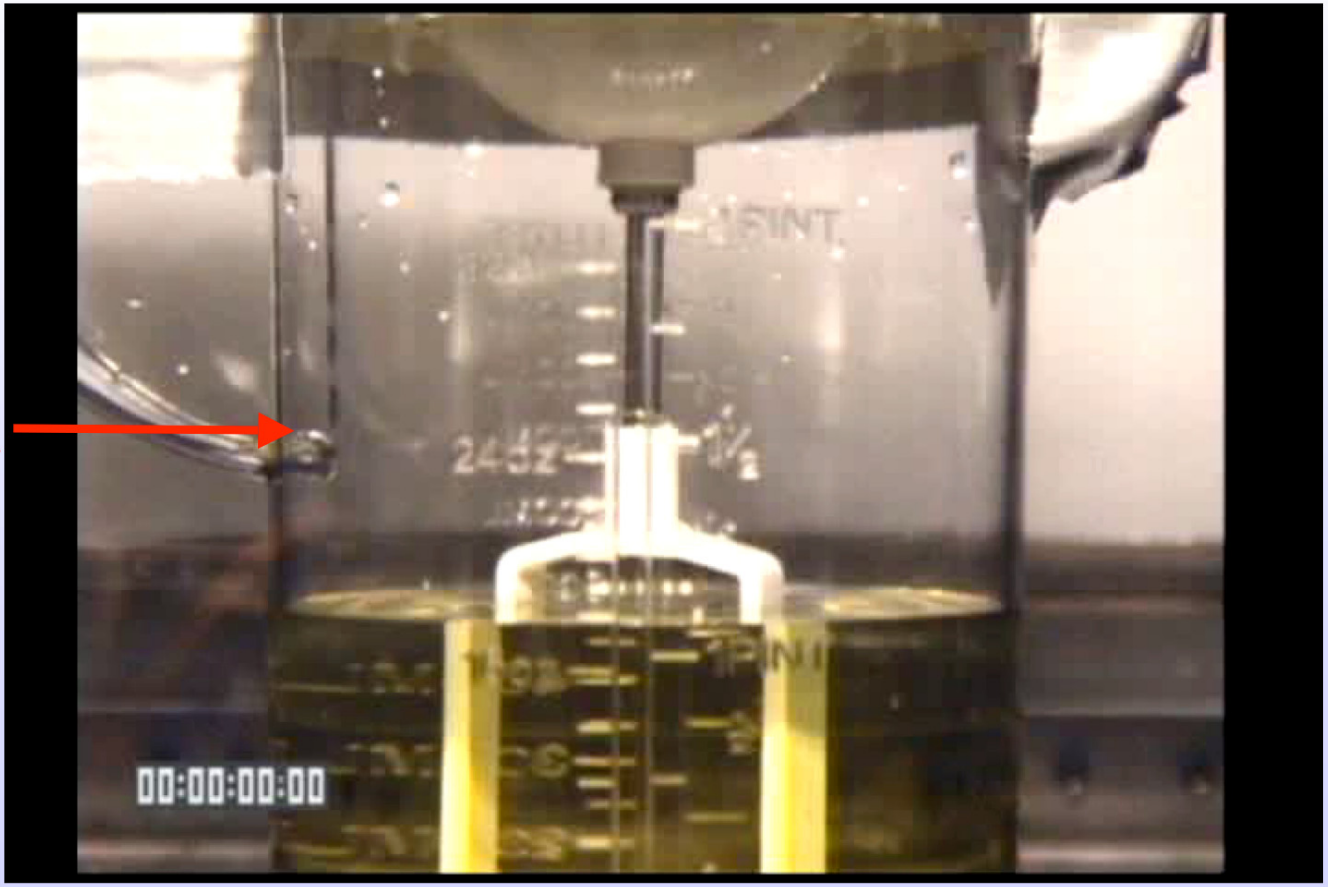
Setup in Education Drop Tower Rig



Initial Test Results

Liquid Only

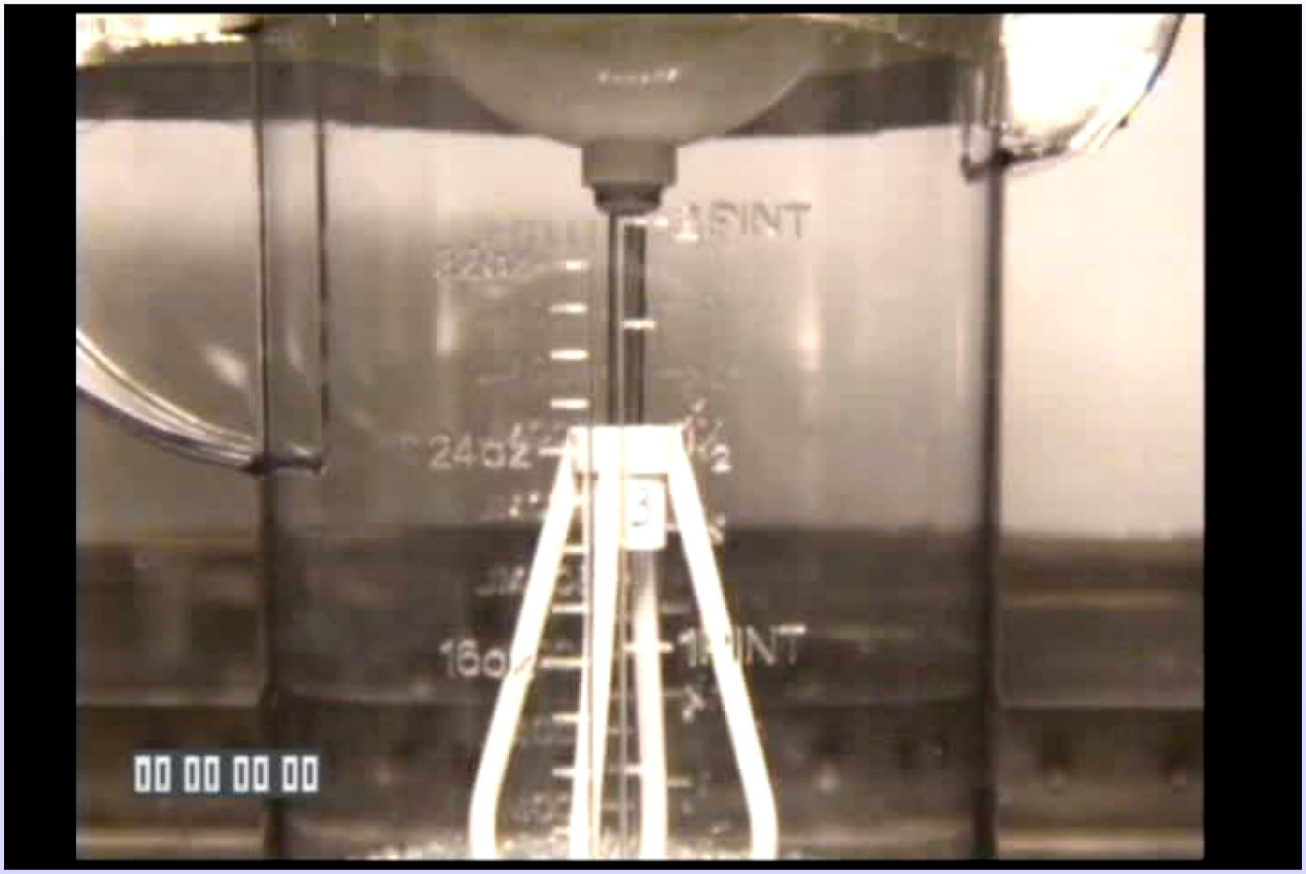
Watch Corner



Containment and Liquid Recirculation are issues!!!

Initial Test Results

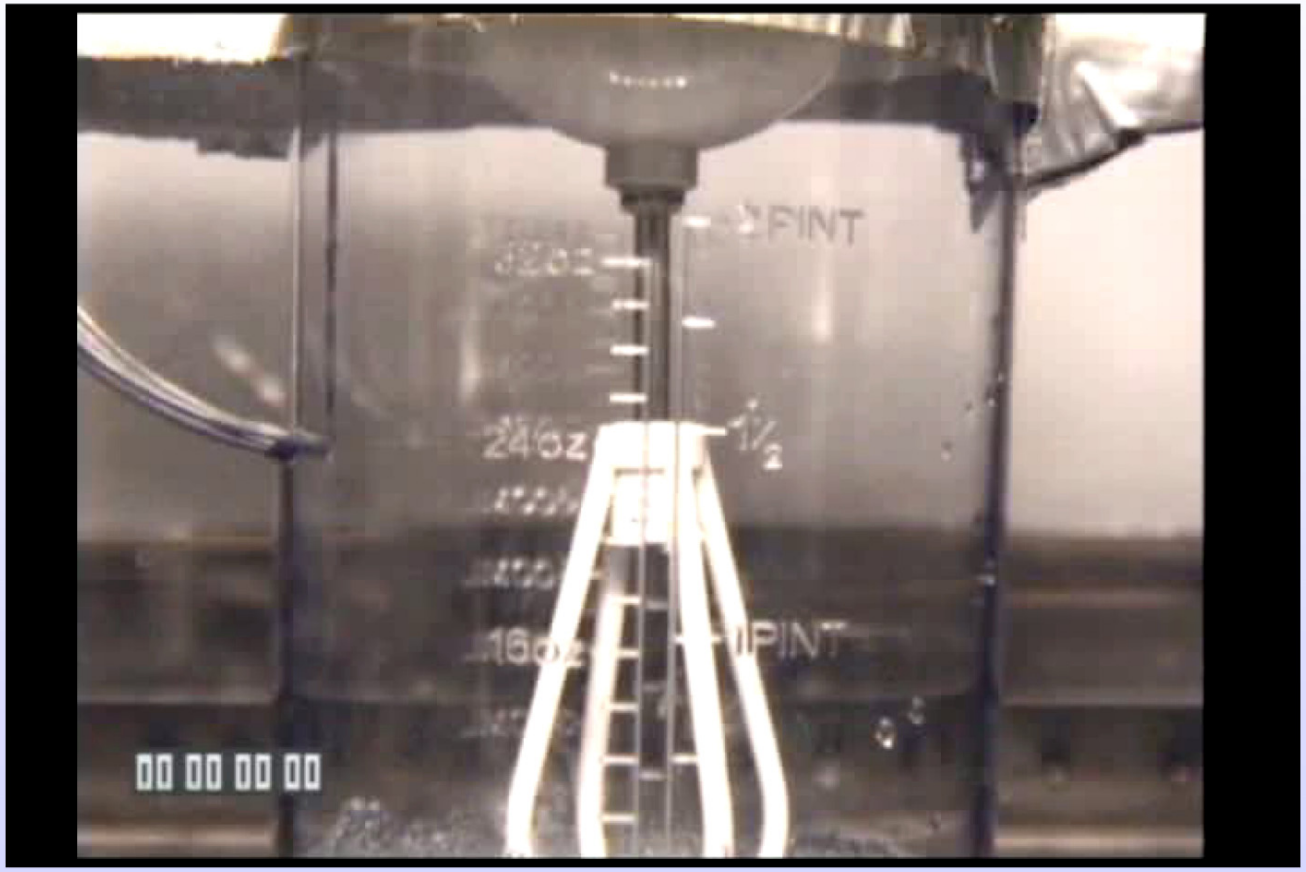
Solids Only (3mm Glass Beads)



Containment is THE issue!!!

Solids & Liquids

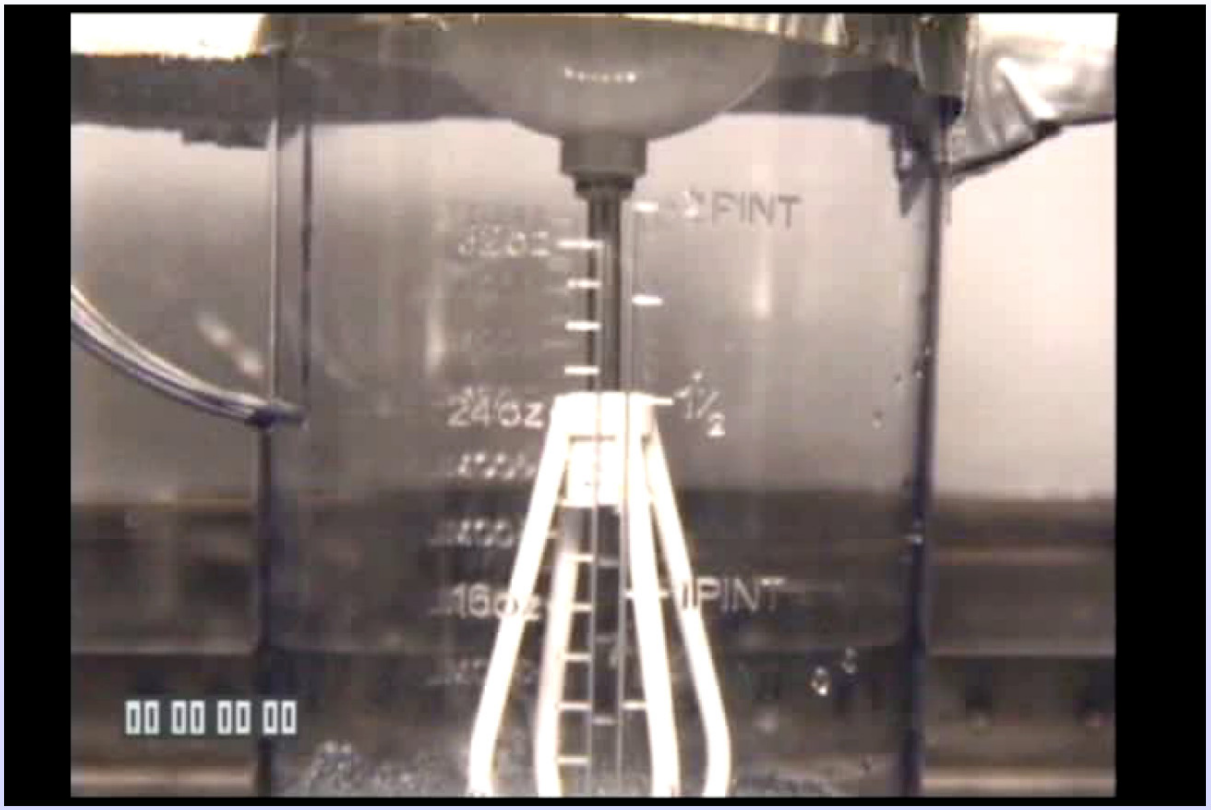
Minimal Liquid – Filled to Just Above Bead



Liquid freezes almost all stirring

Solids & Liquids

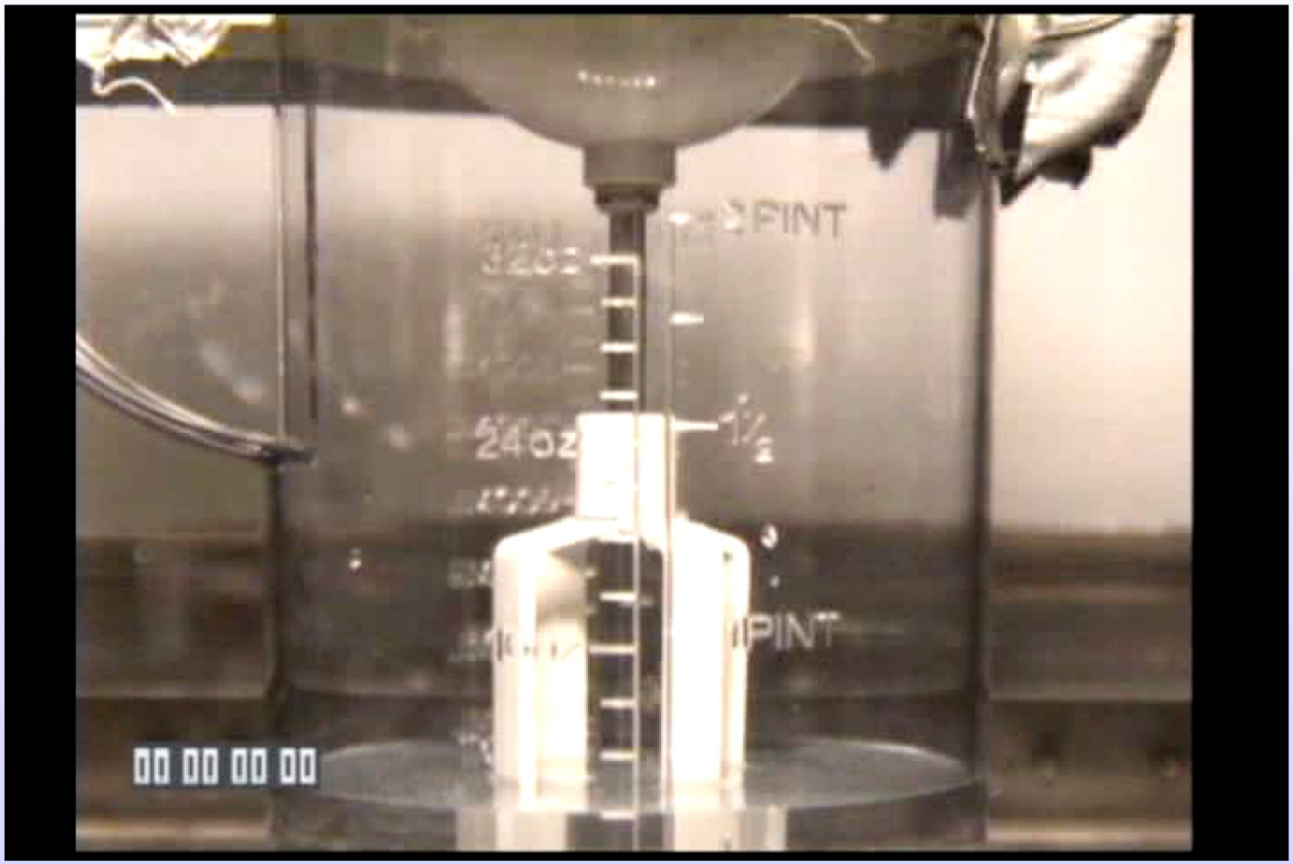
Minimal Liquid – Filled to Top of Bead Packing



Liquid Reduces Amount of “Splatter”

Solids & Liquids

Even MORE Liquid



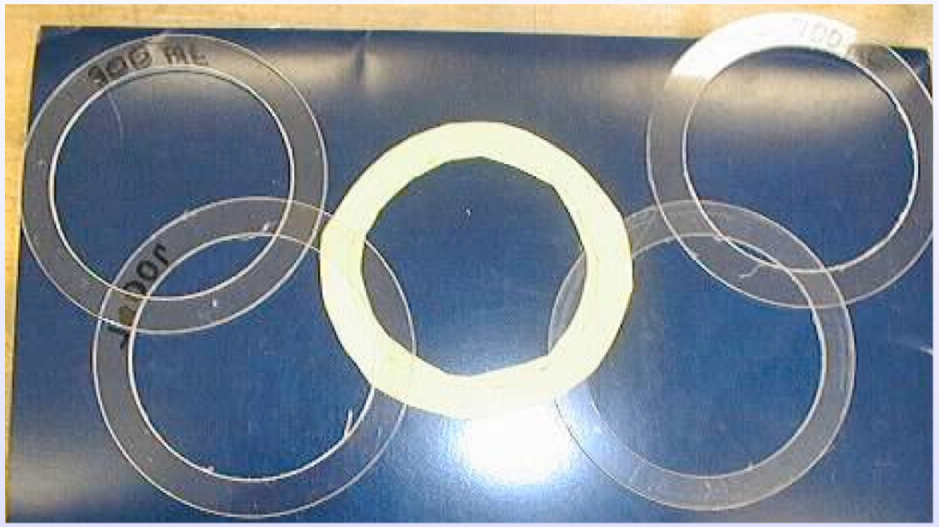
Liquid & Solid Mix Behaves similar to Viscous Liquid

Fluid Containment

- One common technique to limit fluid motion in microgravity within a tank is the use of a “pinning” edge.
- Pinning edges have been effective when fluid motion is perpendicular to edge
- Have never been tried with significant fluid motion that is nearly parallel to edge

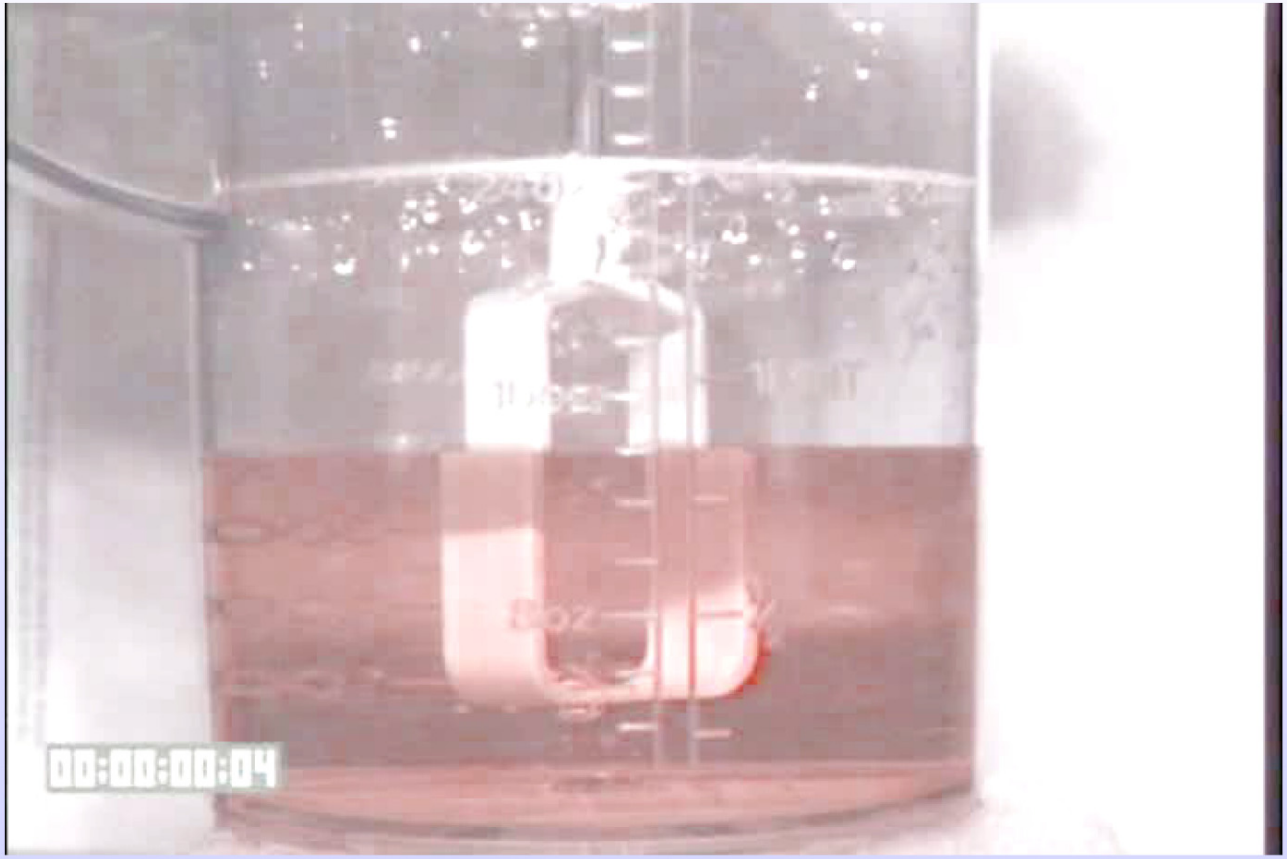
Pinning Edge Fabrication

- "Sharp" pinning edges fabricate from acrylic sheets 1.6 mm thick to fit in "tapered" bowl at different locations
- "Rounded pinning edges from Tygon tubing taped into position in bowl



Test Results

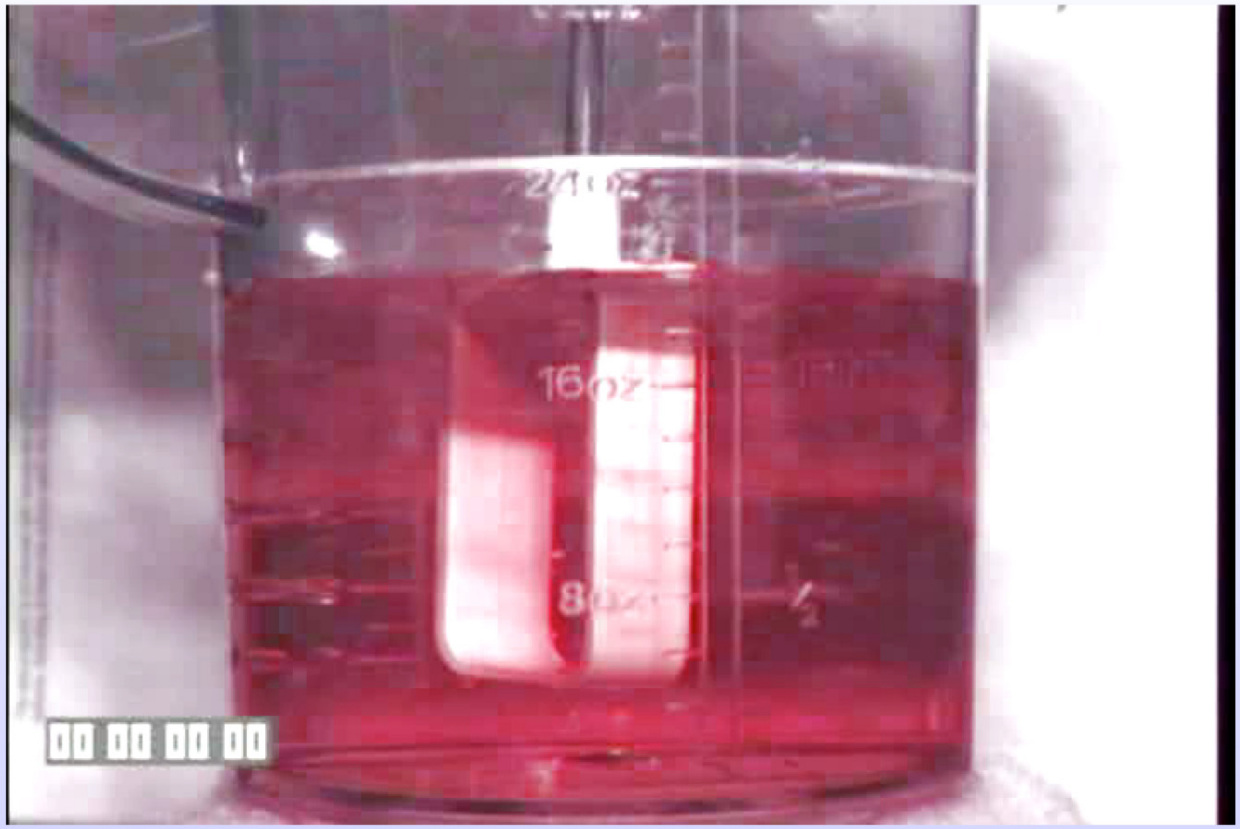
Significant Distance Between Edge and Fill Level



EUREKA!!!!

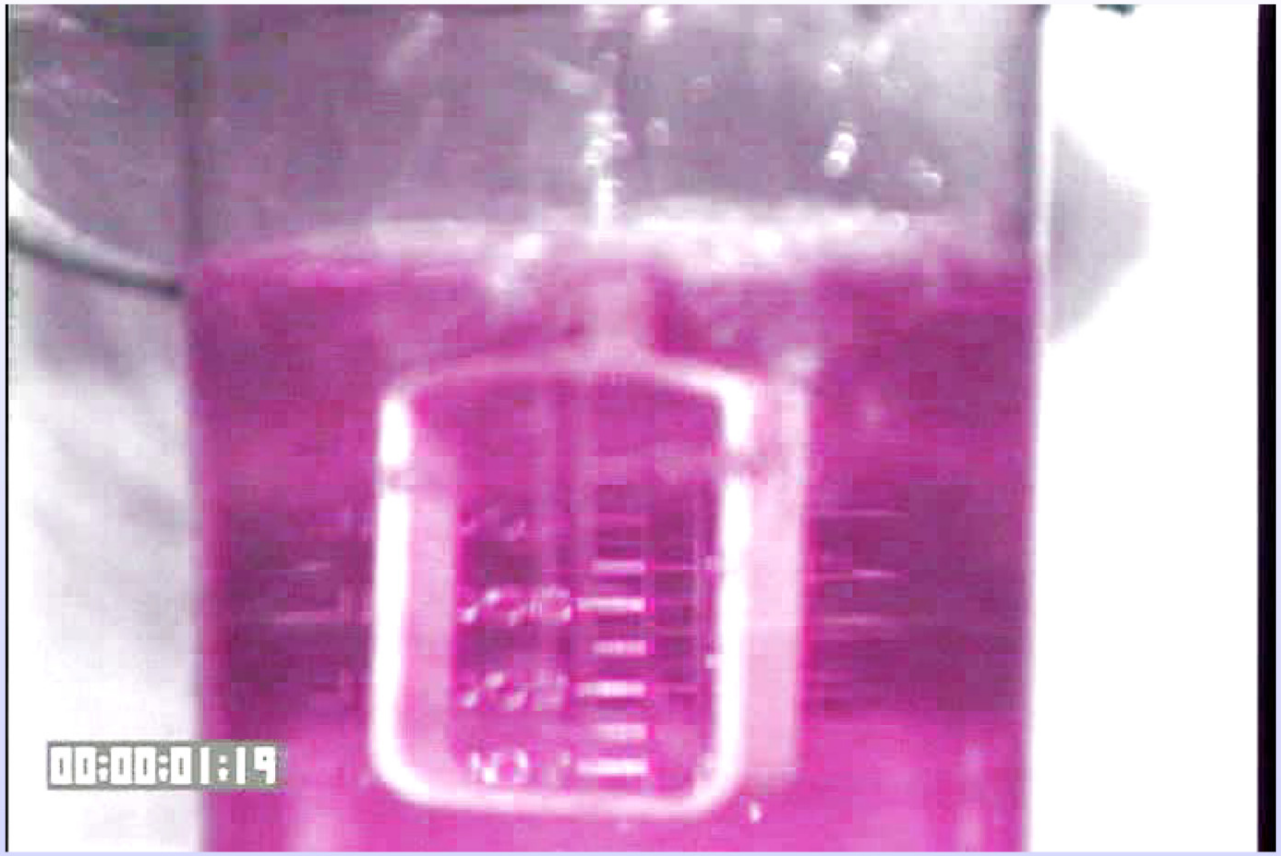
Test Results

Fill Level Close to Edge



Pinning Edge Restrains Liquid BUT
2.2 Seconds is not enough to make final call!!!

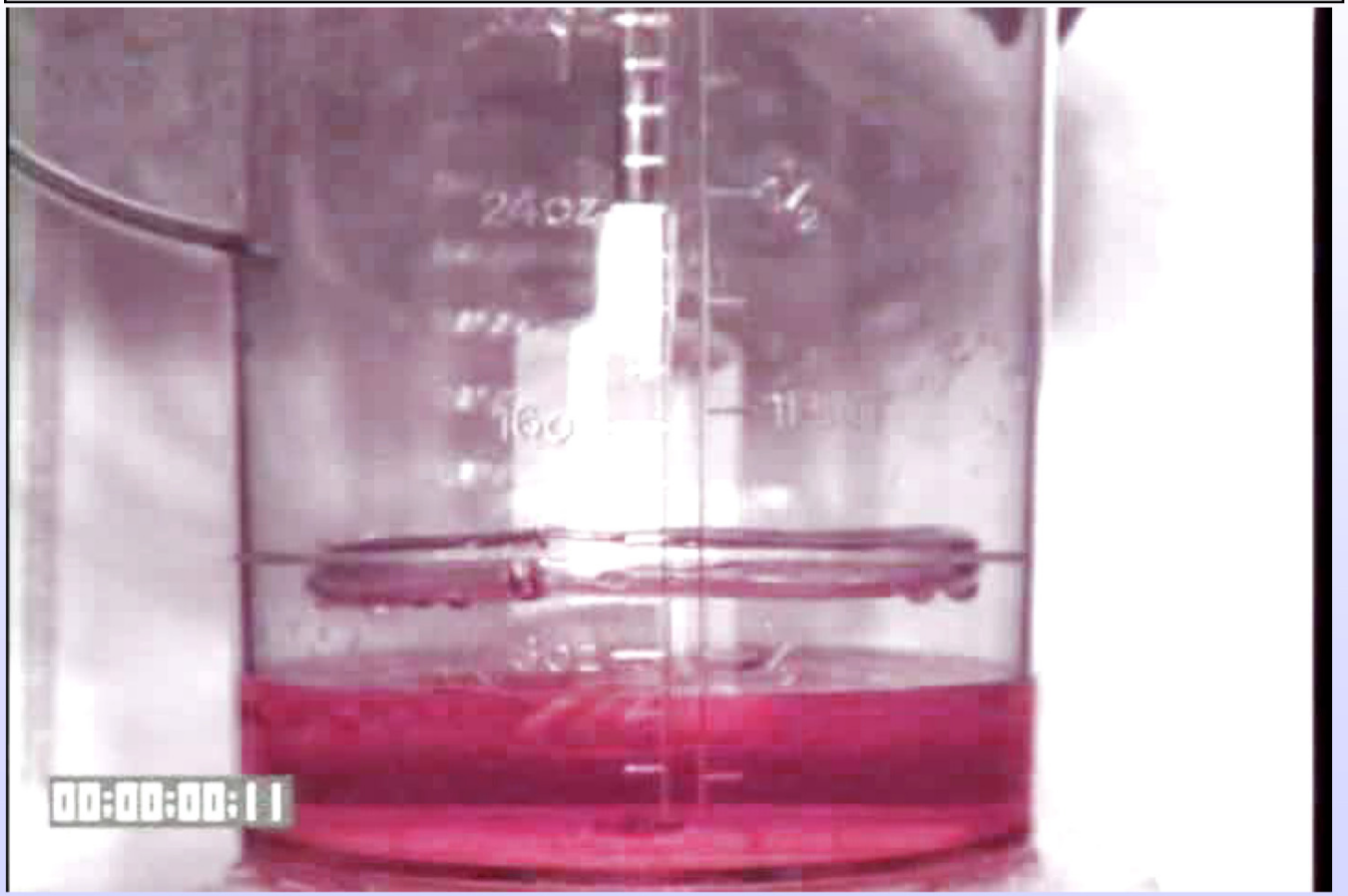
Test Results
Fill Level At Edge



OOPS!!!
Air from above Edge displaces liquid during mixing!!

Test Results

Exposed Mixer Blade



What a Mess!!!

Conclusions

- Some containment of solids appears feasible if they are “wetted down” but this will require a higher “torque” mixer.
- Pinning edges (sharp and round) appear to work provided enough distance is left between pinning edge and fill level.
- “Exposed” mixing vanes above pinning edge contribute to splatter ⇒ Use different (paint?) mixer to reduce vane height

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