Continuation of Dynamic Fluid Flow Due to Capillary Forces in Microgravity

Topic Areas:
Fluid Physics/ Applied Mathematics

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Flight Week Preference

First Choice: March 8-17, 2007
Second Choice: March 22-31, 2007
Third Choice: April 19-28, 2007

Advisor/Mentor Request

No advisor or mentor is requested.

Abstract

Based on our observations from last year, we will use the 23 second period of microgravity onboard the C-9B to obtain quantitative data describing the rate of fluid progression due to capillary action for two different viscous fluids each traversing a set of four different contact angles. We have already studied the dynamic flow induced by capillary action, and we will use that knowledge as the basis for this experiment to calculate the volumetric flow rate of water versus a water/glycerin mix. We will be able to measure the fluids' average velocity and average volumetric flow rate with an improved experimental setup and the knowledge of the capillary action's rate of fluid progression, which depends on the specific geometry of the fluid-surface contact angle. This research has applications in many fields including fluid containment in microgravity such as fuel transport, storage, and pooling in fuel tanks.

1. Technical

1. Introduction

1.1 What is capillary action?

Capillary action is the adhesion of a liquid to a solid surface and is a result of the intermolecular attraction between the molecules in the liquid and the surface molecules of the solid. Surface tension is caused by the interaction of the liquid molecules inside the liquid and on the surface, and when they balance with the adhesive forces between the solid surface and the liquid, capillary action results. Molecules inside of a liquid interact with neighboring molecules on all sides and are considered to be in a favorable energy state. However, a molecule located on the surface loses half of its cohesive interactions, creating a force imbalance. This imbalance causes the liquid to reform itself in order to minimize the surface area of the liquid.

When a liquid comes into contact with a solid surface, the adhesion forces due to the interaction of the liquid and the solid surface once again upset the equilibrium of the liquid. The liquid spreads out on the surface in order to minimize the total energy of the system, causing capillary action [1]. On a vertical surface, this will occur until gravitational forces overcome the adhesive forces of the solid-liquid interaction. This phenomenon is used by plants to draw water to the upper leaves and is also responsible for the formation of menisci in graduated cylinders. Capillary action is enhanced in an inside corner, due to a higher ratio of solid surface area to liquid volume. This allows adhesion forces to more strongly draw the fluid’s surface upwards along the wedge formed by the corner [2].

The corner or angle along which the liquid travels is referred to as the angle of incidence. The height to which the fluid surface will rise is also dependent on the force on the fluid due to gravity. All else being equal, lighter fluids, fluids with lower viscosities, or reduced gravity will cause more pronounced effects due to capillary action. It is possible to calculate the equilibrium position of a solid-liquid surface, given information about the geometry and properties of the system. Such systems are usually studied by minimizing the sum of the surface and gravitational energies as described by the equation:

$$\Delta \cdot (W^{-1} \Delta u) = \kappa u + 2H \qquad \textbf{Eq. 1-1} \text{ [2]}$$

where $W = (1 + u_x^2 + u_y^2)^{1/2}$ and κ and H are constants describing the properties of the system. A boundary condition of constant contact angle is applied such that

$$\cos \gamma = W^{-1} \Delta u \cdot \mathbf{n} \qquad \textbf{Eq. 1-2} \text{ [2]}$$

where γ is the contact angle. In the case of zero gravity, these equations give

$$\Delta \cdot (W^{-1} \Delta u) = 2H \qquad \textbf{Eq. 1-3}$$

$$W^{-1}\mathbf{n} \cdot \Delta u = \cos \gamma \qquad \textbf{Eq. 1-4} \text{ [2]}$$

It can be shown that equations 1-1 through 1-4 have solutions only in the case that $\alpha + \gamma \geq \pi / 2$ where α is half the angle of incidence [2]. Solutions to this problem which are valid in the case where $\alpha + \gamma \geq \pi / 2$ is not satisfied have been shown, but neither this result nor the standard case addresses the time dependence of the surface location [3, 4]. With last year's experiment, we were able to demonstrate that a smaller angled wedge resulted in an increased flow velocity of the fluid. However, due to unforeseen fluid motion, we were unable to determine any volumetric flow rate of the fluid, and would like to determine how the contact angle affects the actual volumetric flow rate of the system.

1.2 Applications of capillary action in microgravity

Capillary action has many applications in microgravity, especially in the development of fuel systems for spacecraft. Studies performed to date have only determine the equilibrium states of liquids in microgravity. An understanding of not only where fuel will be in a storage tanks, but how it will reach that position could allow for the development of pump-less fuel systems to move small volumes of fuel from one place to another. In addition, a study of dynamic capillary action in the absence of gravity may give insight to capillary actions in the presence of gravity and allow for a better understanding of how plants transport water to the upper leaves.

1.3 Role of gravity

As discussed above, gravity plays an important role in how capillary action occurs. In a 1G environment, capillary action is not strongly pronounced except in the case of extremely small contact angles or small angles of incidence on the surface. In the case of microgravity, capillary effects become much more important. Large rises in fluid surface occur due to relatively large angles of incidence in the container surface. This will allow for a much more useful and realistic situation for microgravity capillary experiments. If the angles of incidence are kept small between adjoining surfaces, as in the 1G case, frictional forces between the fluid and the walls become dominant and slow the fluid motion, changing the nature of the flow. The microgravity environment experienced during the C-9B flights will allow us to study capillary flows where friction is not as dominant as well as make the capillary effects much more pronounced, improving data recording and later analysis.

It was shown by our experiment last year that the angle between the two solid surfaces could have a large effect on the dynamic interactions with that surface. With an improved experimental setup, we will be better able to determine the volumetric flow rates at which a fluid with a defined viscosity will travel in planar wedges in microgravity. In addition, we will be able to determine how the viscosity of a liquid will influence the dynamics of the capillary action.

2. Test Objectives

2.1 Objectives of the Experiment

Our objective is to quantitatively measure the effect of capillary action in a microgravity environment. We propose that onboard NASA's C-9B reduced gravity laboratory, we will be able to measure a liquid's average flow velocity and average volumetric flow rate over two adjoining surfaces with differing angles of incidence. We will also attempt to determine the relationship between fluid viscosity and capillary action for fluids with different viscosities.

Goal 1: Allow for the measurement of capillary action using varying angles

We will vary the angle of incidence but keep all other variables constant in order to determine which angle allows for the highest flow velocity (cm/sec) of a liquid due to capillary action in a microgravity environment. The liquid will travel along the wedges of varying tolerance angles. These angles have been determined based on a similar experiment performed last year which was based on Paul Concus's and Robert Finn's research. A measurement tape will be placed near the wedges and a mounted video camera will be used in order to record the liquid's progress. After completing the experiment, we will analyze the videos closely in order to determine the average flow velocities of the liquid over each angle.

Goal 2: Determine the relationship between angle of incidence and volumetric flow rate

We will measure the average volumetric flow rate (ml/sec) of the liquid due to the capillary action. In order to do this, the top of each wedge will be rounded to allow the liquid to flow over the top and into a collection tube. After completing each microgravity portion of the flight, gravity will pull the liquid to the bottom of the collection tube, effectively resetting each experiment. We will record this process, and after all the liquid has been pulled to the bottom of the collection tube, we will allow it to flow back into the main reservoir to reset the experiment. When reviewing the video, we will be able to determine the volume of water collected, and since we will have recorded the amount of time the liquid took to reach the top of the wedge, we will be able to calculate the average volumetric flow rate.

For our wedges we can calculate the angle of incidence for water and the water/glycerin mix in a laboratory setting. Using this calculated value and the video footage to determine velocity; we have another way of calculating volumetric flow. It is important to have this laboratory calculation to use as a reference when doing our experimental calculations to determine volumetric flow.

Goal 3: Determine the effects of fluid viscosity on capillary action

In order to determine the relationship between fluid viscosity and capillary action, we will simultaneously perform two experiments. Using two fluids with similar surface tension and density, we can measure the effects of the viscosity of a liquid. We will complete goals one and two for water (viscosity of 8.90×10^{-4} Pa•s) [5] in one setup, and in a second identical setup, we will complete goals one and two for a water/glycerin mix (glycerin 20% by volume, viscosity of 1.8×10^{-3} Pa•s) [7]. After analyzing our data for both liquids, we will be able to describe the relationship between capillary action and fluid viscosity in a microgravity environment.

2.2 Hypothesis

We theorize that liquid undergoing capillary action in a microgravity environment will have different flow velocities over different angles of incidence. Similarly, we theorize that capillary action will cause different volumetric flow rates over different angles of incidence. We also believe that fluid viscosity will noticeably change the effects of capillary action. We are confident that we will be able to successfully and safely perform this experiment aboard NASA's C-9B. We believe that our techniques will provide ample data in order to develop preliminary empirical equations describing velocity and volumetric flow rate due to capillary action.

3. Test Description

3.1 Description of Phenomena

As any liquid comes in contact with a solid surface, a contact angle is created. This contact angle is the angle of incidence at which the liquid comes in contact with the adjoining surface. In reference to the research done by Concus and Finn, there exists a contact angle, γ_0, which is also known as the critical angle for each surface. For a surface, or in this case a wedge, with an interior angle of 2α, the critical angle is then equal to $\pi/2-\alpha$.

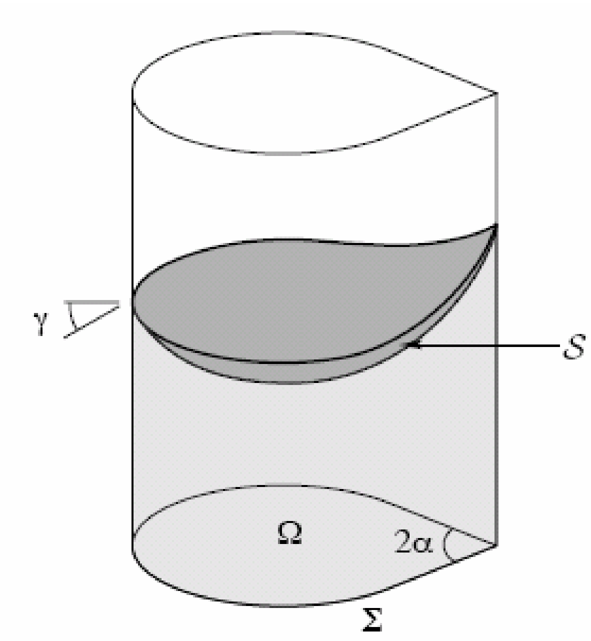

Fig. 3-1: Wedge shaped container showing inner angle 2α, contact angle γ, surface area S, horizontal cross sectional area Ω and horizontal perimeter Σ. P. Concus, R. Finn, M. Weislogel, "Measurement of Critical Contact Angle in a Microgravity Space Environment," Preprint for Experiments in Fluids, 28, pp.197-205, (2000).

Not only is the critical angle important, but the contact angle created from the fluid in contact with the surface is also significant. This angle is determined through experimentation and is a measure of the angle the fluid makes against the surface at the point of contact. The value of a contact angle is inversely proportional to the strength of attraction between the fluid and the solid. A smaller contact angle results in greater capillary action and is evidence of stronger attraction between the fluid and solid.

The liquid will move to the walls and rise along the surface with no pattern if the contact angle's value rests between zero and the critical angle. An experiment performed aboard the United States Microgravity Laboratory Space Shuttle flight STS-73, designed by Finn, Concus, and Weislogel, investigated the behavior of a liquid in a double proboscis shaped container as it neared the critical angle. It was discovered that the liquid will rise discontinuously as the liquid approaches the critical angle.

Our experiment will not concentrate on the specific contact angle or height of the liquid but rather will focus on quantitative values for the velocity and volumetric flow of two different fluids of differing viscosities along wedges with various angles. We will attempt to compare quantitatively the difference of flow between the two liquids.

Our experiment relies on two separate polycarbonate blocks which have wedges of predetermined angles cut into them.

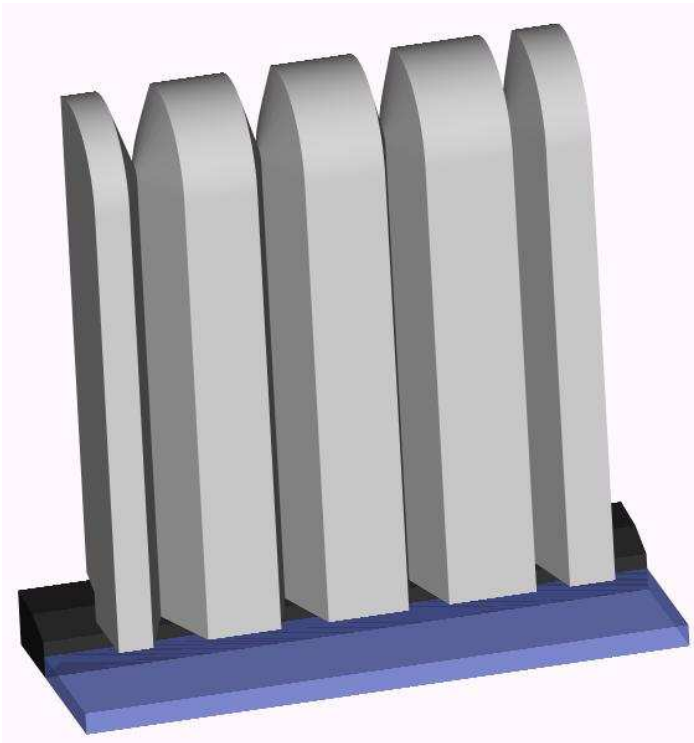

Fig. 3-2: Wedges of varying angles are cut and rounded off at the top and continued over the top to allow the liquids to travel to the collection tubes.

One wedge will have a sponge submerged in water at the base and the other will have a sponge submerged in a water/glycerin mix. Wedges are rounded off at the top and continued over the top to allow the liquids to travel to the back to the collection tubes which are capable of measuring the two liquids at each angle. Water and a water/glycerin mix have been chosen due to their availability in pure quantities, non-toxic characteristics, and positive contact angles with many solid surfaces, one of which is polycarbonate. We will video record the capillary action of each liquid in order to compare them.

The results from this experiment will have applications in microgravity where a fluid can travel from one end of a pipe to another. As a result, research will lead to the discovery of means to transport fluid without the use of a pump. One may only need to change the contact surfaces, angles, and shapes within a tube to displace fluid and from experiments measure and predict fluid displacement rates for any geometric shape

We expect that fluids with lower viscosities and higher surface tensions will be transported at faster rates than those with higher viscosities and lower surface tensions. We also expect that the fluids will travel faster within wedges with smaller angles of incidence and slower within larger angles. This will be shown both qualitatively and quantitatively by the camera and the volumetric measurements respectively.

3.2 Equipment Design

3.2.1 Overview

Our capillary action experiment was designed with safety, visibility, and accessibility as the determinants of the structural design. Safety precautions were considered and implemented into the external and internal design. The outer containment box will be secured to the plane. The fluid tanks will be doubly reinforced and will have pressure release systems built in. These tanks will hold equal amounts of water and water/glycerin mix at the bottom. No toxic materials will be used and kill switches will be implemented for all electronics within the experiment.

3.2.2 Outer Containment

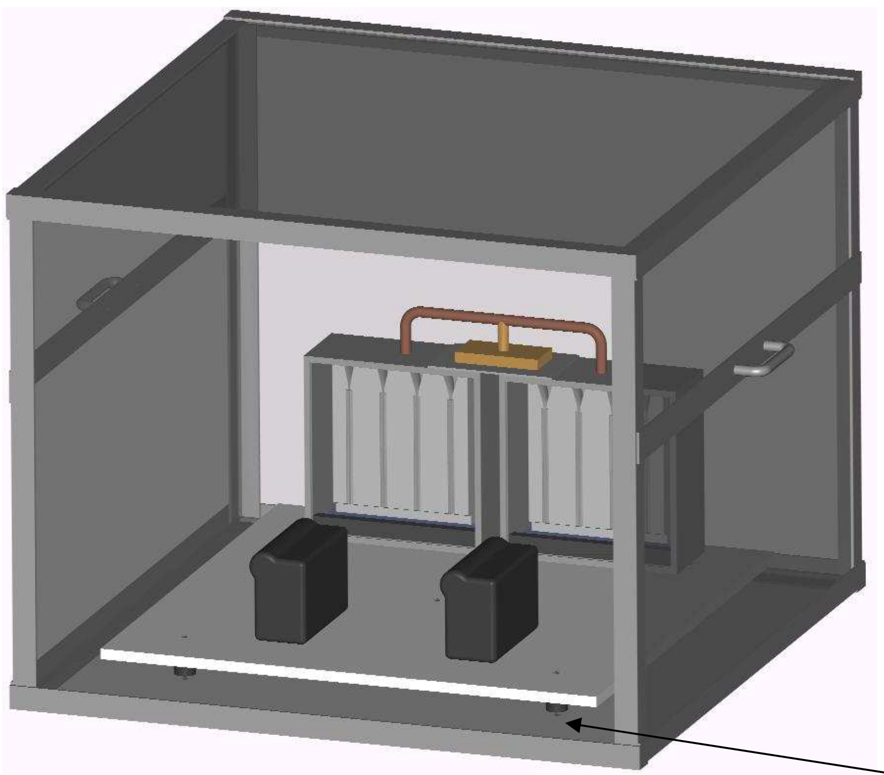

Fig. 3-3: Complete experimental assembly showing outer containment box and inner experiment.

The outer containment box is the same box that was deemed fit to fly for the past two experiments implemented by our group. The box is made of ¼" thick polycarbonate sheets with an outer dimension of 30" x 30" x 24". These sheets are fastened to each other with 1 ½" L-beams made of aluminum and ¼" diameter bolts and nuts made of steel. Both inner and outer edges have been sealed with silicone caulk to provide an airtight containment. There are two handles located on opposing sides to carry the device and to aid in securing the box to the plane.

3.2.3 Mounting and Shock Absorption

Inside the outer containment box, we will secure a 24”x24”x3/8” aluminum platform with five cylindrical neoprene sandwich mounts to the bottom of the box. This platform was used for the last two years to mount our experimental contents. We will be mounting our cameras, fluid tanks, actuator and an accelerometer to this platform to prevent collision of any parts of our experiment with one another. The neoprene, a synthetic rubber polymer, carries great energy absorption properties that should be able to provide sufficient vibration dampening for the experiment.

See Fig. 3-3 for the aluminum plate fitted with vibration damping neoprene sandwich mounts attached to the bottom of the outer containment box.

3.2.4 Electronics

We will be using battery-powered video cameras to observe and record each experimental trial. The cameras will be mounted on the platform and will face the fluid containment tanks. An actuator will lower the polycarbonate wedges into contact with the liquid-saturated sponge once microgravity has been achieved. The block will then be raised off of the sponge when the period of zero gravity has ended. Two buttons on a control box, one to lower it and one to raise it, will control the actuator. Please see Section 10: Electrical System for a complete overview of our experiment’s electrical system.

3.2.5 Fluid Tanks

Each tank will weigh no more than ten pounds and will be made with clear polycarbonate and aluminum. There will be approximately 2 cm of fluid at the bottom of each tank. The fluids will be water and a water/glycerin mix providing different viscosities so that we may compare the flow rates of the fluids. In the past years, we have observed that the motion of the plane causes unrestrained fluids to splash along the sides of fluid tanks. To prevent this, we will have a sponge on the bottom of the containment tanks to contain the liquid.

These tanks will be considered pressure vessels, because they are sealed. Although we do not expect the pressure in these tanks to reach dangerous levels, we will install a pressure relief valve that will release any pressure at or above 14.7 psi (1 atm). Our polycarbonate wedges will be placed inside these tanks. The pieces will stay at the top until microgravity is achieved, where they will be lowered to contact the fluid-saturated sponge by sliding down rails under the power of an actuator. The blocks will be tapered at the top to continue the capillary action, and once we are no longer in microgravity, the fluid will flow down into the collection tubes. There will be narrow tubes that will collect the liquids to be measured. The camera will record as the fluid travels over the top of the wedge and down into the container so that we can perform a quantitative analysis on volumetric flow rates. For better visibility, the water will be dyed with food coloring. The bottom of the tubes will be plugged by a rubber block to prevent the liquid from escaping while in microgravity as the wedge is in its lowered position which is when we will be measuring the volumetric flow. However, the tubes will have to be far enough away from the sponges so that when the wedges are initially pushed into the liquid, that liquid will not enter the tubes. When microgravity ends and up to 2Gs are pulled, the wedges will be raised off the sponges and the tubes will open, letting the liquid fall off the wedges and out of the tubes back onto the sponges so the experiment can be repeated. Each angle will have its own tubes, so that we can measure individually the volume of the liquids for each angle.

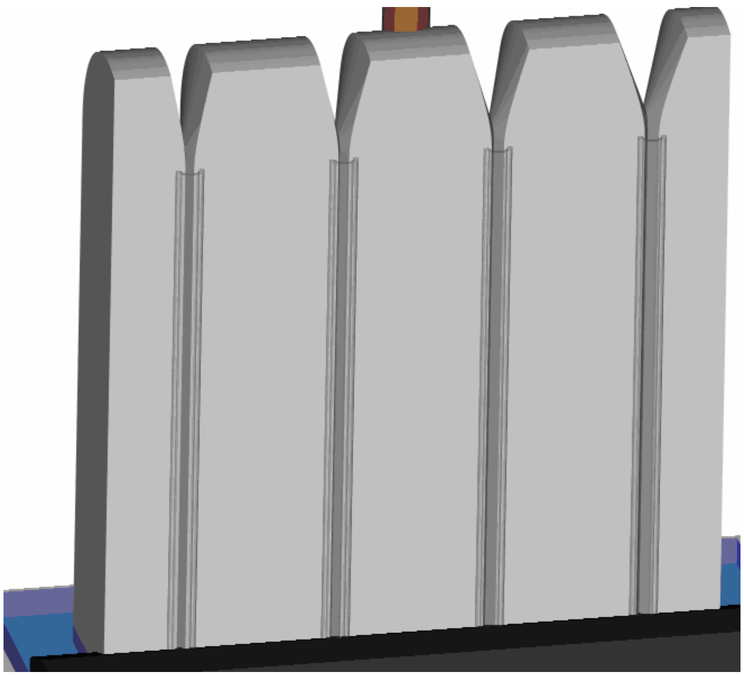

Fig. 3-4: Tubes collect liquid when it flows over the tops of the wedges when the bases of the wedges are in contact with the saturated sponge.

3.3 Procedures

3.3.1 Pre-Flight

We will conduct a pre-flight checklist before each flight to ensure our experiment is ready for flight. The checklist includes:

1) Outer Containment Box Integrity: Examine the outer box for cracks, misalignments, or other abnormalities.
Reaction Plan: Replace with alternate outer box that has no cracks, misalignments, or abnormalities.
2) Inner Tanks Integrity: Examine both inner tanks for cracks, misalignments or other abnormalities that may cause leaks.

Reaction Plan: Replace one or both tanks with alternate tank that has no cracks, misalignments, or abnormalities.

3) Actuator/Motion of Poles: Run actuator and ensure motion along sides and that the polycarbonate wedges move smoothly and are unobstructed.

Reaction Plan: Remove any obstructions, clean, and lubricate moving parts as needed. Check electrical connections on actuator.

4) Sponge/Liquid Check: Ensure sponges contain correct amounts of water or water/glycerin mix and that water has sufficient food coloring for better visibility.

Reaction Plan: Replace one or both sponges with sponge containing correct amount of liquid and add food coloring to water as needed.

5) Accelerometer: Verify that the accelerometer is working properly and that the laptop is receiving data from it.

Reaction Plan: Examine all the electrical connections between the accelerometer and laptop.

6) Video Cameras: Ensure video cameras are working properly and that batteries are new and fresh tapes are in them.

Reaction Plan: Replace batteries/tape as needed and check electrical connections on video cameras.

7) Computer Software: Validate that all electrical systems are operating properly and communicating with the laptop.

Reaction Plan: Check all connections and restart the laptop

Following a successful review of the checklist, a Test Flight Director will help fasten the apparatus to the floor and finish other pre-flight procedures.

3.3.2 Overview

When the plane enters microgravity, we will start conducting the experiment. The actuator will be controlled by switches activated at various times throughout the flight. In case of any emergencies, there will be a manual power shut off.

3.3.3 In-Flight

1) The video cameras are mounted to the apparatus and are turned on before the parabolas start.

2) Once microgravity begins, one of the researchers will activate the actuator, which will move the wedges towards their respective sponges. The liquid in each sponge will climb up the angles of the wedges and over to the other side into a collection tube.

3) Once normal gravity begins, the liquid in the tubes will drop to the bottom, enabling a measurement to be recorded by the video cameras.

4) Then a researcher will push a button to move the actuator and wedges back up so the liquid can return to the sponge for the next trial.

5) Repeat steps 2 through 4 for every parabola.

6) After the last parabola is completed, the actuator and video cameras will be turned off.

3.3.4 Data Collection

The video cameras will start recording before the first parabola. The cameras will record the liquid moving along the wedges and the level of the liquid in the collection tubes before the actuator moves back up and the liquid returns to the sponge. The data will be saved for future analysis.

3.3.5 Post Flight

We will unload our apparatus at the end of the flight. Video camera batteries and tapes will be replaced for the next flight. After each flight, an overview of our pre-flight checklist will be conducted again to ensure the apparatus is ready for the next flight.

3.4 Necessity of Microgravity

In the presence of gravity, a liquid has molecular interactions with the surfaces containing it. For this experiment, it will have interactions with the clear polycarbonate creating a contact angle. However, gravity would prevent any water from traveling up the walls. If there is no gravity restricting the capillary action, the liquids will freely move up the surface. This experiment needs to be conducted in microgravity because we are attempting to study the rate at which a fluid will rise in a planar wedge in the absence of gravity.

4. A Follow-Up Flight

Last year, we studied the dynamic flow induced by capillary action in order to better understand the time dependent fluid location. We studied the rate of fluid progression to capillary action as dependent upon geometry of four different contact angles. We intended to measure the progress of the fluid up the wedges as well as the volumetric flow.

However, we were unable to make any measurements of the volumetric flow or perform any quantitative analysis due to many unforeseen inconsistencies. There were some difficulties in smoothly lowering the wedge assembly onto the sponge, causing undesired fluid motion in the tank which obscured our view of the wedges. The addition of the actuator should eliminate this problem, providing controlled raising and lowering of the wedges thus eliminating any undesired fluid motion. In manufacturing the wedge assembly, we had left small gaps between the different wedges, unexpectedly interfering with fluid movement in the wedges. These problems will be taken into account when we are constructing the new wedges and tanks.

A follow-up experiment is merited to obtain better results. This repeat experiment will allow us to obtain quantitative data of the volumetric flow rate involving fluids of differing viscosities. We have consequently changed our experiment. The basic design is similar to the previous experiment except for changing the geometry of the top of the wedge to allow the fluid to flow over the top and into a tube to be measured. Here, we will be able to record the amount of fluid that passes through each wedge.

In addition to studying flow rate, we will also study the relationship between flow rate and liquid viscosity. We plan to do this through identical tests performed adjacent to each other using water in one of the containment tanks and water/glycerin mix in the other.

5. Bibliography

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II. Safety Evaluation

6. Flight Manifest

Flyers
Mai Lee Chang
Ben Conrad
Lisa McGill
John Springmann

Alternate Flyer
Lowell Farrell

Ground Crew
Andrew Elizondo
Jason McDowell
Eric Liegel
Adam Helgren
Alyssa Skulborstad
Curtis Laluzerne
Alex Robinson
Stephen Bonney
Keith Rein
Pete Penegor
Meg Reinbold
Ben Longmier

7. Experiment Description/Background

Please see Sections 1, 2, and 3.1 for a complete description and background of our experiment.

8. Equipment Design

Please see Section 3.2 for our experimental design.

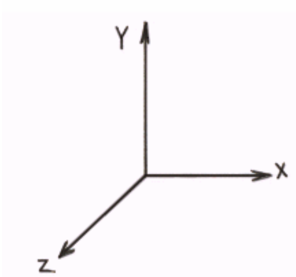
9. Structural Design

In this section we will analyze the structural components of our experiment and explain the calculations used to find them. The outer containment box we are using was previously used in the past two NASA RGSFOP experiments. The only difference will be the inner test components that we use. The calculations for the structural design will be very similar to the previous year's.

9.1 Overview

Our experiment has been carefully designed to pass all of the G-load requirements of NASA's Reduced Gravity Flight Program. Calculations to find the center of gravity were determined first. Next we used the center of gravity to calculate how the box will function under different G-loads. We will secure the box to the floor of the plane by using two 2-inch wide cargo straps. Our experiment will be subject to loads of 9 G's forward, 3 G's aft, 6 G's down, 2 G's up and 2 G's lateral. These G-loads have been used to determine if the cargo straps will be sufficient to hold the experiment in place. The structural analysis of the inner box has shown that the components will remain isolated from the fuselage of the aircraft. The inner components have been analyzed to show that they will remain in the outer containment box. The G-loads and critical factors of safety (FS) are included to show that the experiment is safe for the aircraft and all passengers. For our calculations, the right side of the experiment is toward the front of the C-9B aircraft.

9.2 Centers of Gravity



The 3-D right-hand coordinate system shown to the left will be used. The origin will be the lower-left-rear corner of the outer containment box's aluminum frame. All of the components weights and relative centers of gravity to this point will be used to calculate the center of gravity of the whole system. All of the measurements are in inches.

Under normal gravity conditions (1 G), the inner components have a weight of 50 lbs. The video cameras each weigh 5 lbs. for a total of 10 lbs. The actuator weighs 5 lbs. The aluminum plate weighs 15 lbs. The two inner tanks weigh 10 lbs. each, totaling 20 lbs. The centers of gravity can be found because they are all relatively symmetric. To simplify the calculations for the inner tanks and the video camera, they will each be treated as one unit. The center of gravity can be found easily because of the symmetry of the system of cameras or tanks.

Object	X (in)	Y (in)	Z (in)	Weight (lbs)
Inner Tanks	25.0	7.5	15.25	20
Video Cameras	9.5	4.5	13.5	10
Aluminum Plate	15.25	2.0	15.25	15
Actuator	25.00	17.0	15.25	5

The center of gravity of the inner components can be found using the table above.

CG_x = (20*25 + 10*9.5 + 15*15.25 + 5*25.0) / 50 = 18.97
CG_y = (20*7.5 + 10*4.5 + 15*2.0 + 5*17.0) / 50 = 6.20
CG_z = (20*15.25 + 10*13.5 + 15*15.25 + 5*15.25) / 50 = 14.90

The center of gravity of the inner component is (18.97, 6.20, 14.90)

Next, the center of gravity of the whole box has been calculated by combining the inner components and the outer box. This will be used later for G-load forces. The box has dimensions of 30.5 x 24.5 x 30.5. Since the box is relatively symmetric in all directions the center of gravity is the center of the box (15.25, 12.25, 15.25).

$\mathbf{CG_x}$ = (40*15.25 + 50*18.97) / 90 = **17.32**
$\mathbf{CG_Y}$ **=** (40*12.5 + 50*6.20) / 90 = **9.00**
$\mathbf{CG_z}$ **=** (40*15.25 + 50*14.90) / 90 = **15.06**

The center of gravity of the whole system is (17.32, 9.00, 15.06)

9.2.1 9 G's Forward

When this system is under an induced gravity of 9 G's in the forward direction, the weight can be calculated by multiplying the weight at 1 G by a factor of 9. Thus the induced weight is 9*90 = 810 lbs. The cargo straps mentioned earlier will counter this weight. They will each have to supply a force of 405 lbs in the negative X-direction. Each strap can supply a max force of 5000*cos(72) = 1,545 lbs. The safety factor is 1545/405 = 3.81. Taking the moment about point (0, 0, 15.25) shows that the reaction moment for each strap needs to be 810*15.06 / 2 = 6,099 in-lbs. The straps can produce a moment of 5000*sin(72)*5=23,780 in-lbs. This results in a factor of safety of 23708 / 6099 = 3.89. This shows that the straps will be sufficient to prevent rotation or translation under 9 G's forward.

9.2.2 3 G's Aft

The equipment will experience an induced gravity of 270 lbs. (90*3), which will be countered by the same cargo straps. Each strap will have to provide a force of 135 lbs. Each are capable of producing a force of 5000*cos (72) =1545 lbs. The horizontal safety factor is 1545 / 135 **=** 11.44. Taking the moment about position (30.5, 0, 15.25) it can be seen that each strap needs to create a reaction moment of 270*15.06 / 2 = 2033 in-lbs. Each strap is capable of producing 5000*sin (72) =23,780 in-lbs. The safety factor for this is 23708 / 2033 = 11.67. The two straps will hold the system static during 3 G's backwards.

9.2.3 6 G's Down

Under an induced gravity of 6 G's down, the apparatus will experience an induced weight of 540 lbs. The area of the bottom of the equipment is 30.5 X 30.5 in or 6.46 ft^2. The max in flight stress on the fuselage will be 540 / 6.46 = 83.6 lbs. / ft^2. The max allowable stress on the floor is 200 lbs. / ft^2. The factor of safety is then 200 / 83.6 = 2.39. Our experiment does not need to provide floor shoring to satisfy the G-load specifications in the 6 G's down situation.

9.2.4 2 G's Lateral

Under an induced gravity of 2 G's lateral direction, the equipment will experience a weight of 180 lbs. To avoid translation in the z direction, the box will have to be ratcheted down with enough force so that the frictional force between the box and the aircraft foam is much greater than 180 lbs. In the case of rotation, the straps would have to supply a force to counter the moment about (15.25, 0, 0). The moment that needs to be balanced is 140*17.32 / 2 = 1559 in-lbs. The tether strap going over the top of the outer frame would need to produce a force of 1559 / 30.5 = 31.1 lbs. The strap is able to produce a force up to 5000 lbs, which yield a safety factor of 97.83. Therefore, the two straps will be sufficient to keep the system in place during 2 G's in the lateral directions.

9.2.5 2 G's Up

With the entire system under an induced gravity of 2 G's up, the induced weight of the equipment is 180 lbs. Forces from the straps will counter this weight over the top of the outer frame. Each strap can produce a force of 5000*sin (72) = 4755. This creates a safety factor of 52.8. The two straps will be sufficient to keep the system static in 2 G's up.

9.3 Summary

The above calculations prove that the system of the containment box and inner components will remain in static equilibrium for all G-load cases. The two cargo straps are sufficient restraints.

Case	Force (lbs.)	Force FS	Moment (in-lbs.)	Moment FS
9 G's Forward	405	**3.81**	6,099	**3.89**
3 G's Aft	135	**11.44**	2,033	**11.67**
6 G's Down	270	**2.39**	N/A	**N/A**
2 G's Lateral	90	**need more info**	1559	**97.83**
2 G's up	90	**52.8**	N/A	**N/A**

Fig. 9-1: Summary of the FS calculations for fastening the apparatus under all G-load situations. Forces and moments shown are the reactions that need to be provided by one cargo strap.

10. Electrical System

Our simplistic electrical system will involve very few components. An electric actuator will be wired to a control box and the appropriate fuses to move the sliding wedge piece up and down.

To record the experiment, two standard video camcorders will be used to videotape the wedges and the measuring tubes. The camcorder will run off of battery power.

We will mount an accelerometer in our outer containment box and hook it up to a laptop computer. This will enable us to view the G force on the plane so that the researchers know when to begin the experiment. The accelerometer and laptop will be wired into an analog to digital converter (ADC).

The actuator, control box, and ADC will all need to be wired to a power strip. The power strip will have a breaker switch in case of a malfunction, enabling us to kill the power.

Name	DC Voltage (V)	Max Current (A)	Function
Accelerometer	5	0.1	Collect Data
ADC	5	0.2	Measure G-forces
Laptop*	12	2	Interface between PC & accelerometer

Fig. 10-1: Electrical Components

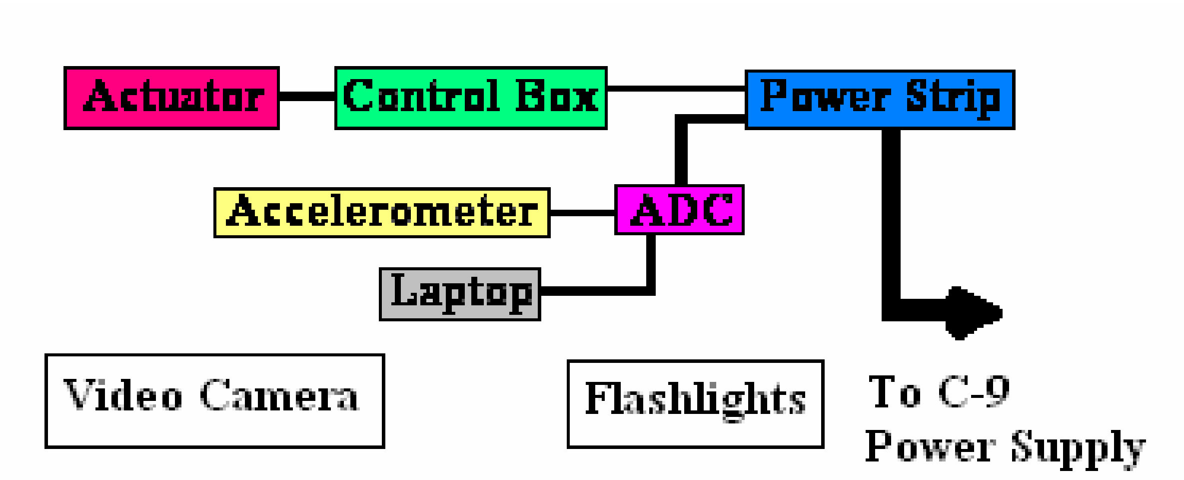


Fig. 10-2: Schematic

11. Pressure/Vacuum System

Although our experiment does not contain any components intended to operate at an altered pressure, it does contain a rigid, fully sealed fluid containment tank that could be considered a pressure vessel if the plane were to lose cabin pressure. Our innermost layer of containment has an airtight seal. We are using the same inner containment box from last year, and consequently already have pressure tested it. However, we will perform the tests again and also to the other identical containment box, so that it will withstand a pressure of up to 5 psi. Also, a dual directional relief valve is set to release at a pressure of 3 psi, allowing the tank pressure to equalize well before its rated strength. The valve will be located at the top of the tank so that liquid cannot leak out. In addition, the tank will contain only air, deionized water, and water/glycerin mix, none of which are toxic or corrosive. Both the water and the water/glycerin mix will be confined to the bottom of the tank in a sponge.

12. Laser System

Our experiment does not involve the use of lasers.

13. Crew Assistance Requirements

Crew assistance is requested for loading the experiment onto the plane and proper strap attachment. In flight crew assistance is not required.

14. Institutional Review Board

The experiment does not involve human or animal test subjects or biological material.

15. Hazard Analysis

Hazard Number: 1

Hazard Description: Tank leaks

Hazard Causes:

1) Cracks/fractures develop as a result of stresses from the experiment
2) Tank dislocates and hits another object which creates a crack/fracture

Hazard Controls:

1) The two sides, top, and bottom are made of ¼" thick aluminum, the front and back are made of very strong clear polycarbonate
2) During preflight, the tank will be examined visually for cracks/fractures
3) Only water with a food coloring dye will be used in the tank
4) Tank will be firmly bolted to the aluminum platform

Hazard Number: 2

Hazard Description: Actuator comes in contact with the water or water/glycerin mix

Hazard Causes:

1) Top of the tank breaks due to stresses during the experiment

Hazard Controls:

1) Actuator is splash resistant
2) Will have fuses and a master kill switch to turn the power off
3) Top of tank is made of ¼" thick aluminum
4) The actuator will only provide a force of <25 lbs. which is not sufficient to damage any components of the experiment
5) During preflight, tank will be carefully inspected visually

Hazard Number: 3

Hazard Description: Sliders are jammed

Hazard Causes:

1) Dirt/foreign objects on the poles
2) Actuator does not work properly
3) Control box fails to work properly

Hazard Controls:

1) Power will be turned off by the master kill switch
2) During preflight, we will test the motion of the sliders to make sure that they work properly and examine the poles to make sure they are free of dirt and any foreign objects
3) We will verify that the actuator works properly during the preflight check

Hazard Number: 4

Hazard Description: Too much current runs through the actuator

Hazard Causes:

1) Current regulator for actuator does not function properly
2) Insulation of wire is worn
3) Control box malfunctions

Hazard Controls

1) Actuator will use a small amount of current
2) Will have a fuse to turn off the power in case of a current overdraw
3) Will have a master switch to turn all power off
4) During preflight check, we will verify that all wires and connections work properly

Hazard Number: 5
Hazard Description: Malfunction of control box
Hazard Causes:
1) Sliders jam causing the actuator to not work properly
2) Wires are damaged or worn
3) Electrical malfunction or shortage
Hazard Controls:
1) If the control box does not function properly, preventing the actuator from working properly, no damage to the experiment or operator will occur
2) The actuator is properly contained
3) A master kill switch will be available
4) See Hazard Control Number 3: "Sliders are jammed"
5) Prior to flight, the box will be tested to make sure it works properly and the wires will be carefully examined to ensure that there is no damage.

Hazard Number: 6
Hazard Description: Malfunction of camera
Hazard Causes:
1) Camera is not connected properly
2) Camera is damaged
3) Electrical malfunction or shortage
Hazard Controls:
1) We will test electrical parts
2) Before take-off, we will make sure the camera works properly

Hazard Number: 7
Hazard Description: Damage to experiment equipment
Hazard Causes:
1) Experiment becomes detached from the platform
2) Fluid comes in contact with the electronics
Hazard Controls:
1) Components will be firmly bolted to the aluminum platform
2) Outer containment box will control any free floating parts
3) All sides and corners of outer containment box will be padded with closed cell foam
4) A master kill switch will be available for all electronics
5) See Hazard Number 2: "Actuator comes in contact with the water or water/glycerin mix"

Hazard Number: 8
Hazard Description: Electrical shock of operator

Hazard Causes:
1) Worn or damaged wire
2) Overload of current
Hazard Controls:
1) Before take-off, all wires will be checked
2) A master kill switch will be available
3) See Hazard Number 4: “Too much current runs through the actuator”

Hazard Number: 9
Hazard Description: Damage to DC-9
Hazard Causes:
1) Experiment detaches from the floor of the plane due to a failure of stowage restraint, which could cause damage to the cabin and crew
Hazard Controls:
1) Outer containment box will be made from polycarbonate with aluminum on the edges
2) All edges and corners of the outer containment box will be padded with closed cell foam
3) Outer containment box will be restrained with straps rated to a maximum tensile strength of 5,000 lbs.

16. Tool Requirements

We will limit the amount of tools we bring. Standard tools will be borrowed from Ellington Field's tool chests. Any tools we do bring will be controlled in accordance with Naval Aviation practices to minimize any FOD issues.

Tools that may be needed include:
Flat-head screwdriver set
Phillips screwdriver set
Standard wrench set
Standard socket set
Duct tape
Electrical tape

17. Ground Support Requirements

Power Requirements

A standard 120 VAC 60 Hz power source is required to test the equipment.

Hazardous Material Storage

Storage of hazardous materials is not required.

Building 993 Access

Access to building 993 is only required during normal working hours.

Loading/Unloading

A forklift or pallet jack is requested to move the experiment to and from the storage area and aircraft.

18. Hazardous Materials

Glycerin and water will be used as testing mediums with the experiment.

Material Safety Data Sheet [6]
Glycerin
ACC# 10440
Section 1 − Chemical Product and Company Identification
MSDS Name: Glycerin
Catalog Numbers: S71228, S71229, S74606-1, S746061, BP229-1, BP229-4, G153-1, G153-4, G30-20, G30-200, G30-4, G31-1, G36-20, G37-20, G37-200, NC9484773
Synonyms: Glycerol; 1,2,3-Propanetriol; Glycyl alcohol; 1,2,3-Trihydroxypropane
Company Identification:
Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410
For information, call: 201−796−7100
Emergency Number: 201−796−7100
For CHEMTREC assistance, call: 800−424−9300
For International CHEMTREC assistance, call: 703−527−3887

Section 2 − Composition, Information on Ingredients

CAS#	***Chemical Name***	***Percent***	***EINECS/ELINCS***
56-81-5	Glycerin	100	200-289-5

Section 3 − Hazards Identification
EMERGENCY OVERVIEW
Appearance: Clear Liquid.
Caution! This is expected to be a low hazard for usual industrial handling. May cause eye and skin irritation. May cause respiratory and digestive tract irritation.
Target Organs: None known.
Potential Health Effects
Eye: May cause eye irritation.
Skin: May cause skin irritation. Low hazard for usual industrial handling.
Ingestion: Ingestion of large amounts may cause gastrointestinal irritation. Low hazard for usual industrial handling. May cause headache.
Inhalation: Low hazard for usual industrial handling. Inhalation of a mist of this material may cause respiratory tract infection.
Chronic: No information found.

Section 4 − First Aid Measures
Eyes: Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. If irritation develops, get medical aid.
Skin: Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.
Ingestion: Never give anything by mouth to an unconscious person. Do NOT induce

vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water. Get medical aid if irritation or symptoms occur.

Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.

Notes to Physician: Treat symptomatically and supportively.

Section 5 − Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Use water spray to keep fire-exposed containers cool. Vapors may be heavier than air. They can spread along the ground and collect in low or confined areas. Containers may explode when heated.

Extinguishing Media: Use water spray to cool fire-exposed containers. Use agent most appropriate to extinguish fire. Use water spray, dry chemical, carbon dioxide, or appropriate foam.

Flash Point: 193 deg C (379.4 deg F)

Auto ignition Temperature: 400 deg C (752.00 deg F).

Explosion Limits, Lower: 1.1.

Upper: Not available.

NFPA Rating: (estimated) Health 1 ; Flammability 1 ; Instability 0:

Section 6 − Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Absorb spill using an absorbent, noncombustible material such as earth, sand, or vermiculite. Avoid runoff into storm sewers and ditches which lead to waterways. Clean up spills immediately, observing precautions in the Protective Equipment section. Remove all sources of ignition. Provide ventilation.

Section 7 − Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Do not get on skin or in eyes. Do not ingest or inhale. Keep container tightly closed. Use with adequate ventilation.

Storage: Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances. No special precautions indicated.

Section 8 − Exposure Controls, Personal Protection

Engineering Controls: There are no special ventilation requirements.

Exposure Limits

Chemical Name	***ACGIH***	***NIOSH***	***OSHA − Final PELs***
Glycerin	10 mg/m^3	none listed	15 mg/m^3 TWA total dust; 5 mg/m^3 TWA respirable fraction

OSHA Vacated PELs: Glycerin: 15 mg/m^3 TWA total dust; 5 mg/m^3 TWA respirable fraction

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA;s eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 − Physical and Chemical Properties

Physical State: Liquid
Appearance: Clear.
Odor: Faint odor
pH: Not available.
Vapor Pressure: .0025 mmHg @ 5.
Vapor Density: 3.17 (air=1)
Evaporation Rate: Not available.
Viscosity: Not available.
Boiling Point: 290 deg C.
Freezing/Melting Point: 20 deg F.
Decomposition Temperature: 290 deg C.
Solubility: Miscible in water. Insol. In chloroform,
Specific Gravity/Density: 1.2610g/cm^3 @ 20
Molecular Formula: $C_3H_8O_3$.
Molecular Weight: Not available.

Section 10 − Stability and Reactivity

Chemical Stability: Stable.
Conditions to Avoid: Incompatible materials, ignition sources, excess heat.
Incompatibilities with Other Materials: Acetic anhydride, potassium permanganate, strong acids, caustics, isocyanates, oxidizing agents, aliphatic amines..
Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, irritating and toxic fumes and gases.
Hazardous Polymerization: Will not occur.

Section 11 − Toxicological Information

RTECS#:
CAS# 56-81-5: MA8050000
LD50/LC50:
CAS# 56-81-5:
Draize test, rabbit, eye: 126 mg Mild; Draize test, rabbit, eye: 500 mg/24H Mild; Draize test, rabbit, skin: 500 mg /24H Mild; Inhalation, rat: LC50 = > 570 mg/m3/1H; Oral, mouse: LD50= 4090 mg/kg; Oral, rabbit: LD 50 = 27 gm/kg; Oral,

rat: LD 50=12600 mg/kg; Skin, rabbit: LD 50 = >10 gm/kg.
.
Carcinogenicity:
Glycerin: Not listed by ACGIH, IARC, NTP, or OSHA.
Epidemiology: No information available.
Teratogenicity: No information available.
Reproductive Effects: No information available.
Mutagenicity: No information available.
Neurotoxicity: No information available.
Other Studies: No data available.

Section 12 − Ecological Information

Ecotoxicity: Cas# 56-81-5: LC50 (96 Hr.) rainbow trout = 50-67 mg/L; 12 deg C LC 50 (96 Hr.) goldfish = >5000mg/L.
Environmental: No information reported.
Physical: No information available.
Other: None.

Section 13 − Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.
RCRA P−Series: None listed.
RCRA U−Series: None listed.

Section 14 − Transport Information

US DOT: No information available
Canada TDG: No information available

Section 15 − Regulatory Information

US FEDERAL
TSCA
CAS# 56-81-5 is listed on the TSCA inventory.
Health &Safety Reporting List
None of the chemicals are on the Health &Safety Reporting List.
Chemical Test Rules
None of the chemicals in this product are under a Chemical Test Rule.
Section 12b
None of the chemicals are listed under TSCA Section 12b.
TSCA Significant New Use Rule
None of the chemicals in this material have a SNUR under TSCA.
CERCLA Hazardous Substances and corresponding RQs
None of the chemicals in this material have an RQ.
SARA Section 302 Extremely Hazardous Substances
CAS# 56-81-5: chronic.

Section 313 No chemicals are reportable under Section 313.
Clean Air Act:
This material does not contain any hazardous air pollutants.
This material does not contain any Class 1 Ozone depletors.
This material does not contain any Class 2 Ozone depletors.
Clean Water Act:
None of the chemicals in this product are listed as Hazardous Substances under the CWA.
None of the chemicals in this product are listed as Priority Pollutants under the CWA.
None of the chemicals in this product are listed as Toxic Pollutants under the CWA.
OSHA:
None of the chemicals in this product are considered highly hazardous by OSHA.
STATE
Glycerin can be found on the following state right to know lists: PA, MN, MA
California Prop 65
California No Significant Risk Level: None of the chemicals in this product are listed.
European/International Regulations
European Labeling in Accordance with EC Directives
Hazard Symbols: Not available.
Risk Phrases:
Safety Phrases: S 24/25 Avoid contact with skin and eyes.
WGK (Water Danger/Protection)
CAS# 56-81-5: 0
United Kingdom Occupational Exposure Limits: CAS# 56-81-5: OES-United Kingdom, TWA 10 mg/m3 TWA (mist)
Canada − DSL/NDSL
CAS# 56-81-5 is listed on Canada's DSL List.
Canada − WHMIS
This product has a WHMIS classification of Not controlled.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.
Canadian Ingredient Disclosure List: Not listed

Section 16 − Additional Information
MSDS Creation Date: 7/20/1999
Revision #4 Date: 2/20/2002

19. Procedures

19.1 Pre-Flight

We will conduct a pre-flight checklist before each flight to ensure our experiment is ready for flight. The checklist includes:

1) **Outer Containment Box Integrity:** Examine the outer box for cracks, misalignments, or other abnormalities.
Reaction Plan: Replace with alternate outer box that has no cracks, misalignments, or abnormalities.
2) **Inner Tanks Integrity:** Examine both inner tanks for cracks, misalignments or other abnormalities that may cause leaks.
Reaction Plan: Replace one or both tanks with alternate tank that has no cracks, misalignments, or abnormalities.
3) **Actuator/Motion of Poles:** Run actuator and ensure motion along sides and that the polycarbonate wedges move smoothly and are unobstructed.
Reaction Plan: Remove any obstructions, clean, and lubricate moving parts as needed. Check electrical connections on actuator.
4) **Sponge/Liquid Check:** Ensure sponges contain correct amounts of water or water/glycerin mix and that water has sufficient food coloring for better visibility.
Reaction Plan: Replace one or both sponges with sponge containing correct amount of liquid and add food coloring to water as needed.
5) **Accelerometer:** Verify that the accelerometer is working properly and that the laptop is receiving data from it.
Reaction Plan: Examine all the electrical connections between the accelerometer and laptop.
6) **Video Cameras:** Ensure video cameras are working properly and that batteries are new and fresh tapes are in them.
Reaction Plan: Replace batteries/tape as needed and check electrical connections on video cameras.
7) **Computer Software:** Validate that all electrical systems are operating properly and communicating with the laptop.
Reaction Plan: Check all connections and restart the laptop.

Following a successful review of the checklist, a Test Flight Director will help fasten the apparatus to the floor and finish other pre-flight procedures.

19.2 Overview

When the plane enters microgravity, we will start conducting the experiment. The actuator will be controlled by switches activated at various times throughout the flight. In case of any emergencies, there will be a manual power shut off.

19.3 In-Flight

1) The video cameras are mounted to the apparatus and are turned on before the parabolas start.

2) Once microgravity begins, one of the researchers will activate the actuator, which will move the wedges towards their respective sponges. The liquid in each sponge will climb up the angles of the wedges and over to the other side into a collection tube.

3) Once normal gravity begins, the liquid in the tubes will drop to the bottom, enabling a measurement to be recorded by the video cameras.

4) Then a researcher will push a button to move the actuator and wedges back up so the liquid can return to the sponge for the next trial.

5) Repeat steps 2 through 4 for every parabola.

6) After the last parabola is completed, the actuator and video cameras will be turned off.

19.4 Data Collection

The video cameras will start recording before the first parabola. The cameras will record the liquid moving up the wedges and the level of the liquid in the collection tubes before the actuator moves along and the liquid returns to the sponge. The data will be saved for future analysis.

19.5 Post Flight

We will unload our apparatus at the end of the flight. Video camera batteries and tapes will be replaced for the next flight. After each flight, an overview of our pre-flight checklist will be conducted again to ensure the apparatus is ready for the next flight.

III. Outreach

20 Outreach Plans

20.1 Outreach Goals:

1. Target students with under-represented backgrounds to let them know more about engineering, science, and math fields
2. Share our experience of microgravity and NASA with smaller cities that are not usually reached by similar initiatives so that they will learn more about the science and engineering opportunities at the universities as well as at NASA
3. Inspire elementary, middle, and high school students to attend college and to get involved in engineering and science
4. Show the exciting opportunities provided by the University of Wisconsin and NASA to young students and community members
5. Encourage students and the public to be involved in science and engineering events happening in their state and universities
6. Inform students and the public about our capillary action research, why we are studying it and the critical role that NASA plays in this research

We have chosen the following outreach initiatives to achieve our goals:

20.2 Hmong Population Outreach Initiative:

Background:

During the Vietnam War, the Hmong were allies to the United States. They rescued down American pilots, disrupted the Communist's supply lines, and protected the U.S.'s radar base. When the U.S. pulled out of Southeast Asia, many Hmong fled to the refugee camps in Thailand and then eventually immigrated to the U.S. as well as other countries in order to escape prosecution from the Communists taking revenge on them. More than 100,000 Hmong died due to the war. Today, about 250,000 Hmong live in the U.S. Wisconsin ranks third with the largest Hmong population.

20.2.1 Hmong Academy Charter School

Hmong Academy Charter School is in Minnesota, which is the state with the second largest Hmong population. Hmong Academy Charter School has students from grades 9-12. One of its main goals is to prepare students for college. Physics teacher, Sheila Sullivan, contacted our team member, Mai Lee Chang, to give a presentation about our microgravity experiment to her students. Even though St. Paul, MN is far from Madison, she has agreed to give a presentation that will include our microgravity research, engineering, science, and math majors/careers, and the various opportunities that NASA offers such as the co-op and internship programs. She is a current NASA JSC Co-op Student. Since she is Hmong, she will be able to relate to them directly, and she plans to continue doing this again in the future.

20.2.2 FutureHmong Magazine

FutureHmong Magazine is based in Appleton, WI and publishes monthly, distributing across the nation. Many young Hmong read this magazine. FutureHmong's mission is to further Hmong advancement in the U.S. by educating them about various issues in American society as well as issues within the Hmong community. Team member Mai Lee Chang has contacted them to see if they will be interested in running a story about our microgravity experience.

20.2.3 Hmong National Radio

Hmong National Radio serves as a voice for the Hmong. Its mission is to inform and educate the Hmong community through broadcasting current news events as well a sharing ideas and thoughts through debates. Mai Lee Chang has spoken with them, and she has been scheduled for a one-hour talk show. She speaks Hmong well and will be able to explain our research to the entire Hmong community. In addition, she plans to talk about engineering, science, and math majors/careers, and NASA's internship and co-op programs hoping to inspire the young ones to become interested. Since 95% of the Hmong population listens to this radio, we'll be able to accomplish our goal of reaching out to them.

20.2.4 Oshkosh Hmong Local Channel 2

This news station has a one-hour evening segment every Tuesday, Thursday, and Saturday that presents community and general news to the Hmong community in the Winnebago County area in Wisconsin. One goal of this channel is to present educational materials and opportunities to the Hmong children in the community. Mai Lee Chang contacted them already, so she will be presenting our capillary experiment while specifically reaching out to the children to inspire them to consider careers in science and engineering. Since we are scheduled to have the entire one-hour segment, we will be showing video clips of our flight as well as well as her experience as a NASA JSC Co-op thus far.

20.2.5 Hmong American Student Association

The Hmong American Students Association (HASA) is an active organization on UW-Madison's campus that consists of about 40 active members. Mai Lee Chang is also a member of HASA and after conducting our microgravity project, we will share our results with the HASA members by giving a presentation in hopes to spark interest in the science and engineering majors.

20.2.6 Hmong Association of Engineers

Hmong Association of Engineers (HAE) is a newly founded organization on campus that serves as a networking and support group. Mai Lee Chang is one of the founders. One of the main objectives of the organization is to make aware of all the support and opportunities that UW-Madison's College of Engineering provides for students and to encourage them to take advantage of them. After conducting our experiment, she will give a presentation to the group to share our research findings and hands-on engineering opportunities that the university as well as NASA has available for undergrads to get involved in.

20.3 Other Targeted Population Outreach Initiative:

20.3.1 Expand Your Horizons

Expand Your Horizons is a one-day career conference that invites up to 400 6th, 7th, and 8th grade girls from Southern Wisconsin to come to the UW-Madison campus to experience a variety of math and science related careers. This year, team member Meg Reinbold is volunteering as a science activity leader on November 11, 2006. She will discuss the concepts of microgravity, share with them what it is like to experience microgravity, and explain how the microgravity program fits into a career in science.

20.3.2 Society of Hispanic Professional Engineers

The UW-Madison chapter of the Society of Hispanic Professional Engineers was established in 1991 to advance its mission by serving the Hispanic student body. Today SHPE is involved with numerous activities that aid under-represented students in achieving academic excellence. One of the programs that SHPE has become a part of is tutoring and lecturing the students of Madison East High School. The program entails members of SHPE going to the high school and tutoring the students struggling in areas such as: conversational English for non-native students, math, world history, biology, pre-engineering, etc. Members also present a lecture on different areas of engineering in a pre-engineering class where students are introduced to the various fields of engineering. It is SHPE's goal to increase the number of under-represented students in universities, especially at the UW-Madison. Andrew Elizondo, a team member as well as an active member of SHPE, plans to volunteer as well as share with them the uniqueness of the microgravity program.

20.3.3 Asian and Pacific American Council (APAC) Prodigy Newsletter

The APAC Prodigy Newspaper serves the Asian and Pacific American student population of the University of Wisconsin-Madison. About fourteen Asian student organizations such as Filipino, Hmong, Laotian, Malaysian, Hawaiian, Vietnamese, and Indonesian are a part of APAC. The Newsletter is in the process of writing a story about our capillary experiment. Our story in this newsletter will be able to reach out to the Asian and Pacific American students to let them know about our microgravity experience and the vital role that NASA plays.

20.3.4 Leaders in Engineering Excellence and Diversity (LEED)

LEED is an organization for under-represented students in the College of Engineering and any undergraduates interested in diversity. Even LEED is open to all students, it is competitive to become a scholar. LEED also provides academic and career goals support by holding a meeting each month for members to get to know each other more and network, to know about available scholarships, tutoring services, internship/co-op opportunities, and other opportunities that are available. Mai Lee Chang is an active LEED Scholar. A picture of her conducting our capillary action during flight will appear in the LEED brochure. The team also plans to give a presentation to the group during one of the meetings to share why we are studying capillary forces in microgravity and NASA's Co-op and Internship programs.

20.4 Youth in Science and Engineering Initiative:

20.4.1 Engineering Saturdays for Tomorrow's Engineers at Madison (ESTEAM)

ESTEAM is a bi-annual, daylong program that invites top-performing Wisconsin high school juniors and seniors and their parents to campus. In the past, team member Keith Rein met with groups of high school students for about 15 minutes each. During that time, he gave an overview of the RGSFOP, our microgravity experiment, and explained how a microgravity environment is achieved. In addition, he answered questions about what the students could expect if they decided to pursue an engineering mechanics degree from UW-Madison. Keith plans to continue participating again this year and will share with them his direct experience of being in microgravity as well as the results of our capillary experiment.

20.4.2 Madison Neighborhood House

Neighborhood House is an after school program for students K-12 that can not go home right after school due to harsh situations at home. Since it is located very near campus, it is easy for us to reach out to them more often, and it is so important that we do reach out to them. Mai Lee Chang is a volunteer there. The team plans to create a mentor/mentee program with the children so that they can get to know each other on a personal level with a focus on encouraging and exposing them to engineering and science.

20.4.3 Science Olympiad

Science Olympiad is a competition that is created to get K-12 students interested in science by showing them that it can be fun, exciting, and challenging. Students compete in various tournaments involving disciplines of biology, earth science, chemistry, physics, computers, and technology. During the year, students work hard to prepare for the competitions. We plan to help by being mentors and work with the Madison Public Schools. This mentoring relationship will give us the chance to expose them more to science and engineering.

20.4.4 Hometown High School Presentations

Many of the members are planning to give individual presentations at the high school that they graduated from and also other high schools in their hometown to the physics classes. Besides presenting about the microgravity program, the team's experiment, and the opportunities available in engineering, math, science, and technology, they will also be focusing on the importance of teamwork.

20.4.5 Madison Memorial High School

Madison Memorial High School is a local school that has a high number of students who are interested in science and engineering. Team member Ben Longmier has given classroom presentations to Memorial High School’s Aerospace class and Astronomy classes on our past experiments. Afterwards, several students that are very eager to setup programs at their future universities have contacted him, and the class in general was very pleased with the content and flow of the presentation. There was even a comment that “this was by far the best presentation that I have had all year in any class.” This was thought to be an ideal audience for the microgravity topic both because of the unique science being done and the novel aerospace experience. Due to the interest of students, we plan to continue to give more presentations this year.

20.4.6 Madison East High School

Madison East High School is also a local school with a diverse student body that includes many low income and minority students. We will give presentations to the freshman integrated science class and advanced physics class by using hands-on activities, video footages, and demonstrations to give them a better understanding of our microgravity experiment. In addition, we plan to discuss different opportunities available to them in engineering, science, and technology and encourage them to pursue college after graduation.

20.4.7 Wednesday Night at the Lab

The Science Alliance, the Wisconsin Alumni Association, and the UW-Madison Osher Lifelong Learning Institute sponsor Wednesday Night at Lab. Presenters give a 35-40 minute talk and then engage with the participants in a discussion. The demographics of the participants are about 50% active retirees with some families and 50% students. Ben Longmier has given a presentation focusing on our ZeroG team's past and current experiments and the critical contribution from NASA.

20.5 Other Outreach Activities:

20.5.1 Science Alliance

Science Alliance is a very popular annual event that takes place on UW-Madison's campus to give the public the opportunity to know more about students’ and faculties’ work/research. This event attracts 500-700 students from ages 8-15 and interested adults. We have always participated in Science Alliance in the past and will continue to do so. We will set up an exhibit of our zero gravity research that includes pictures, videos, and our experiment. We will explain how and why we are conducting our experiment as well as majors/careers in engineering and science, and the opportunities that NASA has available**.**

20.5.2 UW-Madison's Engineering EXPO 2007

On April 19-21, 2007, UW-Madison's College of Engineering will be hosting Engineering EXPO 2007 which is a huge event that is designed to showcase the exhibits of students, faculty and staff to K-12 students and the general public. Out of the 10,000-15,000 attendees, the majority of them are K-12 students from around Wisconsin, and for many, it is their only or first experience with college engineering. We will be there to present our zero gravity research, explaining why and how we are studying dynamic fluid flow due to capillary forces in microgravity, an overview of the RGSFOP, and opportunities with NASA such as the Co-op and Internship programs. Our exhibit will include pictures and videos of our present and past experiences with weightlessness and visits to NASA in Houston. In addition to the exhibit, we plan to give underrepresented students a more personal learning experience by having some of our team members be their mentors and guide small groups through the exhibits and around the campus.

20.5.3 CAP ZeroG Website

The CAP ZeroG website (http://homepages.cae.wisc.edu/~rmzerog/) is designed to let the general public know about our research as well as a place for our members to find more information such as the proposal, pictures, and useful links. This website plays a vital role because others interested in our research have contacted us after looking through our website such as Sheila Sullivan, a physics teacher at the Hmong Academy School, and new team members.

20.5.4 WI Engineer Magazine

The WI Engineer Magazine is a part of the Engineering College Magazines Association and is student run. It is published four times a year. Team member Pete Penegor is on the photography staff, so he spoke with the editor. The magazine will publish an article about our microgravity experience. We will use this as a tool to encourage more student and faculty involvement as well as to generate funding for next year's project.

20.5.5 Wisconsin International Scholars Program (WISc)

The Wisconsin International Scholars Program gives undergraduates the opportunity to add an international dimension to their education while they undertake their regular degree program. Scholars must apply to the program when applying for admission to the university as a freshman, so it is competitive to get in. The program provides many international academic and co-curricular activities including studying abroad. One of the activities is to share among scholars what extracurricular activities each person is involved in on campus. Mai Lee Chang will share with them the importance of our capillary research experiment and its applications.

20.5.6 American Institute of Aeronautics and Astronautics (AIAA) Presentations

Most of our team members are a part of the local student chapter of AIAA. At the monthly meetings, we will update everyone on the status of our experiment progress as well as provide the opportunity for our members to discuss the implications of our research in greater detail. Two members, Mai Lee Chang and Lisa McGill, will be presenting our first capillary experiment in the session called "Future Exploration Leaders Networking Event" at the AIAA Exploration Conference in Houston on December 5, 2006.

20.6: Community Outreach Through the Media:

20.6.1 Badger Herald

The Badger Herald was started in 1969 as an alternative voice on campus. Currently, it is the largest independent daily campus newspaper in the nation. We will be able to reach the majority of the University of Wisconsin student population through this newspaper. After conducting our experiment, we intend to write an article for publication in *The Badger Herald* with a focus on increasing non-engineering students' participation in microgravity research.

20.6.2 The Daily Cardinal

The Daily Cardinal has been around since 1892. It is an award winning student newspaper that is published weekdays and circulates to 10,000 people including the UW-Madison and the surrounding community thus allowing us to reach a more diverse audience. Once we have completed our experiment, we will submit our findings to the paper with the intention of getting more students, faculty, and community members to become interested in zero gravity research as well as understanding the significance of this kind of research.

20.6.3 Madison Observer

The Madison Observer is an independent, student-run publication that distributes on a bi-weekly basis on campus and in the Madison area. Historically, Madison residents have a strong interest in science and academia. We will contact *The Madison Observer* in hopes of submitting an article for publication. This newspaper will allow us to reach out to the greater community and not just the students and faculty on campus. Again, we hope to increase the campus's and community's interest in microgravity research.

20.6.4 The Wisconsin State Journal

The Wisconsin State Journal is Wisconsin's official state newspaper and is distributed throughout Wisconsin. In the past, the newspaper's reporters have traveled with us to Houston during our flight week. Responses regarding the articles demonstrated that *The Wisconsin State Journal* is an excellent way for reaching to areas across the state that might not otherwise be aware of the NASA opportunities available to students. We would like to continue to share our research findings with the public by planning to work closely with *The Wisconsin State Journal* this year.

20.6.5 FutureHmong Magazine

As described in Section 20.2.2.

20.6.6 Hmong National Radio

As described in Section 20.2.3 .

20.6.7 Oshkosh Hmong Local Channel 2

As described in Section 20.2.4.

20.6.8 Asian and Pacific American Council Prodigy (APAC) Prodigy Newsletter

As described in Section 20.3.3.

20.6.9 WI Engineer Magazine

As described in Section 20.5.4.

IV. Administrative Requirements

Letter of endorsement and **Statement of Supervising Faculty** to be included in mailed hard copy.

21. Funding/Budget Statement

Funding/Budget Statement

<u>**Itemized Budget Table**</u>

Materials			
Inner containment tank materials	$100/ea	1	$100
Bolts, connectors, etc.	$0.50/ea	30	$15
Total			**$115**
Chemicals			
De-ionized water	$10/liter	1	$10
Dyes	$5/oz	1	$5
Total			**$15**
Electronics			
Resistors, breakers, etc	$2/ea	10	$20
Actuator	$200/ea	1	$200
Actuator controls and connectors	$100/ea	1	$100
Video Camera	$350/ea	1	$350
Total			**$670**
Travel			
UW Fleet Vehicle	$27/day	10	$270
Added mileage costs	$.16/mile	2600	$416
Hotel in Houston	$125/night	10	$1,250
Food	$100/person	8	$800
Total			**$2,736**
Project Total			**$3,536**
Current Sources of Funding			
Wisconsin Space Grant Consortium (Travel Costs)			$2,000
UW Space Science and Engineering Center			$2,000

UW Engineering Physics Department	$500
UW Mechanical Engineering Department	$500
Total	**$5,000**

22. Experiments Involving Animals

Our experiment does not involve animal test subjects.

23. Parental Consent Forms

All team members are over the age of 18 at the time of proposal.