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CORRELATION OF BUBBLE RISE VELOCITY AND VOLUME (U)

by

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Classification: Unclassified

Authorized Derivative Classifier: J.P. Faraci 7/25/91

My project was conducted at Westinghouse's Savannah River Laboratories (SRL). The goal of SRL is to make certain that the modifications on the reactor are safe for those working at the plant as well as the general public.

One of the steps needed to insure safety is the knowledge of the occurrences that result from a plenum pipe breakage. When a plenum pipe breaks, two things occur:(1) air is sucked into the pipe and is trapped in the cooling water; and (2) water used to cool the fuel rods is lost. As a result of these occurrences, the water is slowed down by both the loss in water pressure and the upward force of air bubbles pushing against the downward force of the water, as Figure #1 illustrates.

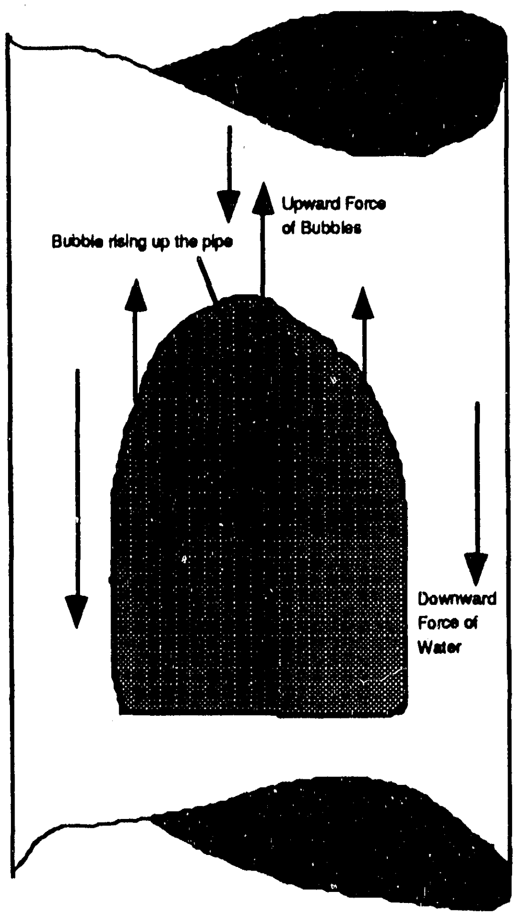
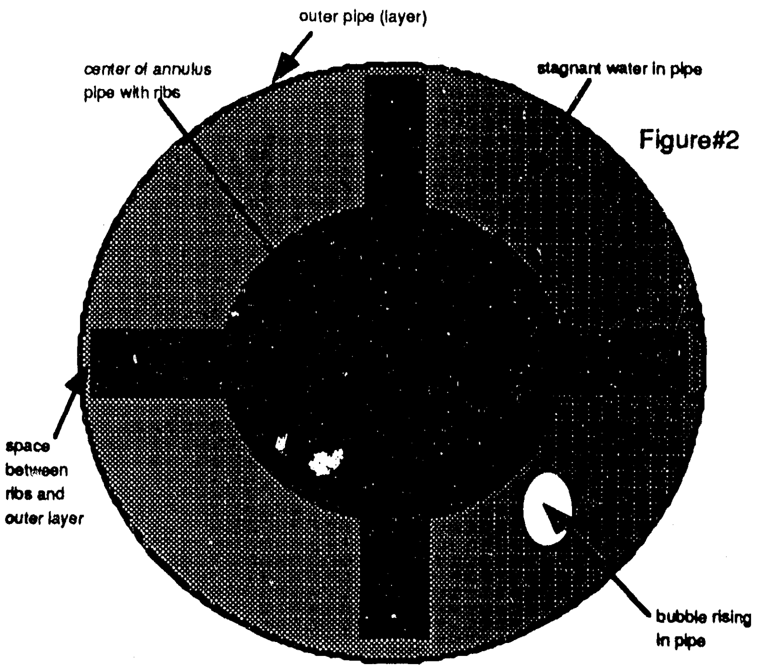


Figure #1 - Bubble rise in pipe

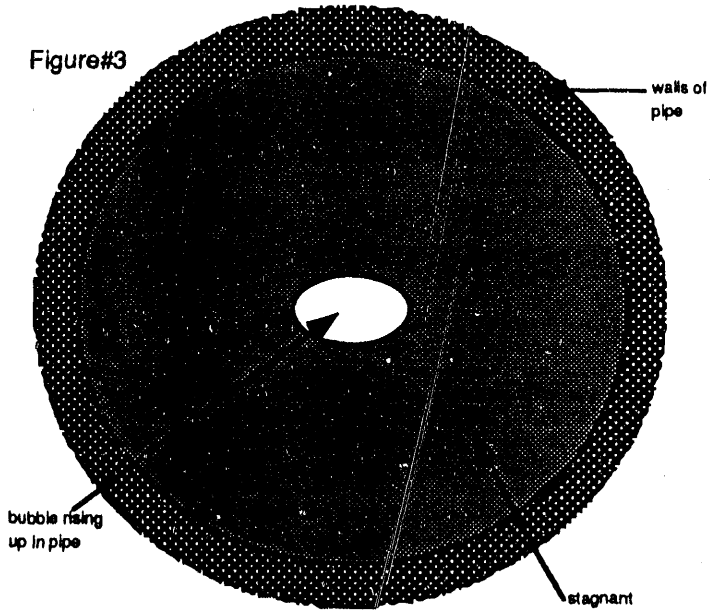
Tests using annular and regular pipes have been conducted at other research facilities. Their research has shown that the larger the bubble the larger its terminal velocity. At a certain volume, the velocity of the bubble begins to level off and eventually hits a maximum velocity which an increase in volume of the bubble cannot change.

The tests show that the shape of the pipe also determines the bubble's velocity. Bubbles in annular pipes have a faster velocity than those in regular pipes when correlated with the bubble's volume. In these tests the areas of the pipes are the same thus it stands to reason that the geometry of the pipe helps to determine the bubble rise velocity.

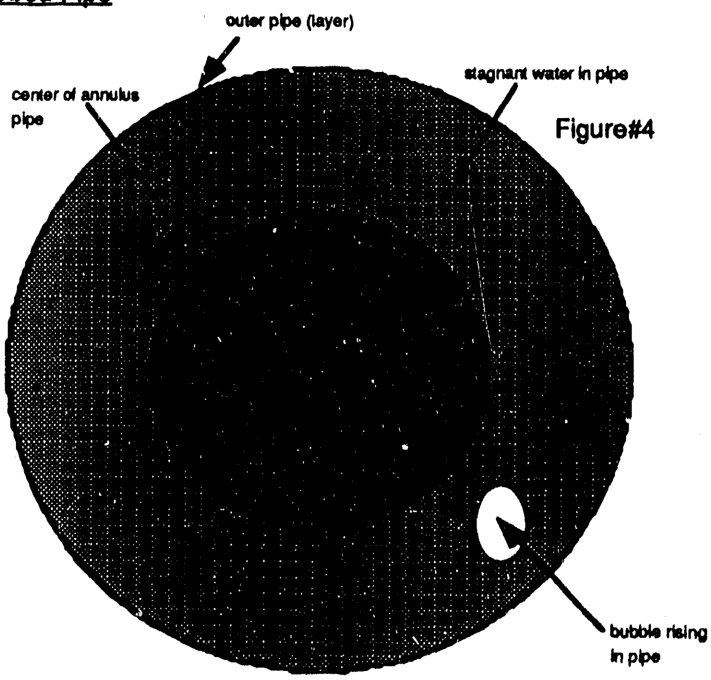
Though research has been done on bubble rise rates in annular and regular pipes, no tests have been conducted with annular-ribbed pipes, to the best of our knowledge. Since the reactor at SRS contains annular-ribbed pipes, we at SRL find it important to know the correlation of bubble volume and its velocity in an annular-ribbed pipe. We need this information so that we can compare it to earlier tests using regular and annular pipes in other tests (Figures #2, #3, & #4 show different kinds of pipes).



Annular-Ribbed Pipe



Regular Pipe



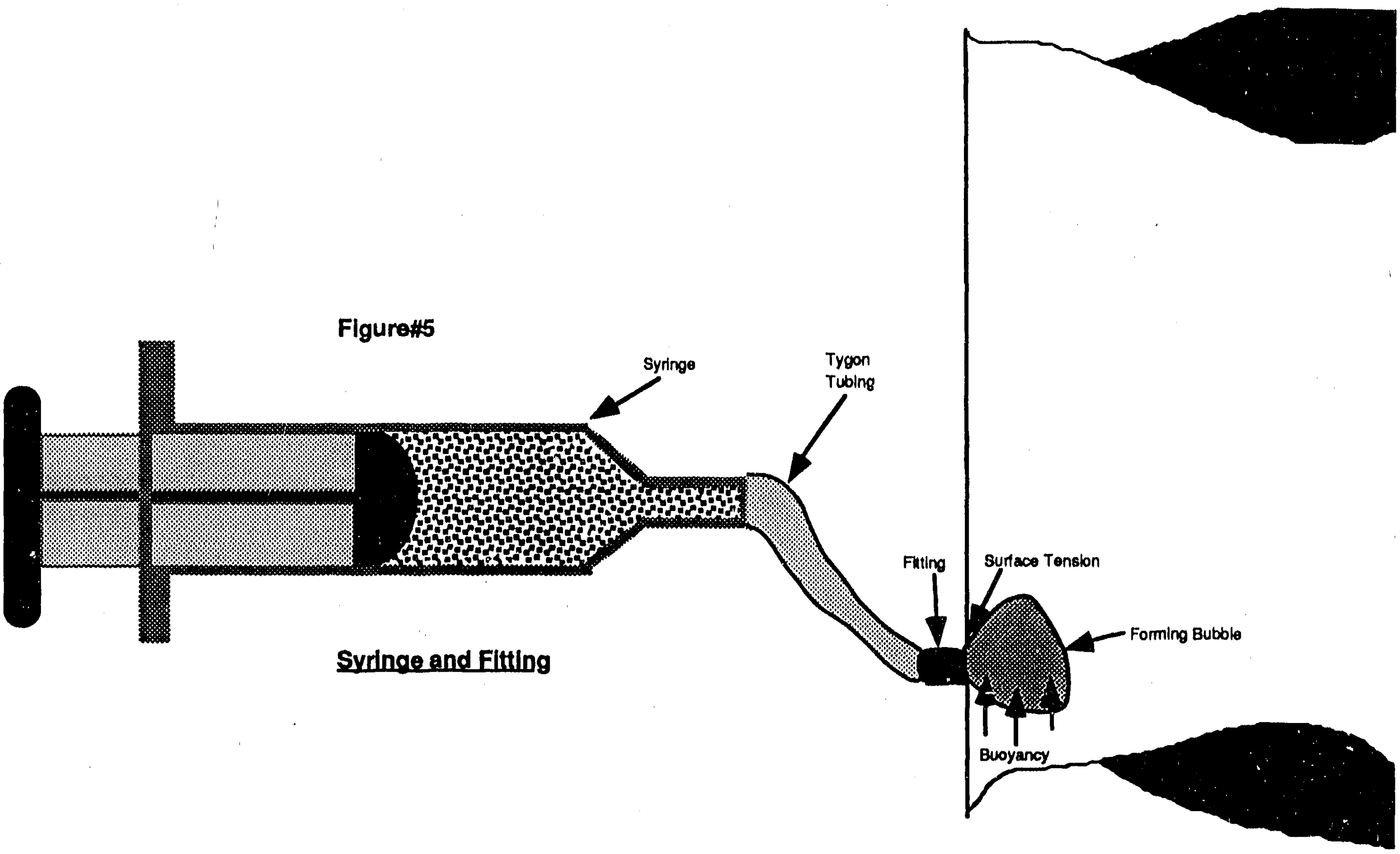
Annulus Pipe

The project that I have been given is in direct compliance with the mission at SRL. It requires me to conduct tests to find the bubble velocity in an annular ribbed pipe filled with stagnant water. The pipe that I work with is Rig C and is normally used to conduct tests that require flowing water in an annular pipe. Along the pipe, four rings, with fittings, are placed thirty three inches apart of each other. These rings have fittings that are used to introduce air in the system.

Before I had been assigned this project, two engineers tried to conduct a similar test with an uncalibrated squeeze bottle connected to a fitting on the ring at the bottom of Rig C. Since the squeeze bottle was uncalibrated and did not show any volume markings, volume was estimated by the use of filming the bubble on a videocamera and recording its length and width. When a bubble would break-up, the run was considered invalid and data was not taken. The run is invalid because the velocity of two bubbles are slower than one bubble of equal size. Their observations show that as volume increased so do the chances of bubble break-up. Eventually, the chances of bubble breakup increases to a point that it becomes impossible to take measurements on one whole bubble. The test done by the engineers ended with few valid points at a low measurement of volume.

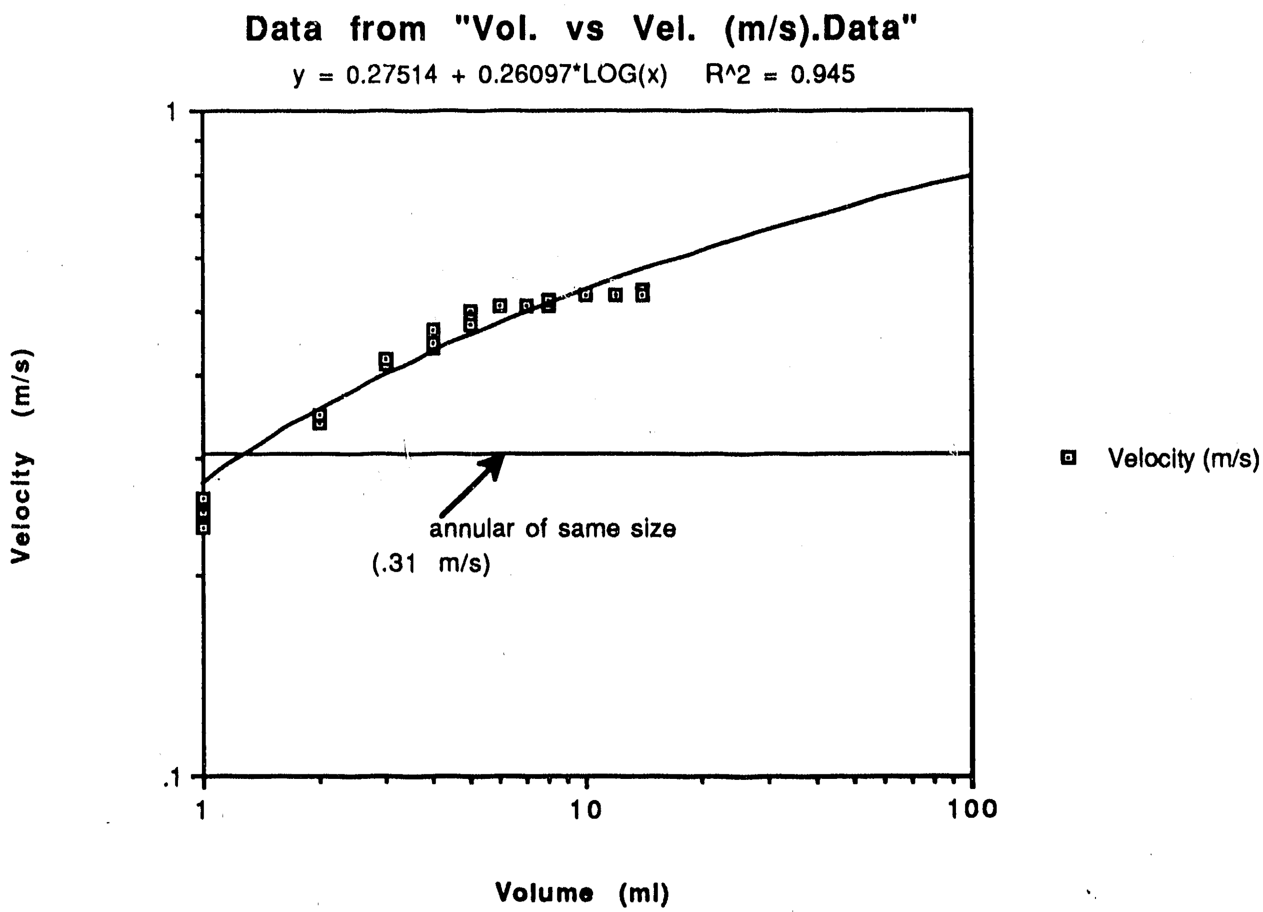
After reviewing their test, I came up with a few ideas on how to limit bubble break-up. The observations of Andrea Kielpinski show that bubble break-up occurs at the entrance of the air bubbles. Based on her observations, I decided that the bubble break-up occurs because of buoyancy force becoming greater than the surface tension of the bubble. Before I was able to run any tests of my own, I came up with three ways of keeping the bubble from breaking up when it enters the pipe. One way is to add on a different kind of fitting to the pipe which allows me to enter the bubble at a different angle. My reason for supporting this hypothesis is the fact that this increases the surface area of the bubble thus increasing the surface tension to a desired size. My second idea is to build an apparatus at the bottom of the pipe which injects enter a certain volume of air in the pipe at one instant. This nullifies the effects of buoyancy force on the bubble. My third solution is that the effect of buoyancy force is less if a heavy, viscous nonsoluble chlorinated hydrocarbon is used as the liquid in the lower portion of the pipe. Since the liquid that the bubble is formed in is more viscous than water, the buoyancy force proves to be small enough to form large bubbles. After reviewing my options, I decided that my first two ideas did not fit with the options I had in solving this problem. This is because I was not given enough time to modify or completely rebuild another rig. My third idea achieves the goal of forming a large single bubble but produces an error in the curve thus causing the bubble to rise slowly up the pipe.

Before resigning myself to having a test with a known error, I decided to conduct a few tests with the rig in a similar fashion to the test with the two engineers. I modified the test by using a syringe with markings of designated volumes. I also calibrated the syringe by using the volume = mass/density equation. This is in hopes of having a more accurate knowledge of the volume of the bubble. Other than using a syringe instead of a squeeze bottle, the test that I conducted is exactly like the one conducted by the two engineers (As Figure #5 shows).



For the first few bubbles that I inserted, no data is taken. This is because I wanted to observe what the bubble does while rising up the pipe. I hoped to use my own observations as a tool towards solving the problem. What I observed is that even at small volumes (i.e. 2 ml) the bubble fills the width of the channel in which it is injected. Beginning at 4 ml, it seems that slugs begin to form in the channel. At 4 ml, bubble break-up begins near the top of the pipe (i.e. 100 inches). Later observations show that break-up caused by the bubble hitting a rib results in a seepage of air in the channel on the other side of the rib. As the bubble increased in volume, the seepage of air into another channel happens sooner and sooner.

Based on my observations in my earlier test, I decided to take data and correlate bubble volume to bubble velocity. Unlike the test conducted by the two engineers, I decided to include data on bubbles that break up. The data taken shows that at approximately 8 ml. the bubble velocity leveled out to a straight line (As Figure #6 illustrates).



This data is comparable to those found with regular and annular pipes except for the fact that the terminal velocity is higher in an annular-ribbed pipe. It seemed as though the seepage was a natural occurrence in keeping the bubble at a terminal velocity.

I reason that there are several factors for air seepage. One factor is the size of the bubble. The length of the bubble increases substantially once the width of the chamber is filled. Based on the film taken of the bubbles, water enters the bubble in tiny waves as air seeps out. The longer length gives the waves a better chance to invade the bubble. If the spacing is large enough, I believe that the space between the ribs and the outer layer attracts bubble seepage . This explains why the bubbles tend to seep at one side rather than the other.

Though the project seems to be complete there is uncertainty in the tests. Further tests should be conducted to determine if seepage did give an acceptable curve by doing tests without seepage. Also, other tests should be done with more accurate equipment so that the curve will be more accurate.

References

1. Kelessidis, V.C., and Dukler, A.E., "Motion of Large Gas Bubbles Through Liquidsin Vertical Annuli" Int. Journal of Multiphase Phase Flow, Vol. 16, No. 3, pp. 375-390, 1990.

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By: Chris Burge

With special thanks to: Dr. Greg Flach and Andrea Kielpinski

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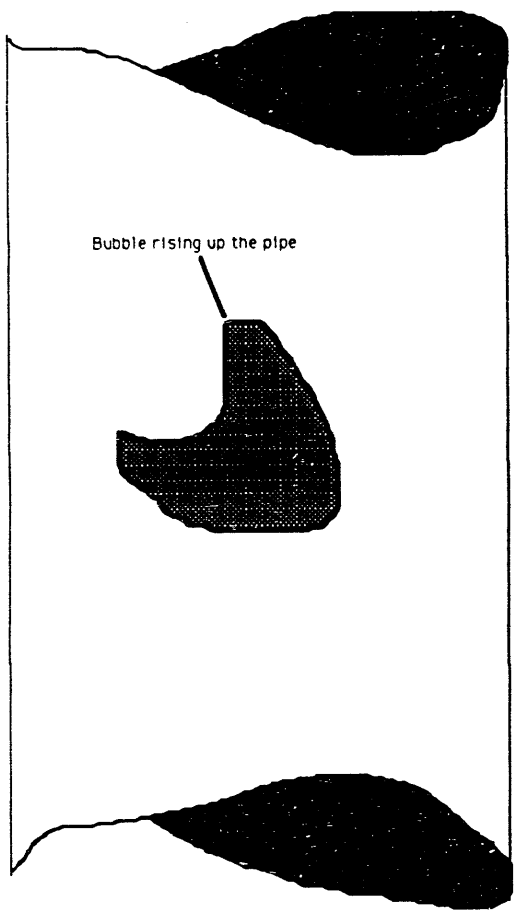
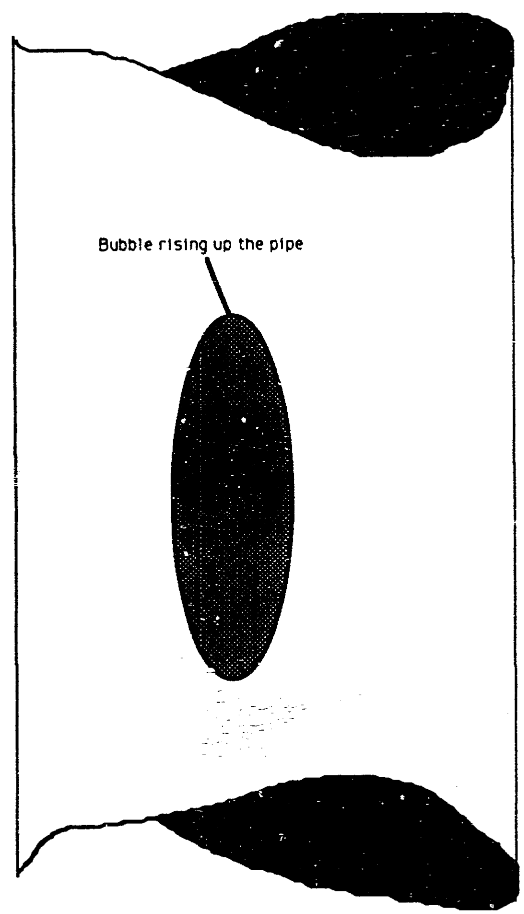
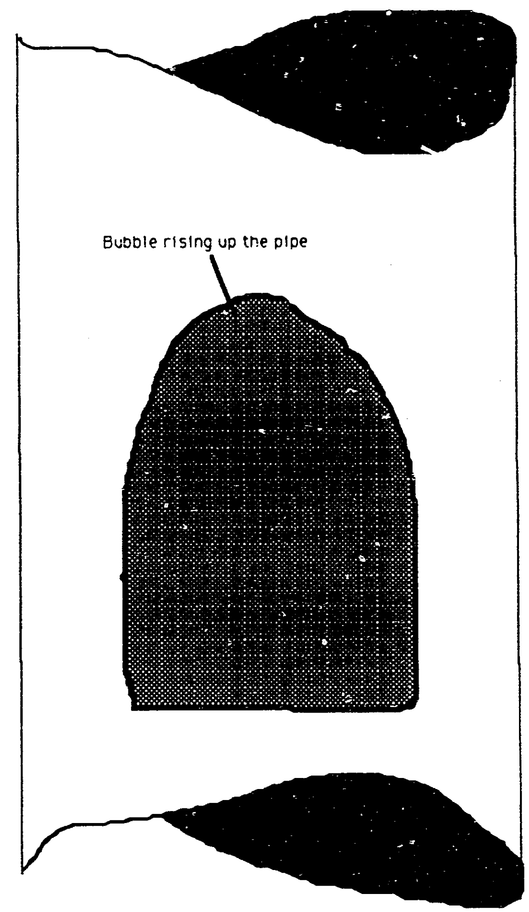
little velocity



medium velocity



high velocity



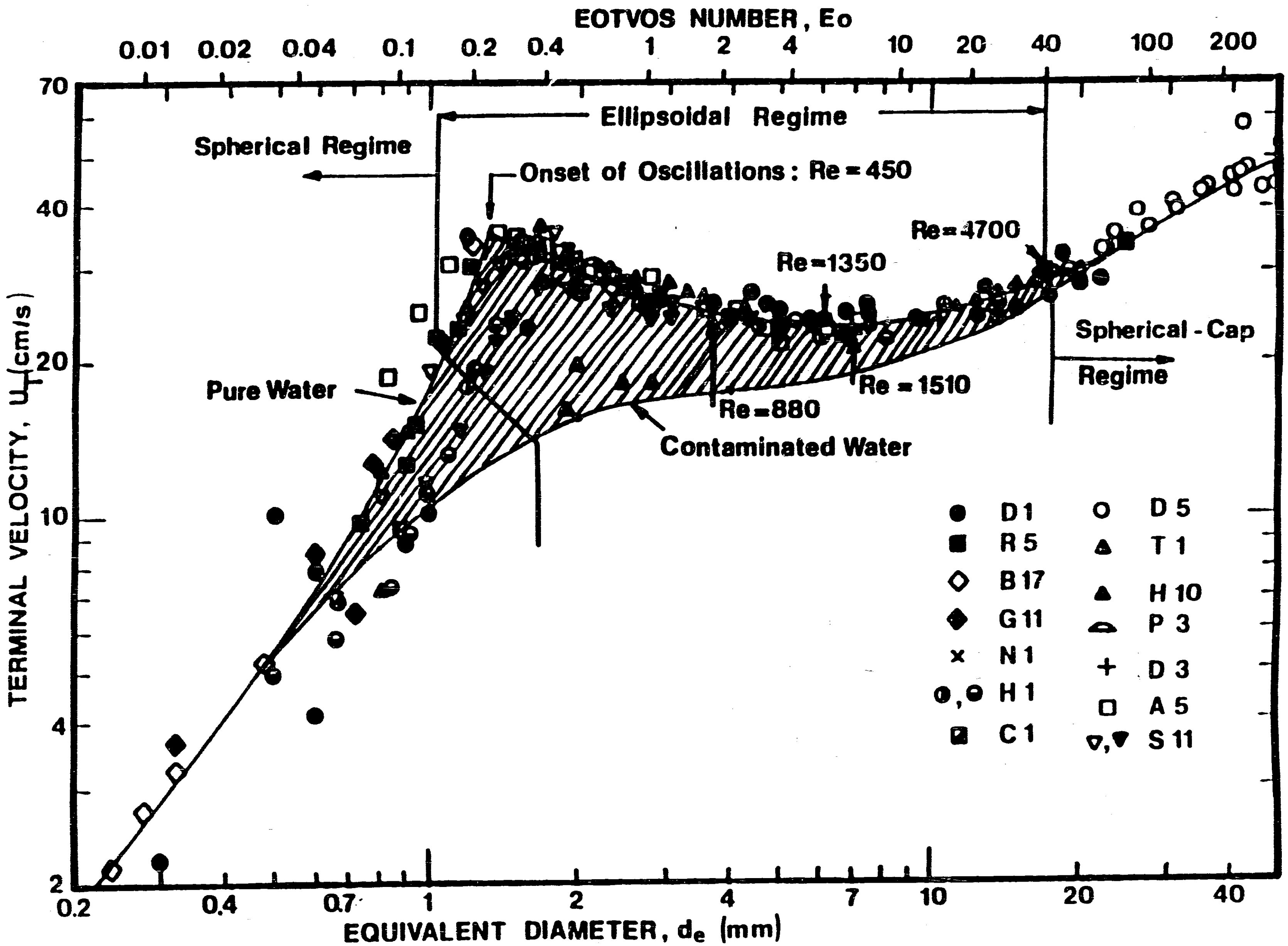
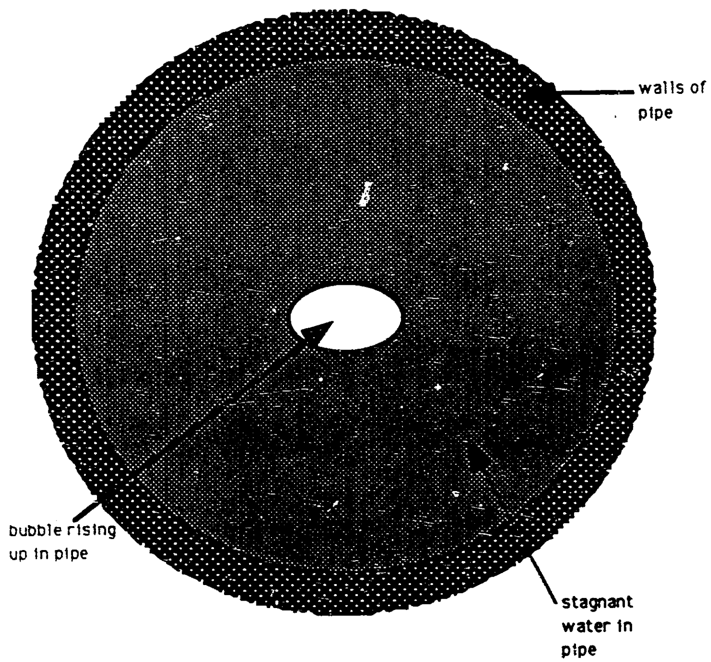
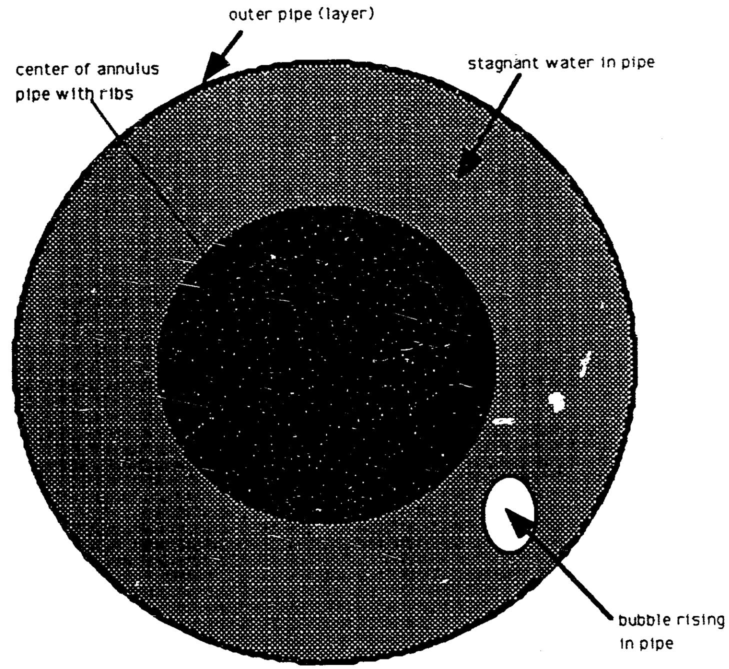
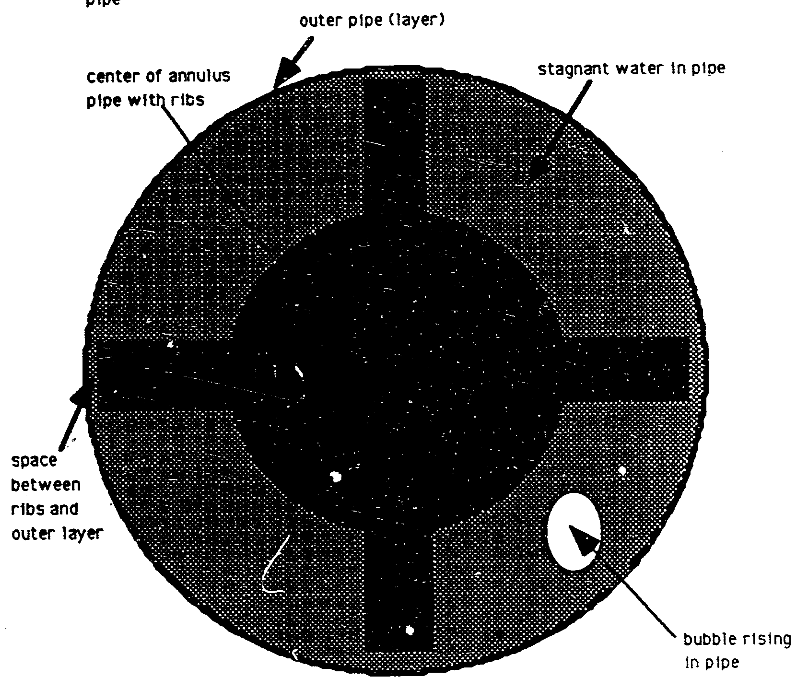


FIG. 7.3 Terminal velocity of air bubbles in water at 20°C.


walls of
pipe
bubble rising
up in pipe
stagnant
water in
pipe


outer pipe (layer)
center of annulus
pipe with ribs
stagnant water in pipe
bubble rising
in pipe


outer pipe (layer)
center of annulus
pipe with ribs
stagnant water in pipe
space
between
ribs and
outer layer
bubble rising
in pipe

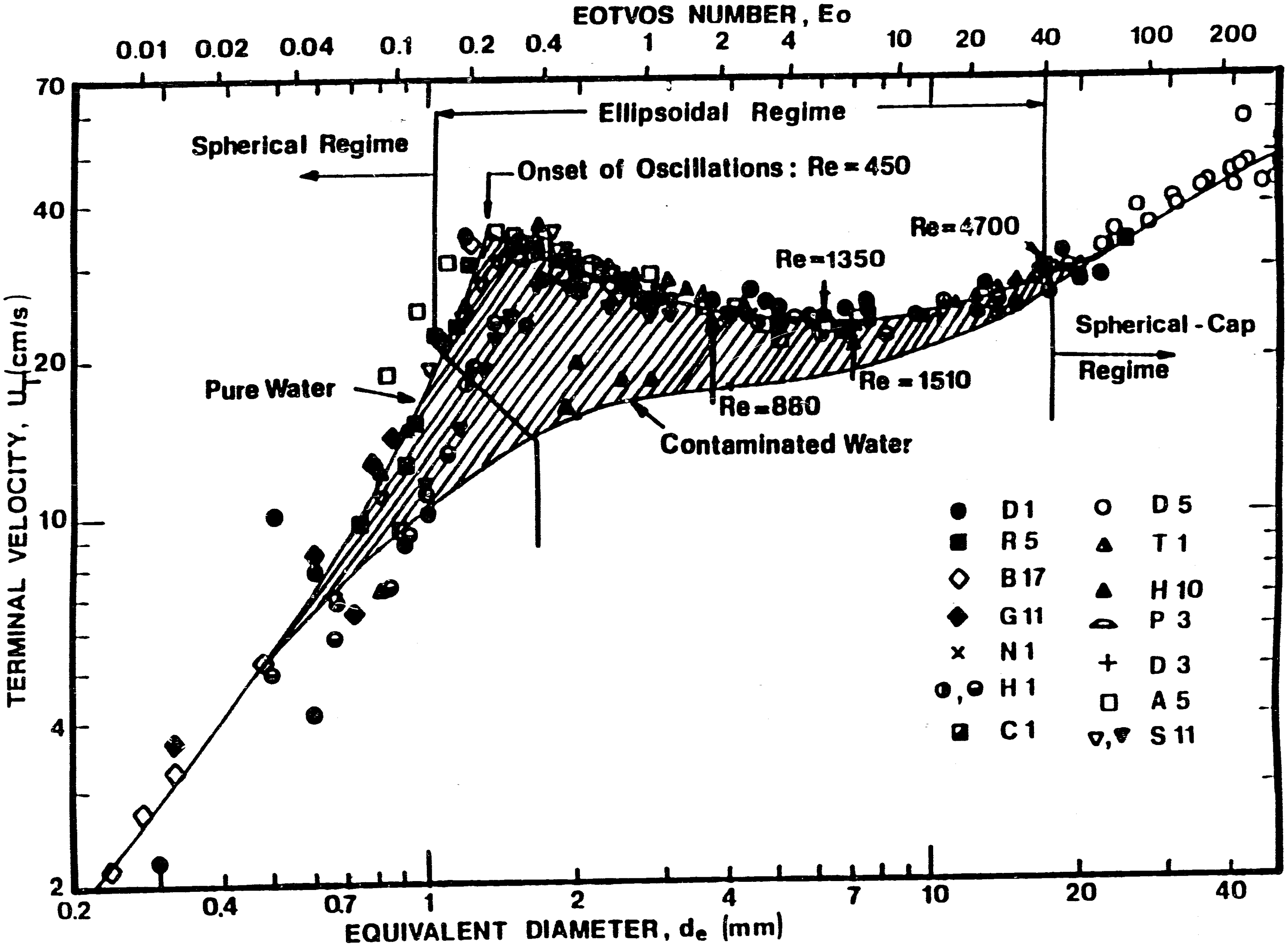
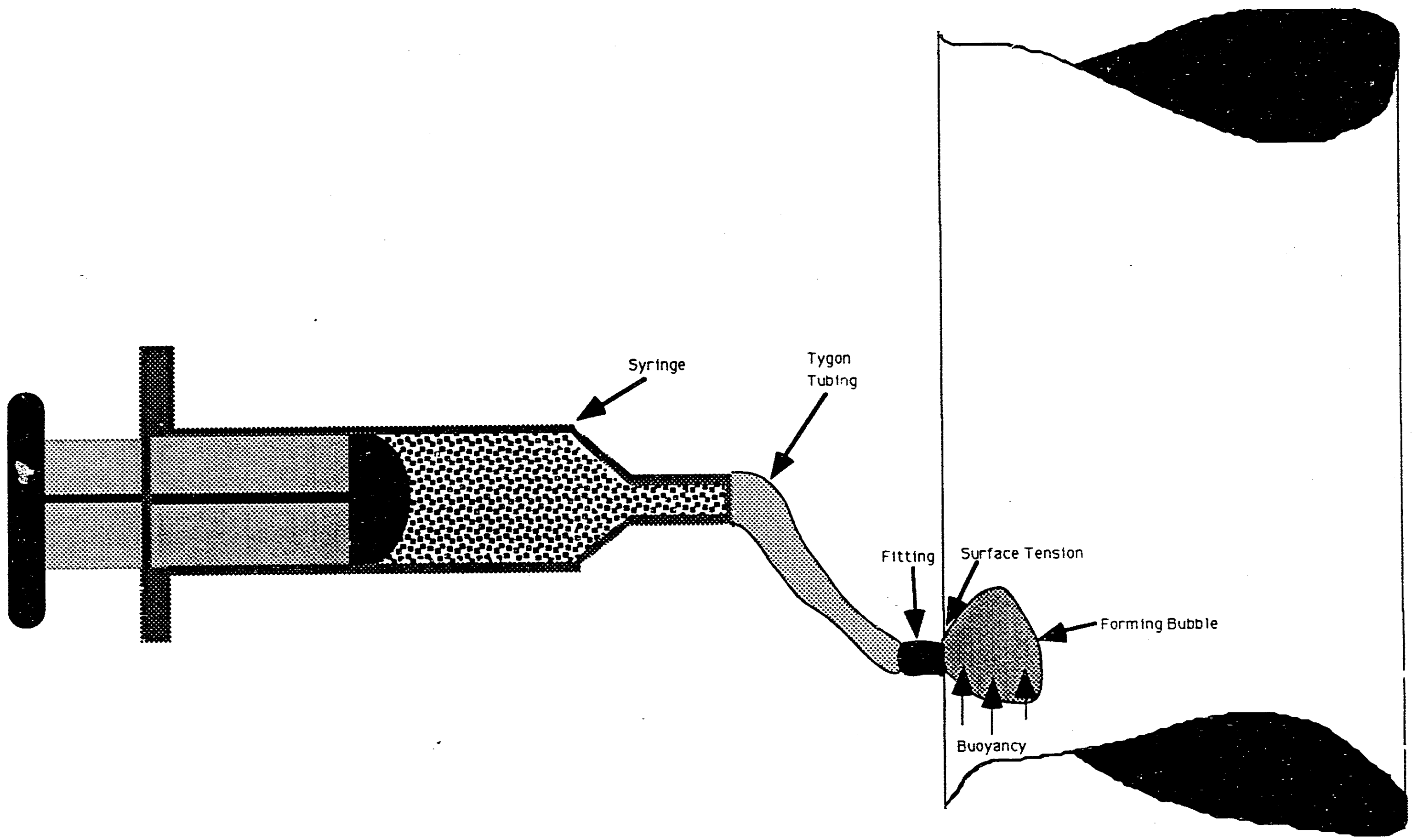


FIG. 7.3 Terminal velocity of air bubbles in water at 20°C.


Syringe
Tygon
Tubing
Fitting
Surface Tension
Forming Bubble
Buoyancy

Reasons for bubble break-up

1. Surface tension of bubble is broken by its buoyancy force before bubble is big enough for to be used as data.

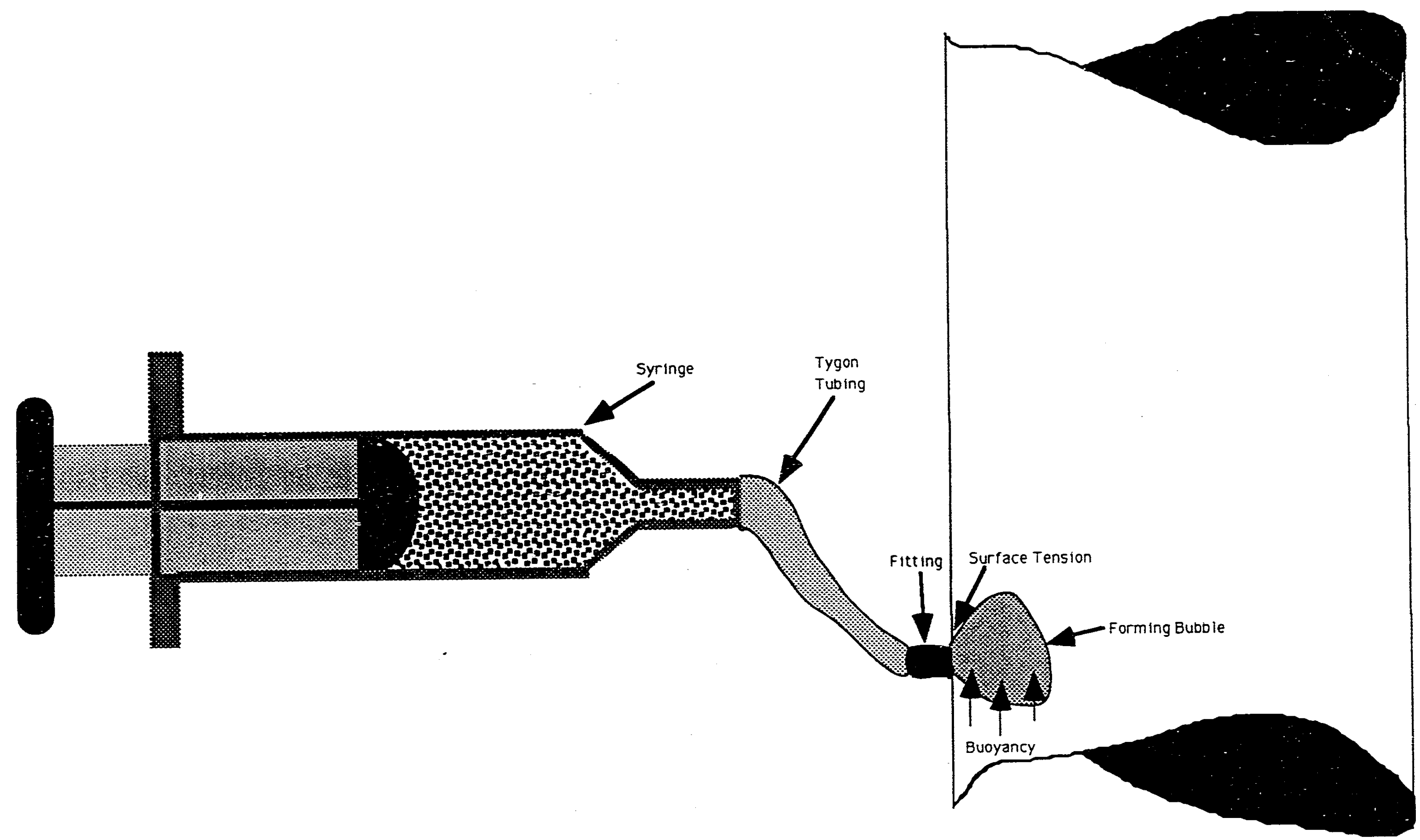
2. Geometry of pipe makes bubble too unsteady for it to remain as a big bubble thus making it shear into smaller bubbles.

3. Unsteady flow of air into the water.

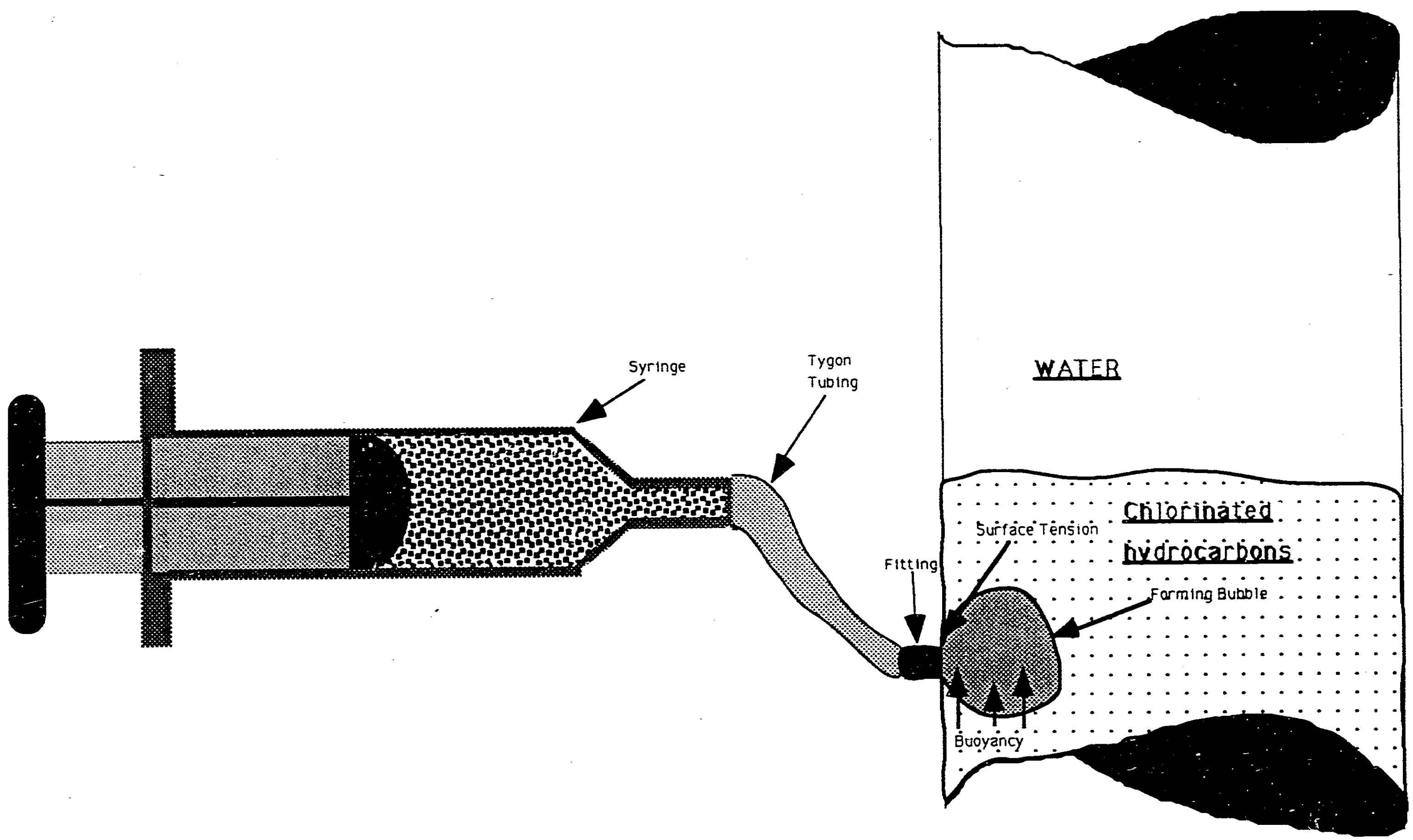
4. Angle of bubble's entry in pipe is too sharp.

How to prevent bubble breakup

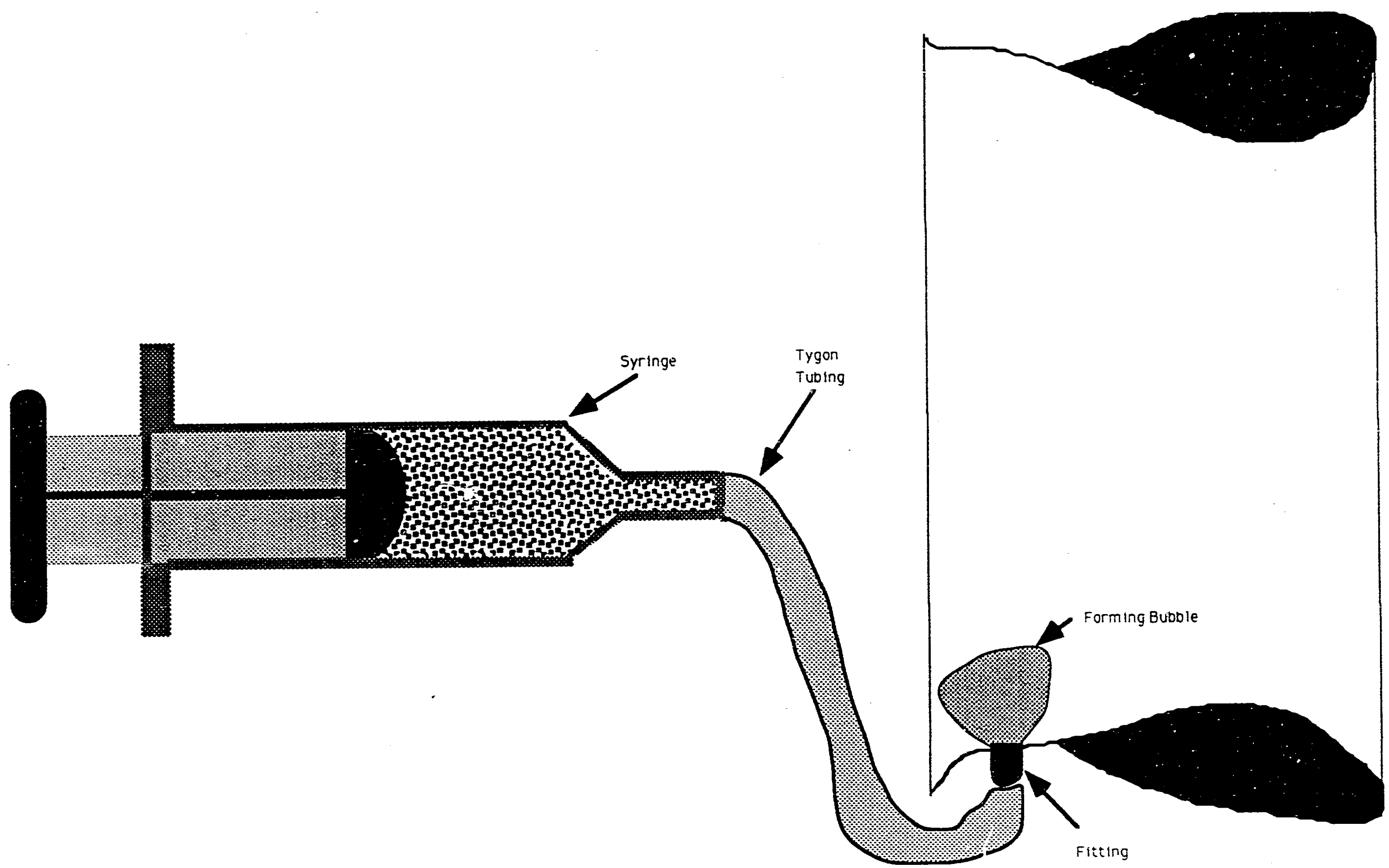
1. Increase bubble surface tension.

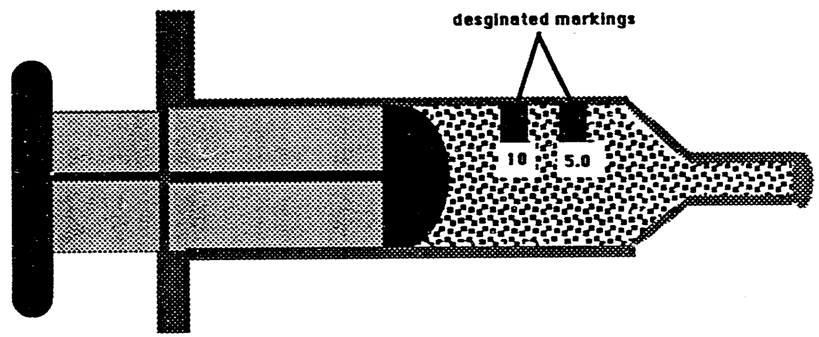


2. Decrease buoyancy force by adding chlorinated hydrocarbons. (such as carbon tetrachloride, chloroform, or chloroethane)



3. **Build another rig that has a larger opening than the original at the bottom of the pipe.**




desginated markings
10
5.0

Steps in calibration for syringe

The following parts are needed:

Syringe

A scale with an accuracy of .01 of a gram

Calculator

Data sheet

Water Beaker

Thermometer

Part 1: Preparation

1. Obtain a copy of the data sheet.
2. Monitor room temperature and record it.
3. Look up water density for the given temperature and record it.
4. Put beaker on scale and weigh it as a tare.
5. Leave beaker on scale and press the reset button.
6. Take beaker off the scale.

Part 2: Data Collection

1. Fill the syringe, with water, to a designated marking.
2. Record the designated volume in liters.
3. Empty contents of syringe into beaker.
4. Weigh beaker.
5. Scale will show weight of water in grams.
6. Record weight on log.

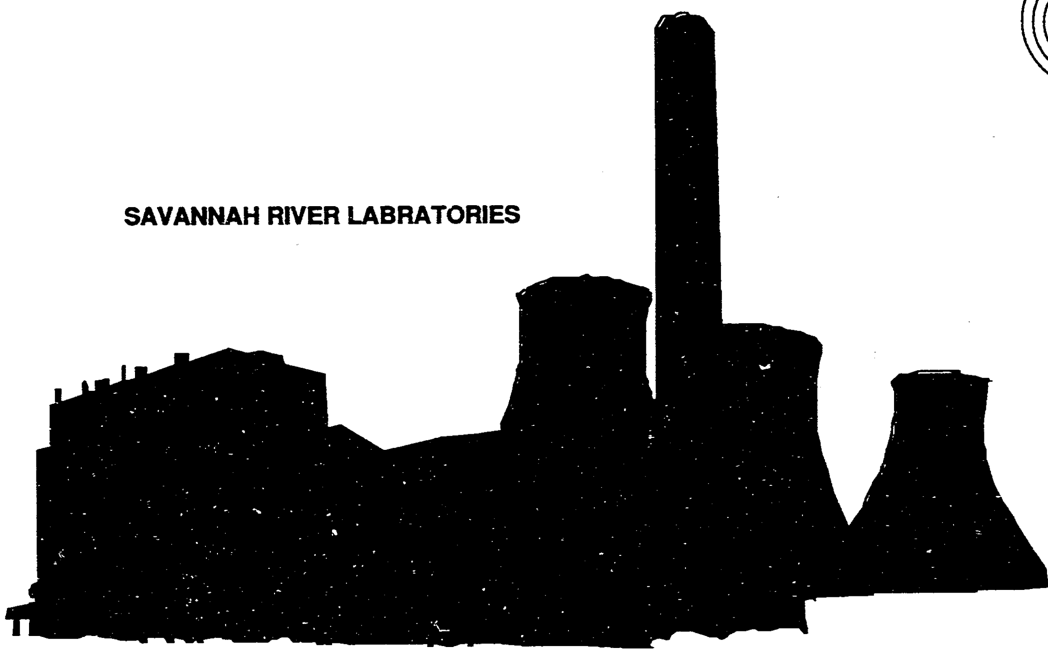
Part 3: Conversion and Calibration

1. Determine density of water at room temperature from an appropriate table (The density of water at 25°C (298 K) is 997). If interpolation is required, $rho=[(rho_2 - rho_1) / (t_1 - t_2)] * (t_1 - t) + rho_1$.

2. Using the Density= equation, calculate the number of liters that corresponds to the number of grams recorded in part one of the procedure.

3. The number of liters found will be the corrected liters for the designated markings.

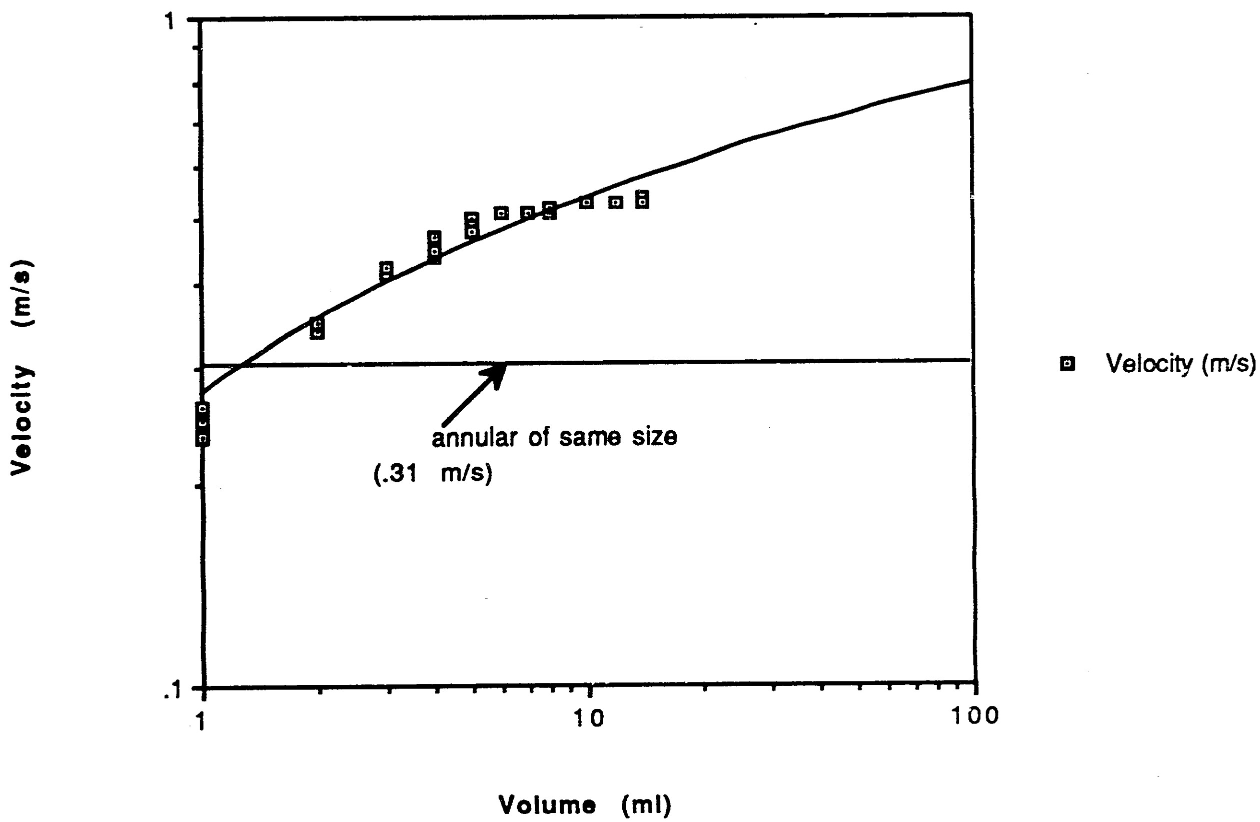
SAVANNAH RIVER LABRATORIES



NRTSC
Technology
On Time
On Target

Data from "Vol. vs Vel. (m/s).Data"

y = 0.27514 + 0.26097*LOG(x)   R^2 = 0.945



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