



**Surface Tension Impelled Low-Gravity Liquid Mixing Experiment**

Project ID: 2003-196

**Test Equipment Data Package**

Principal Investigator:

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## 2. KC-135 Quick Reference Data Sheet

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Experiment Title: Surface Tension Impelled  
Low-gravity Liquid Mixing Experiment

Flight Date(s): April 10<sup>th</sup> – 19<sup>th</sup>, 2003

Overall Assembly Weight (lbs): 212 lbs

Assembly Dimensions (L x W x H): 17" x 42" x 54.5" (without backplate)  
23" x 42.25" x 54.5" (with backplate)

Equipment Orientation Requests: Back 42.25" x 54.5" face against wall of fuselage

Proposed Floor Mounting Strategy: Bolts

Gas Cylinder Requests: None

Overboard Vent Requests: None

Power Requirement: 1.5 Amps (for video camera only)

Free Float Experiment: No

Flyer Names for Each Proposed Flight Day:

Day 1:	Michael Sharma	Day 2:	Paul Gosling
	Henry Mowry Cook		Paul Nerenberg
Alternate:	Sara Marten		

Camera Pole and/or Video Support: Video and photographic support requested

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## 4. Flight Manifest

Michael Sharma

First Flight Date

Previous Flights: None

Henry Mowry Cook

First Flight Date

Previous Flights: None

Paul Gosling

Second Flight Date

Previous Flights: None

Paul Nerenberg

Second Flight Date

Previous Flights: None

Alternate:

Sara Marten

Previous Flights: None

## **5. Experiment Background**

### **5.1 The Field of Study and its Applications**

The study of interfacial surface tension and wetting phenomena is important as an academic pursuit, as well as useful for practical applications. These and related phenomena are not yet fully understood at the atomic level, and studies are more empirical than theoretical. Models are approximate, and experimental data is relied upon heavily for the development of our understanding of this aspect of the physical world. An increased understanding of the atomic scale interactions and forces at play on boundaries between phases of matter at different densities is therefore desirable.

Just as important are the practical applications for current and future technologies. These include, but are not limited to, such everyday applications as the invention of soaps and detergents, the dispersal of insecticides on plants, automobile radiator coolant, windshield modification for visibility in rain, and waterproofing.

There exist a number of important applications in the fields of astronautics and aeronautics as well. Among these are liquid consumables processing and waste recycling on the International Space Station and the Shuttle Transportation System, avoiding use of mechanical power to mix by implementing a passive mixing technique, and the casting of parts in a mold by polymerization of two mixed liquids – useful for long space missions where unforeseen spare parts will be needed.

Another very important application is optimization of heat transfer through boiling in varying acceleration conditions. The ability to transfer heat from one part of an aircraft or spacecraft to another is a necessity for flight. The most efficient way to do this is through boiling, but boiling cannot currently be used in varying or very small acceleration conditions because the bubbles are not reliably driven off of the surface by buoyancy-induced convection. Research is underway to manipulate and move such bubbles by taking advantage of the interaction between electric fields and the change in dielectric constant across a bubble surface. Surface tension and wetting properties in microgravity conditions are needed for these studies.

### **5.2 Mechanism and Components of Surface Tension**

Surface tension, also called interfacial tension because it occurs across all interfaces between different phases of matter, is caused by the interactions of atoms or molecules at the boundary between the two phases. In the case of a liquid – gas boundary, molecules in the liquid volume will feel an attraction toward each other. This cancels out in the volume where a given molecule is being pulled in all directions at once, but at the surface that attraction will only be felt on one side of it, as the attraction to the widely dispersed molecules in the gas is negligible.

This difference causes the liquid surface to be forced inward upon itself. Being incompressible this results in a tension on the surface rather than a change in volume.

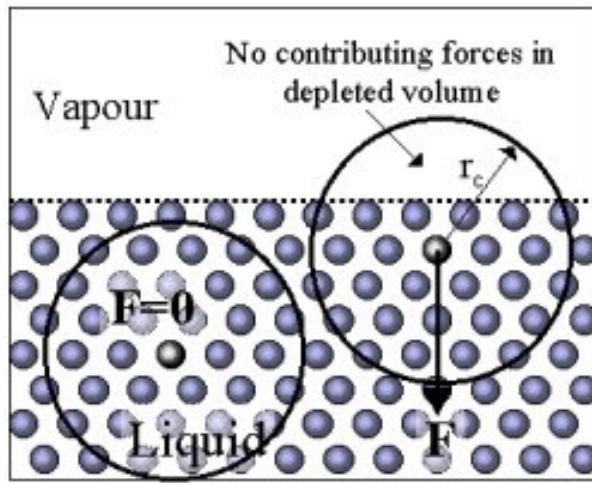


Fig. 5.1 – Mechanism of interfacial tension  
(Source: <http://gre.ac.uk/~gg11/surfacetension.html>)

Any boundary between two phases has interfacial tension. More generally, it is expressed in terms of the difference in free energy per unit area across a given interface. The most common way to account for the forces is to consider the free energies of the Solid-Liquid ( $\gamma_{SL}$ ), Solid-Gas ( $\gamma_{SG}$ ), and Liquid-Gas ( $\gamma_{LG}$ ) boundaries.

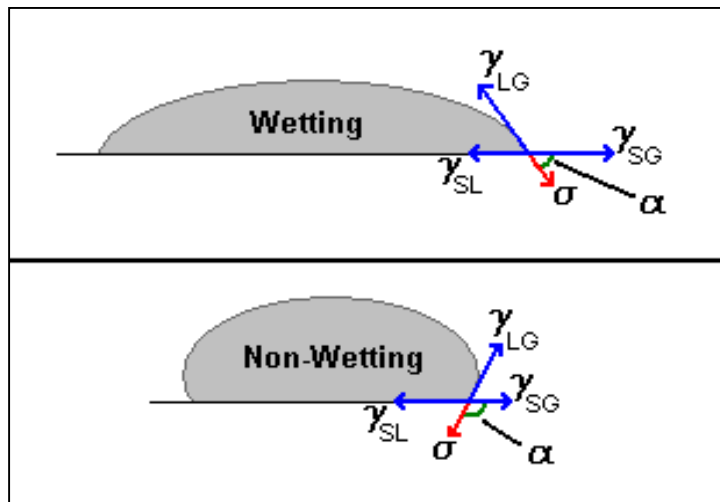


Figure 5.2 – Wetting and contact angle

### 5.3 Theoretical and Empirical Models of Spreading

Liquid propagation is dependent on surface tension and wetting properties of the system, but precise phenomena acting at boundaries of a spreading droplet are generally unknown.

“In spite of their importance, [wetting] processes are still poorly understood.... On the theoretical side, 180 years after the pioneering work of Young and Laplace, a number of basic capillary problems are just beginning to be solved.”<sup>1</sup>

However despite the challenging nature of these studies, successful models have been developed. The spreading properties of a three-phase system are described by the Spreading Coefficient (S) which is defined as  $S = \gamma_{SG} - \gamma_{SL} - \gamma_{LG}$ . There are three basic types of three-phase (liquid spreading through gas on a solid) system properties. 1) Complete wetting: defined as liquid spreading across a surface without stopping ( $S > 0$ ). 2) Partial wetting: if the liquid spreads to an equilibrium radius, stops there and beads ( $S = 0$ ). 3) Non-wetting: the liquid immediately beads up on the surface and does not spread at all ( $S < 0$ ). Figure 5.2 notes the difference in contact angles when a liquid is able to wet a surface and when it remains non-wetting.

The determining factor of whether gravity will have a large effect on a spreading droplet is the Bond Number, Bo:

$$Bo = g(\rho - \rho_f)d^2/g_c\sigma$$

where  $g$  is the acceleration of gravity,  $\rho$  is the density of the liquid droplet,  $\rho_f$  is the density of the gas around the liquid droplet,  $d$  is the ‘characteristic length’ of the droplet (relates Bond Number to volume),  $g_c$  is the dimensional constant, and  $\sigma$  is the surface tension.

If the volume is small, the Bond Number is low, and surface tension becomes the dominant force, regardless of the presence of  $g$ . If the volume is larger, the Bond Number in terrestrial conditions is high, and more dependent on the presence or absence of gravity. For the STILLMix experiment, larger volumes of liquids are being used (~ 30 mL) so the effect of gravity can be clearly determined. In 1976, Lopez et al.<sup>2</sup> found experimentally, with gravity, the radius of a spreading droplet went as:

$$R(t) = \Omega^{3/8}(\rho g t / \eta)^{1/8}$$

where  $\Omega$  is the volume,  $\rho$  is the density,  $g$  is the acceleration of gravity, and  $\eta$  is the viscosity. The time dependence comes in because the droplet settles into its equilibrium configuration within a ‘relaxation time’ defined by its viscosity and other properties. In 1985, De Gennes et al.<sup>3</sup> found, without the effect of gravity, that the radius goes as:

$$R(t) = \Omega^{3/10}(\gamma t / \eta)^{1/10}$$

where  $\Omega$  is the volume,  $\gamma$  is the surface tension, and  $\eta$  is the viscosity. Given the decreased dependence on time, one can assume that unless the surface tension is extraordinarily high, the

<sup>1</sup> P.G. de Gennes, “Wetting: Statics and Dynamics,” Rev. Mod. Phys., Vol. 57, No. 3, Part 1, July 1985

<sup>2</sup> Lopez, J., Miller, C.A., Ruckenstein, E., J. Colloid Interface Sci. 56 (1976), 460

<sup>3</sup> P.G. de Gennes, “Wetting: Statics and Dynamics,” Rev. Mod. Phys., Vol. 57, No. 3, Part 1, July 1985

radius of the droplet grows somewhat more slowly without the additional force of gravity pulling the liquid down onto the surface.

## **5.4 Complications of Gravitational Effects**

When surface tension effects are being studied using large volumes of liquid, gravity forces mask such effects and make it difficult to study key wetting properties. The true nature of the contact angle and equilibrium shape are obscured by the distortion imparted by gravity, restricting the amount of knowledge that can be gained from terrestrial experiments. Since it has only recently become possible to eliminate gravity from studies of surface tension and wetting, this is an opportunity to study these effects under microgravity conditions. One additional concern in gravity is that buoyancy complicates mixing by causing variations in the vertical direction (stratification). Conducting the experiment in microgravity, however, will eliminate buoyancy effects. The STILLMix experiment should also benefit from the greater relaxation times afforded by a microgravity environment as implied by aforementioned research conducted by De Gennes et al.

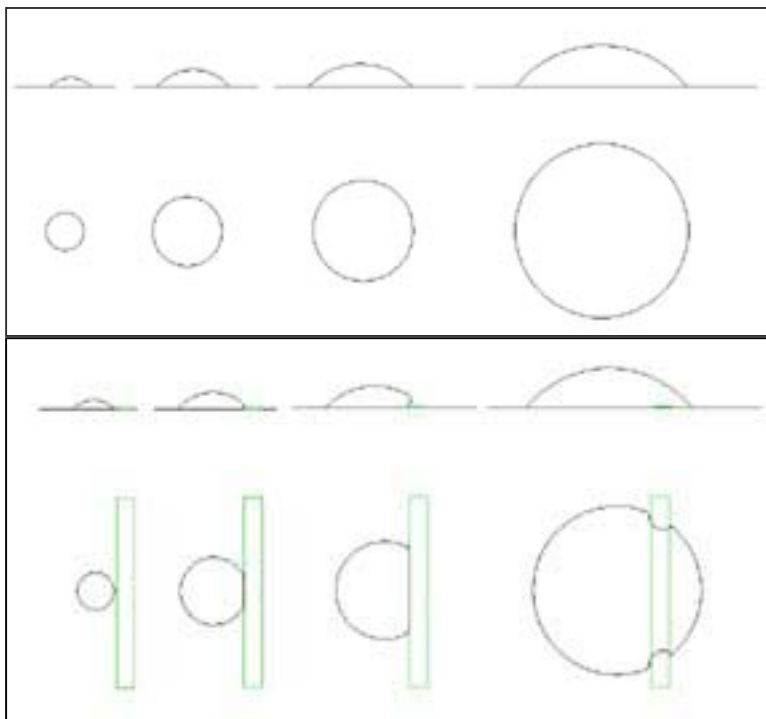
## **5.5 The STILLMix Experiment**

The STILLMix experiment provides a “clean” look at surface tension and wetting properties, without the muddling effects of gravity. The results can be used in microgravity applications, but also to improve understanding of the phenomenon in terrestrial conditions, and therefore are useful for terrestrial applications as well. The team's primary objective is to observe and characterize the surface mixing of two liquids in microgravity conditions. We plan to study the mechanics and dynamics of this mixing by allowing the two liquids to wet the same surface in microgravity conditions and come into contact. Through observation of the boundary (contact line) interactions of the liquids, we feel that a useful and reasonable model of surface mixing can be constructed.

An additional objective of the STILLMix experiment is to attempt to alter the dynamics of the mixing by shaping the contact line of the liquids just before they come into contact with each other. We hypothesize that a more sinusoidally-shaped contact line will allow more mixing to occur on the test section than would occur with the contact line of straight or semi-circular geometry. By analyzing the obtained visual data of liquid/liquid interactions in microgravity conditions, the resulting conclusions are intended to yield a better understanding of microgravity mixing and the effectiveness of different contact line geometries.

The STILLMix experiment utilizes a roughened aluminum surface for its test sections. All of the liquids used in the experiment are wetting on roughened aluminum, and the contact angle of the liquids with the solid boundary are all relatively low. The unique aspect of the experiment arises from the use of specifically cut Teflon<sup>®</sup> tape on to the aluminum test surfaces. Teflon<sup>®</sup> tape forms a non-wetting system with the liquids we are using. When the liquids reach the Teflon<sup>®</sup> tape, they will “see” a non-wetting surface and alter their shape and course to follow

the path of least resistance. The samples will flatten out along the surface, straightening out their forward edge. When given an extra perturbative ‘push’ over these Teflon<sup>®</sup> boundaries, they overcome the obstacle and soon adopt their original equilibrium shape on the roughened Aluminum again (Figure 5.3). We plan to take advantage of this brief period before equilibrium is restored, allowing the two samples to be pushed over two close parallel boundaries and immediately hit each other while still flat, before they have a chance to re-adopt their equilibrium rounded shape. This will be followed by a dotted line of Teflon<sup>®</sup> which will cause the wavefront to adopt a “fingered” shape, increasing the length of the contact line. If the two fingered contact lines are intertwined, a more thorough mixing should take place.



*Figure 5.3 – Droplet expansion across surfaces without Teflon<sup>®</sup> tape (top) and with Teflon<sup>®</sup> tape obstruction (bottom).*

The STILLMix apparatus is designed to be expandable for future experiments that will be able to generate different types of data utilizing a number of different methods. For example, future experiments using dielectric liquids, such as the silicone oil being used in the current experiment, will inject the liquids using electric fields generated in thin cylindrical capacitor tubes. Each experiment will also yield improved designs for the arrangements of Teflon<sup>®</sup> tape, as this is an iterative process. Future experiments would also afford an opportunity to test and develop hydro- or lipophilic surfactant coatings, using surfactants such as sodium 2-ethylhexyl sulfate, that could be used to coat any surface and improve the type of mixing used in the STILLMix experiment.

## 6. Experiment Description

### 6.1 Overview

The purpose of this experiment is to observe and characterize the mixing of liquids on a surface in microgravity. This experiment will take place under the KC-135A Reduced Gravity Research Program in order to minimize forces not related to interfacial tension. Characterization of the mixing process will provide insight into a number of physical and manufacturing processes in microgravity and on the ground. Additionally, in an effort to further improve mixing, this experiment will attempt to shape the contact line of the two liquids through alteration of the interface area of the test surface (see Sec. 7.2).

### 6.2 Experiment Methodology

Two liquids will be introduced onto a selected test surface during the microgravity segments of the flight. Over the next 10-15 seconds, the liquids will spread across this surface and begin mixing with each other. This process will be recorded by video for post-flight analysis. To aid the filming, each liquid will be dyed a different contrasting color.

This experiment will be run 18 times over the course of each flight. Test surfaces will be completely independent of the each other, offering redundancy and error reduction. Before each test is run, the camera will be positioned over the test surface to be used. As microgravity is achieved, one of the researchers will depress the plungers on the plastic syringes containing the liquids to be tested. After each microgravity segment ends, the camera will be repositioned to prepare for the next test.

Liquids to be Mixed	Surface to be Tested	Number of Tests
D.I. Water - D.I. Water	Aluminum	5
	Aluminum with Interface	4
D.I. Water - Ethyl Alcohol	Aluminum	5
	Aluminum with Interface	4
D.I. Water – Silicone Oil AR20	Aluminum	5
	Aluminum with Interface	4
D.I. Water – MEM Buffer	Aluminum	5
	Aluminum with Interface	4
Total:		36

*Table 6.1 – Summary of experiments to be performed*

### **6.3 Accompanying Ground-Based Experiments**

Each combination of liquids and test surfaces will be performed under normal laboratory conditions using the same apparatus and observational scheme. These experiments will be identical to those performed on the KC-135A in every respect except gravitational acceleration. This will make it possible to draw conclusions about the effects of surface tension and gravitational forces on liquid mixing.

### **6.4 Data Analysis**

Digital video recordings of both microgravity and ground experiments will be analyzed using image-processing routines created in MatLab. The image processing technique is based on measuring the color values of individual pixels in the video data. The two colors will combine as mixing begins to occur along the contact line between the liquids. Visually this appears as the formation of a third color along a line in the test section. We will digitally analyze the differentiation of color values, which will indicate saturation levels very precisely. In this way we can begin to construct a time-dependent model of the mixing. We can also look at color intensity to determine thickness of the drop, even when viewed from above.

### **6.5 Expected Results**

We hypothesize that there will be important differences between the results obtained in terrestrial and microgravity conditions. First, there will be no density-driven mixing or volumetric effects because the density differences between liquids will be physically insignificant due to the lack of gravity. Second, the relaxation times for the liquids will be slightly longer as gravity will no longer be forcing the liquid down to the surface, but rather, only surface tension will keep the liquid on the test surface. Finally, we believe that by the addition of specifically designed and positioned pieces of Teflon<sup>®</sup> tape (a non-wetting surface), we will be able to shape the contact line of the two liquids. We hope to achieve a leading edge shape that will create a longer contact line while occupying roughly the same test surface width. Theoretically, by increasing the mixing contact area of the two mixing liquids, the homogeneity of the final solution will also be increased.

## 7. Equipment Description

### 7.1 Coordinate System Convention



*Figures 7.1(a) and 7.1(b) - Front and rear views of the entire apparatus, minus video camera. The origin and coordinate system are noted here for reference in the text.*

### 7.2 Test Surface

In our proposed series of experiments, two liquid samples will be injected with syringes onto an aluminum surface enclosed within a sealed individual test section. To prevent the spreading of the samples outside the mixing surface, a rectangle of Teflon<sup>®</sup> tape will be applied to the aluminum, enclosing the mixing area. The Teflon<sup>®</sup> will form a non-wetting perimeter, across which the wetting tendencies of the liquid flow will be greatly reduced. On four of the nine viewing surfaces per liquid/liquid system, there will be a pattern of Teflon<sup>®</sup> tape at the mixing interface in order to help optimize flow shape upon contact. A dotted line of nonwetting tape will modify the shape of the wavefront to increase the length of the mixing contact line. The remaining five surfaces will simply be aluminum that has been unaltered except for the resurfacing.



Figure 7.2 (a) – Roughened Aluminum test surface



Figure 7.2 (b) – Roughened Aluminum test surface with Teflon<sup>®</sup> interface

### 7.3 Test Sections and Test Racks

The test surfaces must be enclosed and sealed against leakage. For this purpose each has a dedicated ‘test section’ enclosure. The test sections will be constructed in rows of six for structural integrity. Each will be sealed using gasketing and O-rings.

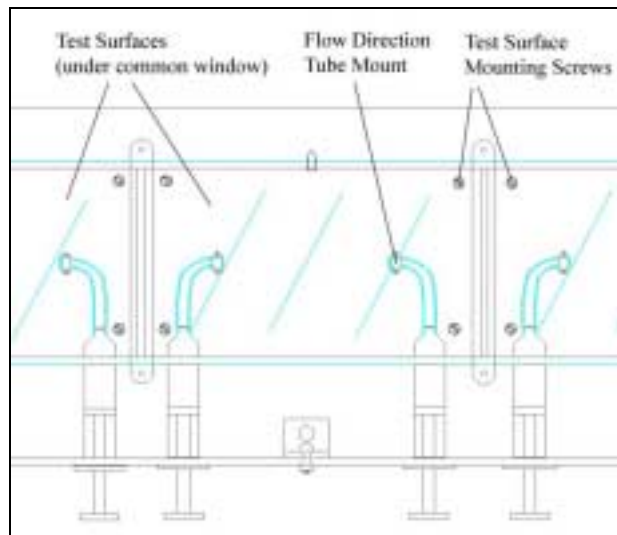


Figure 7.3 – Individual test section schematic

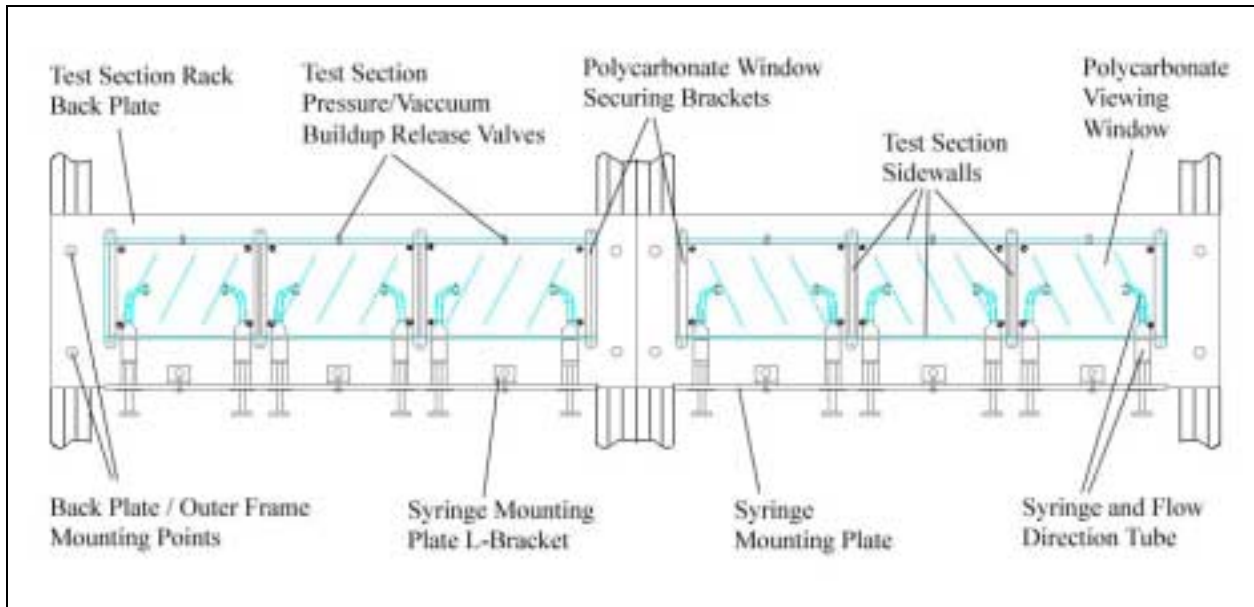


Figure 7.4 – Test rack schematic

Each row of three sections, called a Test Rack, will consist of an Aluminum back plate, top and bottom walls, and partition walls. A polycarbonate viewing window will cover the rack, held down by 1” wide Aluminum braces. The braces will be bolted to the back aluminum plate outside the test section area and will hold the polycarbonate window in place by compression. All Aluminum plates and braces will be ¼” thick. The polycarbonate will be ½” thick. The walls and partitions will be secured in place with screws, as shown in the schematic. Gasket tape will be used along all polycarbonate/aluminum contact lines to ensure a good seal so that the liquids do not spill over from one test section to another or into the cabin during the flight. A piece of aluminum screwed onto the back plate inside each test section will serve as the mixing surface. Each of the three racks weighs 14.3 lbs.

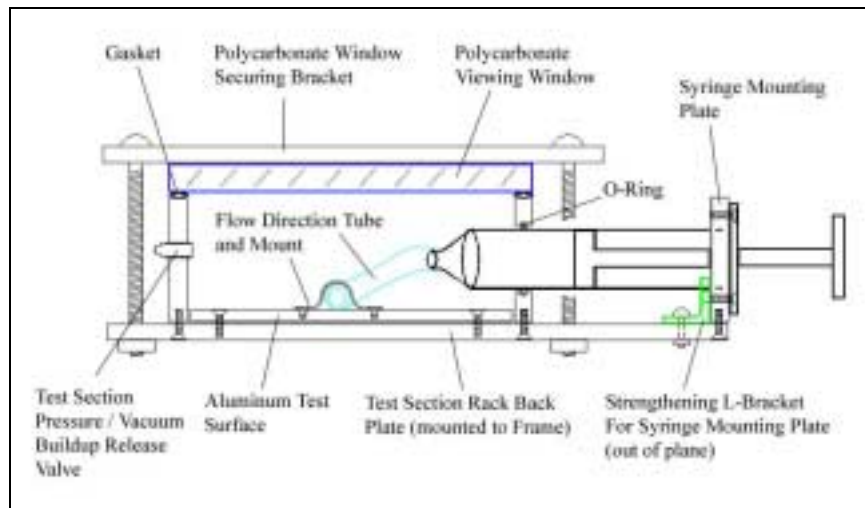


Figure 7.5 – Test section cross-sectional schematic

Two 30 mL syringes (Becton-Dickenson product # 309650) will be installed into each test section through an O-ring-sealed hole in the bottom aluminum plate (Figure 7.5). First, the syringes will pass through and be screwed into a syringe mounting plate, which will then in turn be screwed into the aluminum rack back plate. This will secure the syringes to the apparatus. The syringes will then pass through the bottom aluminum plate into the actual test section.



*Figure 7.6 – Syringe for sample injection*

Each test section will have a pressure / vacuum buildup release valve (McMaster-Carr product # 8063 K37) installed into a tapped hole (sealed with Teflon<sup>®</sup> tape) in the top (uppermost in y) wall of the test sections. The experiment does not involve any active pressure or vacuum maintenance, but the gasket-sealed test sections may experience undesired pressure or vacuum buildup due to changes in aircraft altitude. These valves will be depressed, releasing such pressure, at regular intervals throughout the flight.

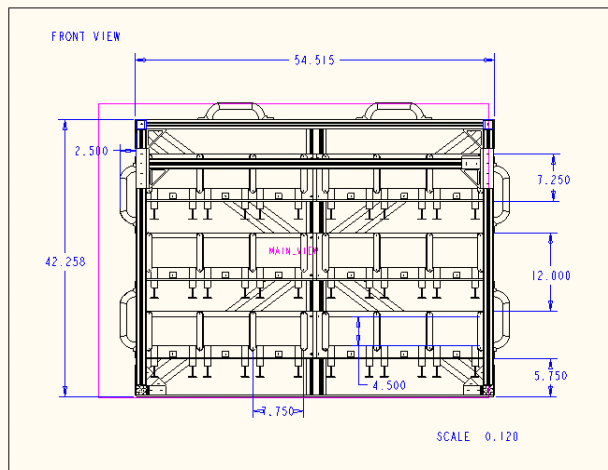
#### **7.4 Outer Frame**

For ease of construction and reduced machining time and costs, we have opted to use prefabricated parts to build the frame, camera mount, and structural stiffeners. The “Modular T-Slotted Aluminum Framing System” comes from 80/20 Inc. (<http://www.8020.net>) and uses standardized sizes that fit together snugly and with minimal machining.



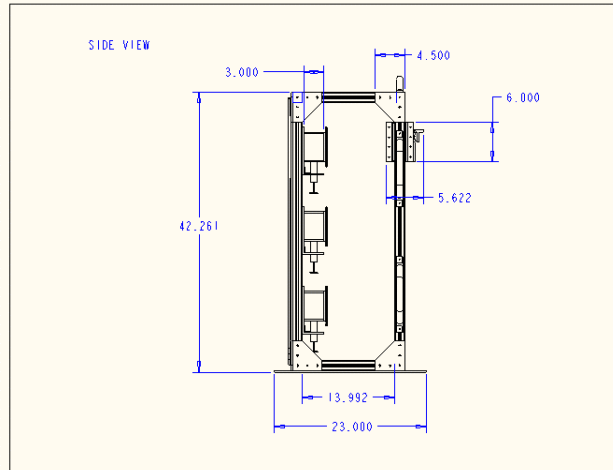
*Figure 7.7 - An example of one of the bars used for the frame. Cross sectional size: 1.5” x 1.5”*

The back plate of each rack will be bolted to these vertical aluminum T-Slotted extrusions on either side of the apparatus (Figure 7.4).



SCALE : 0.031 TYPE : ASSEM NAME : FRAME SIZE : A SHEET 1 OF 2

Figure 7.8(a) – Apparatus as viewed in the  $-z$  direction



SCALE : 0.031 TYPE : ASSEM NAME : FRAME SIZE : A SHEET 2 OF 2

Figure 7.8(b) – Apparatus as viewed in the  $+x$  direction

## 7.5 Video Camera Mount

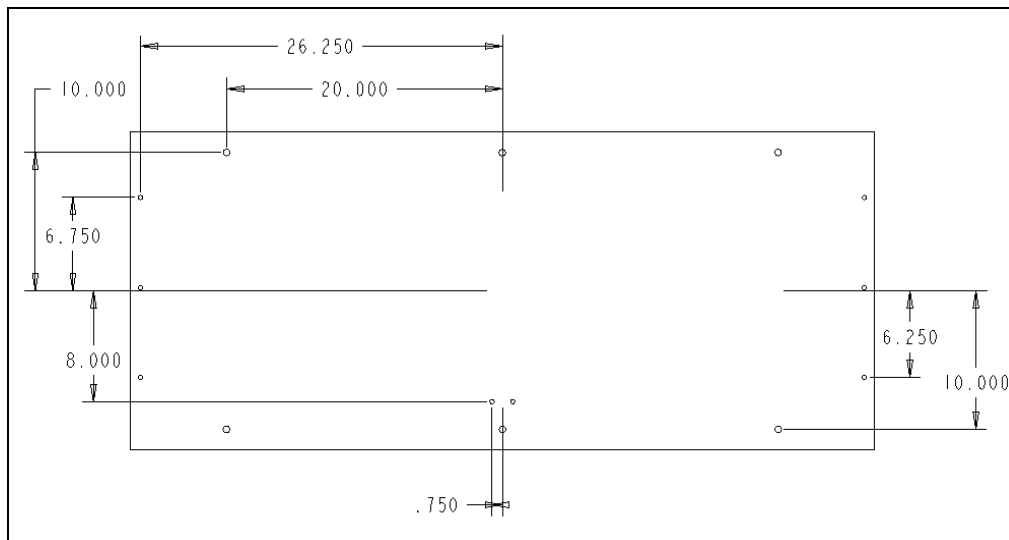
A SONY TRV 740 Digital-8 video camera (with a 1 Megapixel CCD) will be attached to a movable mount on the  $+z$  side of the frame, allowing it to slide in the  $x$  and  $y$  directions. In this manner it can move into place over any given test section. It will provide a visual record of the mixing process and the effect of the interface on the liquids' wavefront geometries. Each of the three sliders (two for movement in  $y$ , one for movement in  $x$ ) will have spring-loaded locking mechanisms. A metal pin will snap into predrilled seats in the bar they are sliding on, prohibiting movement. To move to the next test section for the next experiment, the spring-loaded pins will be lifted out of the seat, slid along, and allowed to snap into the next seat. One of these locking pins (McMaster-Carr product # 90222 A118) is shown below.



Figure 7.9 – Spring-loaded slider locking pin and brass air pressure release valve

## 7.6 Mounting Plate

The entire unified structure is bolted to the aircraft floor through an Aluminum base plate. This is the 'floor' of the apparatus that can be seen in Figure 7.1(a). The center of this plate serves as the origin of our coordinate system. The frame will be bolted to the plate through the + and - y edges of the base plate, and the base plate in turn will be bolted to the spacers in the aircraft floor through its + and - z edges, as shown in Figure 7.10.



*Figure 7.10 – Base mounting plate dimensions*

## 7.7 Tools

The tools that will be needed in flight are one video camera and one roll of electrical tape.

## 8. Structural Analysis

### 8.1 Overview

The STILLMix experiment rack has been designed around the loading conditions provided in the RGSFOP Experiment Design Requirements and Guidelines document. In this section we show that the entire apparatus, including its camera mount and test section subsystems, safely withstands the takeoff and landing loading conditions. The nature of our experiment allows us to mount all test racks directly to the frame, forming a unified rigid structure. We have found this to be advantageous in assuring the safety factors are well within acceptable limits.

### 8.2 Method

We used a combination of the Pro-Engineer computer program and hand calculations to determine the safety factors for the test sections, camera mount, and frame. We analyzed the forces and moments that would be imparted on the apparatus as a result of the loading conditions, and did load-path analysis to follow the loads from the centers of gravity to the spacers on the aircraft floor.

### 8.3 Note of Coordinate System

An origin and coordinate system convention has been established for the STILLMix apparatus (see fig 8.1). All location and direction references in this document use that coordinate system and origin location.

### 8.4 Global Analysis

For the first section of our analysis we assume that all induced loads on our apparatus will act at the centroid of our apparatus. Using Pro-Engineer we found that the centroid of our design (including the base plate) is at  $X = 0''$ ,  $Y = 19.93''$ ,  $Z = -0.73''$ . Our apparatus weighs 212 lbs. *Note: All factors of safety are reported in the table at the end of each section.*

#### 8.4.1 - Forward 9 g's

The loading condition of 9g's forward produces a "weight" directed forward of  $212 * 9 = 1,908$  lbs. The bolts must resist this shear load. Each of the six bolts used to secure the plate to the spacers is rated to resist up to 5,000 lbs of shear. So the total plate can resist up to  $5,000 * 6 = 30,000$  lbs of shear.

The weight created by this loading acts at the centroid which is 20" above the baseplate. Taking moments about the centroid, the bolts must create a counter-clockwise moment of  $20'' * 1,908$  lbs = 38,160 in-lb. The two bolts aligned along the center of the z-

axis cannot create any moment. The other four bolts are all 20" off center from the z-axis, so each pair of bolts must create  $38,160 \text{ in-lb}/20\text{in} = 1,908 \text{ lbs}$  of force. The two bolts toward the front of the aircraft will be in compression, where they carry no load. The two bolts toward the aft of the plane will be in tension, each carrying  $1,908/2 = 954 \text{ lbs}$  of tensile load. Each bolt is rated to 5,000 lbs of tension.

#### 8.4.2 - Aft 3 g's

The loading condition of 3g's aft produces a "weight" directed forward of  $212*3 = 636 \text{ lbs}$ . The bolts must resist this shear load. Each of the six bolts used to secure the plate to the spacers is rated to resist up to 5,000 lbs of shear. So the total plate can resist up to  $5,000*6 = 30,000 \text{ lbs}$  of shear.

The weight created by this loading acts at the centroid which is 20" above the base of the plate. Taking moments about the centroid, the bolts must create a counter-clockwise moment of  $20"*636 \text{ lbs} = 12,720 \text{ in-lb}$ . The two bolts aligned along the center of the z-axis cannot create any moment. The other four bolts are all 20" off center from the z-axis, so each pair of bolts must create  $12,720 \text{ in-lb}/20\text{in} = 636 \text{ lbs}$  of force. The two bolts toward the aft of the plane will be in compression, where they carry no load. The two bolts toward the front of the plane will be in tension, each carrying  $636/2 = 318 \text{ lbs}$  of tensile load. Each bolt is rated to 5,000 lbs of tension.

#### 8.4.3 - Down 6 g's

Our project will rest on three spacers, each of which can handle a live-6g load of 1,200 lbs. The induced weight of our apparatus under 6g's down is  $212 \text{ lbs}*6\text{g's} = 1,272 \text{ lbs}$ . So each spacer must resist 636 lbs. Therefore our project will not need additional floor shoring.

#### 8.4.4 - Up 2 g's

6 bolts, each of which is rated to 5,000 lbs in tension, will bolt our project to the floor. The total force upward that can be resisted by our bolts is therefore 30,000 lbs. Under 2g's upward, the bolts must resist  $212*2 = 424 \text{ lbs}$  of tensile force.

#### 8.4.5 - Lateral 2 g's

The loading condition of 2g's lateral produces a "weight" directed laterally of  $212*2 = 424 \text{ lbs}$ . The bolts must resist this shear load. Each of the six bolts used to secure the plate to the spacers is rated to resist up to 5,000 lbs of shear. So the total plate can resist up to  $5,000*6 = 30,000 \text{ lbs}$  of shear.

The weight created by this loading acts at the centroid which is 20” above the base of the plate. Taking moments about the centroid, the bolts must create a counter-clockwise moment of  $20'' * 424 \text{ lbs} = 8,480 \text{ in-lb}$ . In this loading condition, the axis of rotation is the x-axis. There are two rows of three bolts, each bolt is 10 inches perpendicularly from the x-axis. Each row of bolts must create a force of  $8,480/10'' = 848 \text{ lbs}$ . Each bolt on the tension side must therefore resist  $848/3 = 282.67 \text{ lbs}$  of tension. Each bolt is rated to 5,000 lbs of tension.

#### 8.4.6 - Summary of Analysis at Floor Mounting Plate

Table 8.1 summarizes the calculations and factors of safety. Shear and tensile demand are the forces that the load conditions require from the floor bolts. Shear and tensile potential are the maximum possible forces the floor bolts could provide. Note that the case for 6g’s down does not create any forces in the bolts or the plate, as it is transferred directly to the floor spacers.

It should be noted that sometimes the same numbers have shown up for Shear and Tensile demands for a given loading condition and location, giving suspiciously identical factors of safety. This is not a typo, but an artifact of the coincidence that our centroid is 20” from the ground, and the floor spacer bolts are also 20” apart.

Load Factor	Shear Demand	Shear Potential	Factor of Safety	Tensile Demand	Tensile Potential	Factor of Safety
9g’s forward	1,908 lbs	30000 lbs	15.72	1,908 lbs	10000 lbs	5.24
3g’s aft	636 lbs	30000 lbs	47.17	636 lbs	10000 lbs	15.72
6g’s down	NA	NA	NA	NA	NA	NA
2g’s up	NA	NA	NA	424 lbs	30000 lbs	70.75
2g’s lateral	424 lbs	30000 lbs	70.75	848 lbs	15000 lbs	17.69

*Table 8.1 – Global Structural Analysis Summary*

### **8.5 Frequently Used Equations and Calculations**

Our design uses several standardized sections, connections, and materials. The purpose of this section is to provide calculations and values for these standardized parts and connections. The frame, bracing members and gussets of our design all use aluminum parts from 80/20 Inc. and all are made of 6105-T5 alloy aluminum ( $F_y = 35 \text{ ksi}$ ,  $E = 10,000 \text{ ksi}$ ). All the bolted connections are bolted by bolts made of at least A36 grade carbon steel ( $F_y = 36 \text{ ksi}$ ,  $E = 30,000 \text{ ksi}$ ). All connections are made excluding bolt threads from the shear plane. Most bolts in our design are .328” diameter. The formula for finding the strength of a bolt in single shear is  $F = .6F_yA$ , where A is the cross sectional area of the bolt. The cross sectional area of a .328” diameter bolt is  $.084 \text{ in}^2$ , so a .328” diameter bolt in single shear can resist up to 1825 lbs. The

formula for finding the strength of a bolt in tension is  $F = F_y A$  where  $A$  is the cross sectional area. A .328" diameter bolt can therefore withstand 3040lbs of tensile force.

Each of the main members of our design is made of 80/20 1515 T-Slotted Aluminum Extrusions. Each 1515 member has a cross sectional area of  $1.156 \text{ in}^2$  the formula for the carrying capacity of a stiff member in axial tension or compression is  $F = F_y A$  where  $A$  is the cross sectional area. So each 1515 member can carry up to 40,000 lbs of axial load. Our design will be analyzed as a simple truss, so we do not need to worry about moment loads or thin-walled buckling.

## 8.6 Analysis of Overall Structure

For the analysis of the structure as a whole we analyzed just the entire structure minus the base plate. We can feel confident in doing so because we have already analyzed the base plate and bolts for all the load factors. The weight of the structure without the base plate is 212 lbs.

### 8.6.1 – Forward 9 g's

An induced load of 9g's acting forward on the centroid of our test section is a force of  $9 * 212 \text{ lbs} = 1,908 \text{ lbs}$ . This load will travel to the base plate through the cross bracing members. It is assumed that only the reinforced back face of the structure will carry the load. This analysis idealizes our structure as a simple planar truss with the corners resisting no moments. The 1,908 lbs of force is carried to the ground by the four cross braces. Simple truss analysis that each cross brace must carry  $1,908 / 4 = 477 \text{ lbs}$  of horizontal force. Since each cross brace is inclined at an angle of  $37.4^\circ$  each must carry a axial load of  $477 / \cos(37.4) = 600.44 \text{ lbs}$ . Each brace is connected to the gusset plate by a single .328" diameter bolt, which has shear strength of 1,825lbs. The gusset plate is connected to the outer frame by two .328" bolts, for a total shear strength of 3,650 lbs. The net cross sectional area of the brace after the area of the bolt hole is taken out is given by  $\text{Area}_{\text{Brace}} - \text{Area}_{\text{Bolt Hole}}$  which is  $.875 * .188 - .328 * .188 = .1028 \text{ in}^2$  net cross sectional area. This net cross sectional area will yield a  $F = F_y A = .1028 * 35000 = 3,600 \text{ lbs}$ .

The forward leg of the frame will carry  $1,908 \text{ lbs} * \sin(37.4) = 1,158.87 \text{ lbs}$  of compressive force. The rear leg of the frame will carry  $1,908 \text{ lbs} * \sin(37.4) = 1,158.87 \text{ lbs}$  of tensile force. The strength of the front legs in tension and compression is 40,000lbs.

### 8.6.2 - Aft 3 g's

A induced load of 3g's acting aft on the centroid of our test section is a force of  $3 * 212 \text{ lbs} = 636 \text{ lbs}$ . This load will travel to the base plate through the cross bracing members. It is assumed that only the reinforced back face of the structure will carry the load. This analysis idealizes our structure as a simple planar truss with the corners resisting no moments. The 636 lbs of force is carried to the ground by the four cross braces. Simple

truss analysis that each cross brace must carry  $636/4 = 159$  lbs of horizontal force. Since each cross brace is inclined at an angle of  $37.4^\circ$  each must carry an axial load of  $159/\cos(37.4) = 200.15$  lbs. Each brace is connected to the gusset plate by a single  $.328''$  diameter bolt, which has a shear strength of 1,825 lbs. The gusset plate is connected to the outer frame by two  $.328''$  bolts, for a total shear strength of 3,650 lbs. The net cross-sectional area of the brace after the area of the bolt hole is taken out is given by  $\text{Area}_{\text{Brace}} - \text{Area}_{\text{Bolt Hole}}$  which is  $.875 \times .188 - .328 \times .188 = .1028 \text{ in}^2$  net cross-sectional area. This net cross-sectional area will yield a  $F = F_y A = .1028 \times 35000 = 3,600$  lbs.

The forward leg of the frame will carry  $200.15 \times \sin(37.4) = 121.57$  lbs of compressive force. The rear leg of the frame will carry  $200.15 \times \sin(37.4) = 121.57$  lbs of tensile force. The strength of the front legs in tension and compression is 40,000 lbs.

### 8.6.3 - Down 6 g's

Under a load condition of 6g's down the total weight down is  $6 \times 212 = 1272$  lbs. Each of the five legs will carry an equal part of this force. That part will be  $1272/5 = 254.4$  lbs. Each leg can carry up to 40,000 lbs in compression.

### 8.6.4 - Up 2 g's

Under a load condition of 2g's acting up the total force upward will be  $2 \times 212 = 424$  lbs. Each of the five legs will carry an equal amount of this force, that amount will be  $424/5 = 84.8$  lbs. Each leg can carry up to 40,000 lbs in tension.

### 8.6.5 - Lateral 2 g's

Under a load condition of 2g's acting laterally,  $2 \times 212 = 424$  lbs of force is applied at the centroid. It is assumed that this force will be carried to the base-plate by shear in the legs of the frame members. This analysis assumes that the two sides of the apparatus will carry the entire load. The 424 lbs of lateral shear is split evenly between the two sides. Each side therefore must resist 212 lbs of force so each leg must resist half of that again (two legs per side) and carry 106 lbs (and four bolts per leg) so each bolt must resist 26.5 lbs of shear. The bolts of the gusset plate will take this force in shear. Each gusset plate is connected to the frame by four bolts. Each  $.328''$  bolt can resist up to 1,825 lbs of shear. Each of the bottom gussets must resist the cantilevered force of 106 lbs at 20 inches = 2,120 in-lbs of moment. The gusset's bolts are set apart by an average perpendicular distance of 2.25", so each side of the gusset must generate  $2,120/2.25 = 942.22$  lbs of shear. Each bolt on each side must generate 471.11 lbs of shear. So the total shear in the bolts is  $471.11 \times 2 = 942.22$  lbs. Each bolt can resist 1,825 lbs of shear.

### 8.6.6 - Summary of Analysis of Structure as a Whole

The preceding analysis has shown that the structure as a whole is more than strong enough to withstand the factored loads. An abbreviated summary of the Factors of Safety is shown in table 8.2 below.

Factored Load	Lowest Available Strength	Highest Demanded Strength	Factor of Safety
9g's forward	1825 lbs	600.44 lbs	3.04
3g's aft	1825 lbs	200.15 lbs	9.12
6g's down	40,000 lbs	254.4 lbs	157.23
2g's up	40,000 lbs	84.8 lbs	471.70
2g's lateral	1825 lbs	497.61 lbs	3.67

Table 8.2 – Overall Structural Analysis Summary

## 8.7 Analysis of Test Section Racks

The analysis of the test section racks shows that the racks are stable under all factored load conditions. The test section rack is a group of three test sections all attached to a single aluminum back plate. That back plate is then attached to the frame of our apparatus. There are six identical test sections, each weighing 14.3 lbs.

### 8.7.1 - Forward 9 g's

During a loading of 9g's forward the induced force from a test section onto the frame will be  $14.3 \times 9 = 128.7$  lbs. This weight is transferred to the frame through the shear of the bolts holding the test section to the frame. Each .328" bolt can resist 1825 lbs of shear. There are four bolts resisting 128.7 lbs, so each bolt must resist 32.18 lbs.

### 8.7.2 - Aft 3 g's

During a loading of 3g's aft the induced force from a test section onto the frame will be 42.9 lbs. This weight is transferred to the frame through the shear of the bolts holding the test section to the frame. Each .328" bolt can resist 1825 lbs of shear. There are four bolts resisting 42.9 lbs, so each bolt must resist 10.73 lbs.

### 8.7.3 - Down 6 g's

During a loading of 6g's down the test section creates an apparent weight of 85.8 lbs. This weight is transferred to the frame through the shear of the bolts holding the test section to the frame. Each .328" bolt can resist 1825 lbs of shear. There are four bolts resisting 85.8 lbs, so each must resist 21.45 lbs.

### 8.7.4 - Up 2 g's

During a loading of 2g's up the apparent weight of the test section is 28.6 lbs. This weight is transferred to the frame through the shear of the bolts holding the test section to the frame. Each .328" bolt can resist 1825 lbs of shear. There are four bolts resisting 28.6 lbs, so each must resist 7.15 lbs.

8.7.5 - Lateral 2 g's

During a loading of 2g's laterally the apparent weight of the test section is 28.6 lbs. This weight is transferred to the frame through tension in the bolts. Each .328" bolt can resist 3040 lbs of tension. Each bolt must resist 7.15 lbs of tension.

8.7.6 - Summary of Analysis of Test Section Racks

The preceding summary has shown that the strength of the test section racks is more than adequate to withstand the factored loads. Table 8.3 is a summary of the available and demanded strengths of the connecting bolts and the associated factors of safety.

Load Factor	Lowest Available Strength	Highest Demanded Strength	Factor of Safety
9g's forward	1832 lbs	32.18 lbs	56.93
3g's aft	1832 lbs	10.73 lbs	170.74
6g's down	1832 lbs	21.45 lbs	85.41
2g's up	1832 lbs	7.15 lbs	256.22
2g's lateral	3040lbs	7.15 lbs	425.17

*Table 8.3 –Structural Analysis of Test Section Racks Summary*

## 9. Electrical Analysis

### 9.1 Schematic

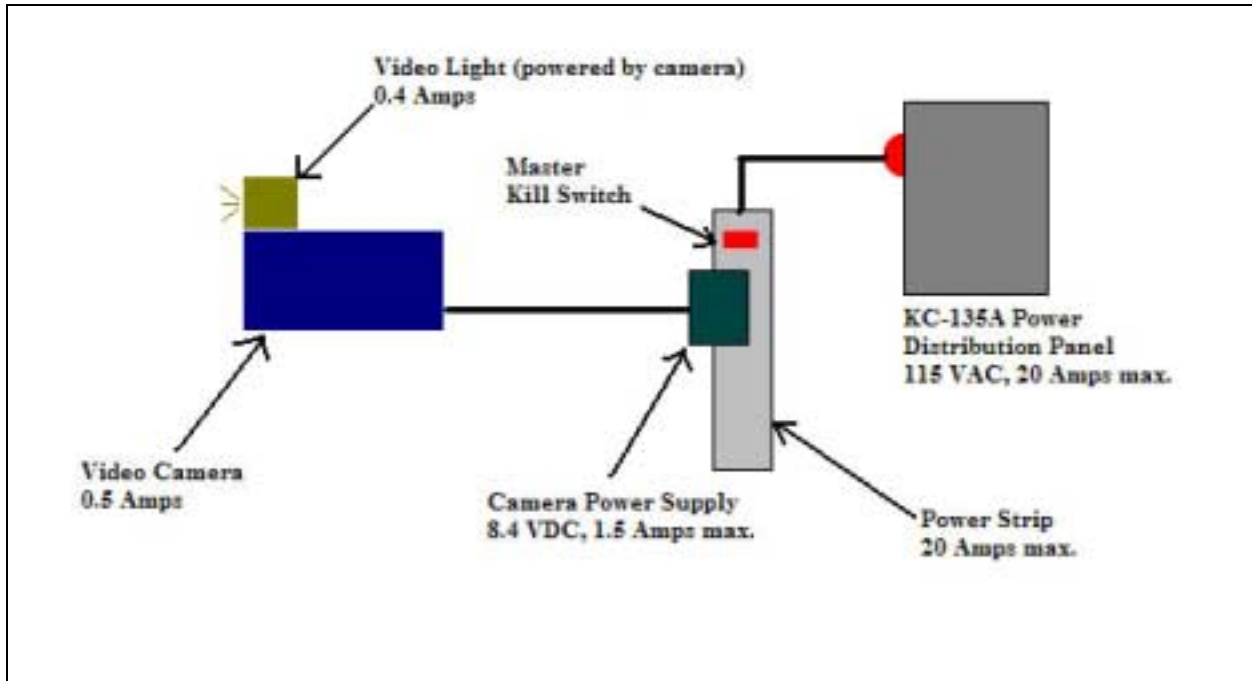


Figure 9.1 - Electrical Schematic

### 9.2 Load Tables

No electrical energy will be stored in the STILLMix experiment. The camcorder does contain one battery. While the camera will be powered at all times by its DC power supply, the battery exists only as a backup power source should there be any difficulty with power sourced from the aircraft's electrical system.

The battery pack is manufactured specifically for this camera by Sony Electronics. Its model designation is NP-FM50. It is a lithium ion battery with a mean output voltage of 7.2 V, a maximum output of 8.4 V, and a capacity of 8.5 Wh.

Power Source Details	Load Analysis
Name: Power Strip/Surge Protector	Camera Power Supply – 1.5 Amps
Voltage: 115 VAC, 60 Hz	
Wire Gauge: 12	
Max. Output Current: <b>20 Amps</b>	Total Current Draw: <b>1.5 Amps</b>

Table 9.1 – Load table for power strip

<b>Power Source Details</b>	<b>Load Analysis</b>
Name: Camera Power Supply	Video Camera – 0.5 Amps Video Light – 0.4 Amps
Voltage: 8.4 VDC	
Wire Gauge: 18	
Max. Output Current: <b>1.5 Amps</b>	Total Current Draw: <b>0.9 Amps</b>

*Table 9.2 – Load table for camera*

### **9.3 Electrical Kill Switch**

The video camera’s DC power supply will be plugged into a surge protector, which will in turn be plugged into the electrical outlet. If the need for an emergency shutdown arises, the electrical surge protector switch can be toggled to the ‘off’ position, stopping the current draw from the aircraft’s electrical system. The camera and video light will then be running on the camera’s internal battery, mentioned in Sec. 9.2. Moving the camera’s power switch to the “off/chg” position can turn off the camera and video light.

### **9.4 Loss of Electrical Power**

The experimental apparatus itself does not require any electrical power, so the loss of electrical power will not affect it in any way. If there is a loss of electrical power, the camera and video light will automatically switch to battery power and then can be deactivated in the manner indicated in the previous section.

## **10. Pressure/Vacuum System Documentation Requirements**

No pressure system will be used in the STILLMix experiment. Pressure release valves will be installed in each sealed test section and opened periodically to prevent any undesired pressure or vacuum buildup due to aircraft altitude change.

## **11. Laser Certification**

No lasers will be used in the STILLMix experiment

## **12. Parabola Details and Crew Assistance**

No partial g levels are requested for the experiment. This will not be a free-floating experiment. The team requests foot straps near the experiment, and notice of upcoming zero-g conditions for each parabola.

## **13. Institutional Review Board**

No human or animal subjects will be used in the STILLMix experiment.

## 14. Hazard Analysis Report

Hazard Description	Section(s)
Flammable/combustible material, fluid (liquid, vapor, or gas)	14.1
Toxic/noxious/corrosive/hot/cold material, fluid (liquid, vapor or gas)	14.2
High pressure system (static or dynamic)	N/A
Evacuated container (implosion)	N/A
<b>Frangible material</b>	<b>14.3</b>
Stress corrosion susceptible material	N/A
Inadequate structural design (i.e. low safety factor)	N/A
High intensity light source (including laser)	N/A
Ionizing/electromagnetic radiation	N/A
Rotating device	N/A
Extendible/deployable/articulating experiment element (collision)	N/A
<b>Stowage restraint failure</b>	<b>14.4</b>
Stored energy device (i.e. mechanical spring under compression)	N/A
Vacuum vent failure (i.e. loss of pressure/atmosphere)	N/A
Heat transfer (habitable area over-temperature)	N/A
Over-temperature explosive rupture (including electrical battery)	N/A
High/low touch temperature	N/A
Hardware cooling/heating loss (i.e. loss of thermal control)	N/A
Pyrotechnic/explosive device	N/A
Propulsion system (pressurized gas or liquid/solid propellant)	N/A
High acoustic noise level	N/A
Toxic off-gassing material	N/A
Mercury/mercury compound	N/A
Other JSC 11123, Section 3.8 hazardous material	N/A
Organic/microbiological (pathogenic) contamination source	N/A
<b>Sharp corner/edge/protrusion/protuberance</b>	<b>14.5</b>
Flammable/combustible material, fluid ignition source (i.e. short circuit; under-sized wiring/fuse/circuit breaker)	N/A
High voltage (electrical shock)	N/A
High static electrical discharge producer	N/A
Software error or compute fault	N/A
Carcinogenic material	N/A
Other:	N/A
Other:	N/A
Other:	N/A

Table 14.1 – Hazard Analysis Checklist

### 14.1 Flammability of Ethyl Alcohol Liquid Sample

**Hazard Description:** If the ethyl alcohol used in our mixing experiment is exposed to high temperatures or an open flame it may ignite.

**Hazard Cause:** High temperature or exposure to an open flame.

**Hazard Control(s):** No elements of the apparatus will involve temperatures above the flash ignition point of ethyl alcohol. The experiment does not make use of any open flames. Additionally, the ethyl alcohol will be sealed within its syringe (before the experiment) or isolated within the sealed test sections (after the experiment). Samples will be labeled and a small warning will also be posted. During ground support operations all ethyl alcohol will be sealed in clearly marked containers.

## 14.2 Toxicity

### 14.2.1 Toxicity of Ethyl Alcohol Liquid Sample

**Hazard Description:** If the ethyl alcohol used in our mixing experiment were to be ingested, it would be toxic.

**Hazard Cause:** Accidental sample ingestion.

**Hazard Control(s):** The ethyl alcohol will be sealed within its syringe (before the experiment) or isolated within the sealed test sections (after the experiment). Samples will be labeled and a small warning will also be posted. During ground support operations all ethyl alcohol will be sealed in clearly marked containers.

### 14.2.2 Toxicity of Silicone Oil AR 20 Liquid Sample

**Hazard Description:** If the silicone oil used in our mixing experiment were to be ingested, it would be toxic.

**Hazard Cause:** Accidental sample ingestion.

**Hazard Control(s):** The silicone oil will be sealed within its syringe (before the experiment) or isolated within the sealed test sections (after the experiment). Samples will be labeled and a small warning will also be posted. During ground support operations all silicone oil will be sealed in clearly marked containers.

## 14.3 Frangibility of Polycarbonate Test Section Covers

**Hazard Description:** If the polycarbonate covers of the test section are exposed to structural forces beyond their capacity, they will fail, possibly creating fragments.

**Hazard Cause:** Excessive mechanical stresses or strains.

**Hazard Control(s):** The safety factors for the mechanical stresses and strains of these components are well within the safe range (see section 8). These components are located in a low stress area of the apparatus and will not be subjected to heavy loads or large moments.

#### **14.4 Failure of the Video Camera Slide Rack Locking Mechanism**

**Hazard Description:** If the locking mechanism on the video camera slide rack fails, the video camera would slide freely in accordance with the acceleration conditions of the aircraft.

**Hazard Cause:** Retraction of metal locking pin from seat.

**Hazard Control(s):** The locking pin is spring loaded so the pin will remain seated and prevent lateral movement. If the spring fails or the system loses its locking ability for any reason, the camera will slide freely on guide beam. The camera will not be able to break loose from the apparatus. If this occurs, the camera will, at the next opportunity, be moved to the storage location and locked into place.

#### **14.5 Corners/Edges of Apparatus**

**Hazard Description:** Impact of a person or body part on a corner of the apparatus could cause injury.

**Hazard Cause:** Impact against corners.

**Hazard Control(s):** The metal corners will be rounded and smoothed to lessen the severity of any possible injury. Furthermore, the corners will be covered in a dense foam padding to blunt impact and prevent injury.

## 15. Tool Requirements

1 Camcorder*	Towels	Nuts, bolts and screws
Screwdrivers	First Aid Kit	Teflon <sup>®</sup> tape
Wrenches	Electrical tape*	1 AC adapter for camcorder
Silicon caulk	Canvas Bag	Extension cords
Gloves	Pliers	Duct tape

\*Items to be carried onboard the aircraft.

## 16. Photo Requirements

The STILLMix team requests a videographer and still photographer, if available, during flight operations. This service would not be needed for data analysis, but just for documentation of the flight for the outreach video. No particular times of flight or parts of the experiment will require documentation more than any other, so it could take place during any of the parabolas. The team does not require S-band downlink.

## 17. Aircraft Loading

A forklift and lifting pallet will be needed to load the STILLMix apparatus onto the KC-135. For hardware manipulation on the ground, the apparatus frame will have handles that allow for manipulation with a load of (265 lbs / 6 handles) = 44.2 lbs per person. As can be seen on the diagrams of the frame, the handles are mounted aligned with the x-y plane. This is to accommodate the apparatus being carried on it's 'back' (z-axis pointing up), for improved stability and weight-distribution during transport.

The base plate will have an area of 8.4 square feet (22" x 55.27"). This will result in a load of 31.55 lbs per square foot on the aircraft floor during loading operations.

## 18. Ground Support Requirements

The STILLMix team requests a workspace area of approximately 10' x 10', a utility sink with running water, and an electrical connection to power the video camera adapter. Pressurized air would be useful (for air-drying recently cleaned test surfaces) but is not necessary.

None of the liquids used in the experiment are corrosive, however some of them are potential irritants if put in contact with the eyes or ingested. All of the liquids used in the experiment will be contained in Lexan bottles (Nalgene product # 402065) sealed with screw tops. For the pre-flight operation, we will open these bottles and fill the test syringes with these liquids, however, none of the liquids produce a significant vapor under any expected conditions that would require ventilation.

The building will only need to be accessed during normal business hours. No special ground handling equipment will be needed. General tool requests include wrenches, screwdrivers, pliers, and other common tools.

## 19. Hazardous Materials

Material	Hazard	Quantity	Uses	Storage/Precautions
Silicone Oil AR 20	Mildly harmful if ingested, inhaled or brought into contact with skin/eyes	30 mL	Liquid will be injected onto test surface to observe and record mixing processes	Oil not used while loading syringes will be kept in original container at ground station Oil that has been used in experiment will be disposed of properly at ground station Oil will be completely contained in syringes and experiment casing
Ethyl Alcohol (denatured)	Flammable, toxic, harmful by inhalation and ingestion, irritating to eyes, respiratory system, and skin	30 mL	Liquid will be injected onto test surface to observe and record mixing processes	Alcohol not used while loading syringes will be kept in original container at ground station Alcohol that has been used in the experiment will be disposed of properly at ground station No open flame or sparks Alcohol will be completely contained in syringes and experiment casing

*Table 19.1 – Hazardous Material Table*

Hazardous material release is not a major concern as these volumes are very small relative to cabin volume and the liquids are only mildly caustic or toxic and neither is corrosive.

## 20. Material Safety Data Sheets

### 20.1 Ethyl Alcohol (Sigma-Aldrich product # 18,738-0)

Valid 02/2003 - 04/2003

Aldrich Chemical Co., Inc.  
1001 West St. Paul  
Milwaukee, WI 53233 USA  
Tel: 414-273-3850

#### M A T E R I A L S A F E T Y D A T A S H E E T

##### SECTION 1. - - - - - CHEMICAL IDENTIFICATION- - - - -

CATALOG #: 187380  
NAME: ETHYL ALCOHOL, DENATURED

##### SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - -

CAS #: 64-17-5  
MF: C2H6O  
EC NO: 200-578-6

##### ADDITIONAL INFORMATION

CONTAINS METHYL ALCOHOL, CHEMICAL ABSTRACTS REGISTRY NUMBER 67-56-1.  
CONTAINS ETHYL ACETATE, CHEMICAL ABSTRACTS REGISTRY NUMBER 141-78-6.  
CONTAINS 4-METHYL-2-PENTANONE, CHEMICAL ABSTRACTS REGISTRY NUMBER 108-10-1.  
CONTAINS HEPTANE, CHEMICAL ABSTRACTS REGISTRY NUMBER 142-82-5.

##### SYNONYMS

ABSOLUTE ETHANOL \* AETHANOL (GERMAN) \* AETHYLALKOHOL (GERMAN) \*  
ALCOHOL \* ALCOHOL, ANHYDROUS \* ALCOHOL DEHYDRATED \* ALCOOL ETHYLIQUE  
(FRENCH) \* ALCOOL ETILICO (ITALIAN) \* ALGRAIN \* ALKOHOL (GERMAN) \*  
ALKOHOLU ETYLOWEGO (POLISH) \* ANHYDROL \* COLOGNE SPIRIT \* ETANOLO  
(ITALIAN) \* ETHANOL (ACGIH:OSHA) \* ETHYL ALCOHOL (DOT:OSHA) \* ETHYL  
ALCOHOL ANHYDROUS \* ETHYL HYDRATE \* ETHYL HYDROXIDE \* ETYLOWY ALKOHOL  
(POLISH) \* FERMENTATION ALCOHOL \* GRAIN ALCOHOL \* JAYSOL \* JAYSOL S \*  
METHYLCARBINOL \* MOLASSES ALCOHOL \* NCI-C03134 \* POTATO ALCOHOL \* SD  
ALCOHOL 23-HYDROGEN \* SPIRITS OF WINE \* SPIRT \* TECSOL \*

##### SECTION 3. - - - - - HAZARDS IDENTIFICATION - - - - -

##### LABEL PRECAUTIONARY STATEMENTS

FLAMMABLE (USA)  
HIGHLY FLAMMABLE (EU)  
TOXIC  
HARMFUL BY INHALATION AND IF SWALLOWED.  
IRRITATING TO EYES, RESPIRATORY SYSTEM AND SKIN.  
TARGET ORGAN(S):  
NERVES  
EYES  
LIVER, KIDNEYS  
KEEP CONTAINER TIGHTLY CLOSED.  
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.  
TAKE PRECAUTIONARY MEASURES AGAINST STATIC DISCHARGES.  
DO NOT BREATHE VAPOR.

WEAR SUITABLE PROTECTIVE CLOTHING, GLOVES AND EYE/FACE PROTECTION.

KEEP TIGHTLY CLOSED.

HYGROSCOPIC

SECTION 4. - - - - - FIRST-AID MEASURES- - - - -

IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES OR SKIN WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES.

IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.

IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS. CALL A PHYSICIAN.

WASH CONTAMINATED CLOTHING BEFORE REUSE.

SECTION 5. - - - - - FIRE FIGHTING MEASURES - - - - -

EXTINGUISHING MEDIA

CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.

SPECIAL FIREFIGHTING PROCEDURES

WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO PREVENT CONTACT WITH SKIN AND EYES.

USE WATER SPRAY TO COOL FIRE-EXPOSED CONTAINERS.

FLAMMABLE LIQUID.

UNUSUAL FIRE AND EXPLOSIONS HAZARDS

VAPOR MAY TRAVEL CONSIDERABLE DISTANCE TO SOURCE OF IGNITION AND FLASH BACK.

SECTION 6. - - - - - ACCIDENTAL RELEASE MEASURES- - - - -

SHUT OFF ALL SOURCES OF IGNITION.

EVACUATE AREA.

WEAR SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES.

ABSORB ON SAND OR VERMICULITE AND PLACE IN CLOSED CONTAINERS FOR DISPOSAL.

USE NONSPARKING TOOLS.

VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

SECTION 7. - - - - - HANDLING AND STORAGE- - - - -

REFER TO SECTION 8.

SECTION 8. - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - -

WEAR APPROPRIATE NIOSH/MSHA-APPROVED RESPIRATOR, CHEMICAL-RESISTANT GLOVES, SAFETY GOGGLES, OTHER PROTECTIVE CLOTHING.

USE ONLY IN A CHEMICAL FUME HOOD.

SAFETY SHOWER AND EYE BATH.

DO NOT BREATHE VAPOR.

DO NOT GET IN EYES, ON SKIN, ON CLOTHING.

AVOID PROLONGED OR REPEATED EXPOSURE.

WASH THOROUGHLY AFTER HANDLING.

KEEP TIGHTLY CLOSED.

KEEP AWAY FROM HEAT, SPARKS, AND OPEN FLAME.

STORE IN A COOL DRY PLACE.

SECTION 9. - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - -

PHYSICAL PROPERTIES

BOILING POINT: 78 C

MELTING POINT: -130 C

FLASHPOINT 48 F

EXPLOSION LIMITS IN AIR:

UPPER 24.5%

LOWER 3.3%

AUTOIGNITION TEMPERATURE: 683 F

VAPOR PRESSURE: 44.6MM 20 C

SPECIFIC GRAVITY: 0.789

VAPOR DENSITY: 1.59

SECTION 10. - - - - -STABILITY AND REACTIVITY - - - - -

STABILITY

STABLE.

INCOMPATIBILITIES

OXIDIZING AGENTS

PEROXIDES

ACIDS

ACID CHLORIDES

ACID ANHYDRIDES

ALKALI METALS

AMMONIA

MOISTURE

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS

TOXIC FUMES OF:

CARBON MONOXIDE, CARBON DIOXIDE

SECTION 11. - - - - - TOXICOLOGICAL INFORMATION - - - - -

ACUTE EFFECTS

HARMFUL IF INHALED OR SWALLOWED.

MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.

VAPOR OR MIST IS IRRITATING TO THE EYES, MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT.

CAUSES SKIN IRRITATION.

CAN CAUSE CNS DEPRESSION.

EXPOSURE CAN CAUSE:

NAUSEA, DIZZINESS AND HEADACHE

GASTROINTESTINAL DISTURBANCES

MAY CAUSE CONVULSIONS.

ANEMIA

NARCOTIC EFFECT

CONTACT WITH EYES CAN CAUSE REDNESS, TEARING, AND BLURRED VISION.

PROLONGED OR REPEATED CONTACT WITH SKIN CAN CAUSE DEFATTING AND

DERMATITIS.

CHRONIC EFFECTS

TARGET ORGAN(S):

NERVES

EYES

LIVER

KIDNEYS

BLOOD

HEART

TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND

TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.

RTECS #: KQ6300000

ETHYL ALCOHOL

IRRITATION DATA

SKN-RBT 400 MG OPEN MLD

UCDS\*\* 7/22/1970

SKN-RBT 20 MG/24H MOD

85JCAE -,189,1986

EYE-RBT 500 MG SEV

AJOPAA 29,1363,1946

EYE-RBT 500 MG/24H MLD

85JCAE -,189,1986

EYE-RBT 100 MG/4S RINSE MOD

FCTOD7 20,573,1982

TOXICITY DATA

ORL-CHD LDLO:2 GM/KG

ATXKA8 17,183,1958

ORL-HMN LDLO:1400 MG/KG

NPIRI\* 1,44,1974

SCU-INF LDLO:19440 MG/KG

AJCPAI 5,466,1935

ORL-RAT LD50:7060 MG/KG

TXAPA9 16,718,1970

IHL-RAT LC50:20000 PPM/10H	NPIRI* 1,44,1974
IPR-RAT LD50:3600 UG/KG	PHMGBN 2,27,1969
IVN-RAT LD50:1440 MG/KG	TXAPA9 18,60,1971
IAT-RAT LD50:11 MG/KG	TXAPA9 18,60,1971
ORL-MUS LD50:3450 MG/KG	GISAAA 32(3),31,1967
IHL-MUS LC50:39 GM/M3/4H	GTPZAB 26(8),53,1982
IPR-MUS LD50:528 MG/KG	STRAAA 127,245,1965
SCU-MUS LD50:8285 MG/KG	FAONAU 48A,99,1970
IVN-MUS LD50:1973 MG/KG	HBTXAC 1,128,1955
ORL-RBT LD50:6300 MG/KG	HBTXAC 1,130,1955
IPR-RBT LD50:963 MG/KG	EVHPAZ 61,321,1985
IVN-RBT LD50:2374 MG/KG	EVHPAZ 61,321,1985
ORL-GPG LD50:5560 MG/KG	JIHTAB 23,259,1941
IPR-GPG LD50:3414 MG/KG	EVHPAZ 61,321,1985
IPR-HAM LD50:5068 MG/KG	EVHPAZ 61,321,1985
IPR-MAM LD50:4300 MG/KG	TXAPA9 13,358,1968

TARGET ORGAN DATA

BEHAVIORAL (SLEEP)  
 BEHAVIORAL (CHANGE IN MOTOR ACTIVITY)  
 BEHAVIORAL (ATAXIA)  
 BEHAVIORAL (ANTIPSYCHOTIC)  
 BEHAVIORAL (HEADACHE)  
 BEHAVIORAL (CHANGE IN PSYCHOPHYSIOLOGICAL TESTS)  
 LUNGS, THORAX OR RESPIRATION (CHRONIC PULMONARY EDEMA OR CONGESTION)  
 LUNGS, THORAX OR RESPIRATION (DYSPNAE)  
 LUNGS, THORAX OR RESPIRATION (OTHER CHANGES)  
 GASTROINTESTINAL (ALTERATION IN GASTRIC SECRETION)  
 GASTROINTESTINAL (HYPERMOTILITY, DIARRHEA)  
 GASTROINTESTINAL (NAUSEA OR VOMITING)  
 GASTROINTESTINAL (OTHER CHANGES)  
 LIVER (FATTY LIVER DEGENERATION)  
 LIVER (TUMORS)  
 ENDOCRINE (CHANGE IN GONADOTROPINS)  
 ENDOCRINE (OTHER CHANGES)  
 BLOOD (OTHER CHANGES)  
 BLOOD (LYMPHOMA INCLUDING HODGKIN'S DISEASE)  
 PATERNAL EFFECTS (TESTES, EPIDIDYMIS, SPERM DUCT)  
 EFFECTS ON FERTILITY (FEMALE FERTILITY INDEX)  
 EFFECTS ON FERTILITY (MALE FERTILITY INDEX)  
 EFFECTS ON FERTILITY (POST-IMPLANTATION MORTALITY)  
 EFFECTS ON FERTILITY (OTHER MEASURES OF FERTILITY)  
 EFFECTS ON EMBRYO OR FETUS (EXTRA EMBRYONIC STRUCTURES)  
 EFFECTS ON EMBRYO OR FETUS (CYTOLOGICAL CHANGES)  
 EFFECTS ON EMBRYO OR FETUS (FETOTOXICITY)  
 EFFECTS ON EMBRYO OR FETUS (FETAL DEATH)  
 EFFECTS ON EMBRYO OR FETUS (OTHER EFFECTS TO EMBRYO OR FETUS)  
 SPECIFIC DEVELOPMENTAL ABNORMALITIES (EYE, EAR)  
 SPECIFIC DEVELOPMENTAL ABNORMALITIES (CRANIOFACIAL)  
 SPECIFIC DEVELOPMENTAL ABNORMALITIES (MUSCULOSKELETAL SYSTEM)  
 SPECIFIC DEVELOPMENTAL ABNORMALITIES (RESPIRATORY SYSTEM)  
 EFFECTS ON NEWBORN (GROWTH STATISTICS)  
 TUMORIGENIC (EQUIVOCAL TUMORIGENIC AGENT BY RTECS CRITERIA)  
 ONLY SELECTED REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES  
 (RTECS) DATA IS PRESENTED HERE. SEE ACTUAL ENTRY IN RTECS FOR  
 COMPLETE INFORMATION.

SECTION 12. - - - - - ECOLOGICAL INFORMATION - - - - -  
 DATA NOT YET AVAILABLE.

SECTION 13. - - - - - DISPOSAL CONSIDERATIONS - - - - -  
BURN IN A CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND  
SCRUBBER BUT EXERT EXTRA CARE IN IGNITING AS THIS MATERIAL IS HIGHLY  
FLAMMABLE.

OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

SECTION 14. - - - - - TRANSPORT INFORMATION - - - - -  
CONTACT ALDRICH CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

SECTION 15. - - - - - REGULATORY INFORMATION - - - - -  
EUROPEAN INFORMATION

EC INDEX NO: 603-002-00-5

HIGHLY FLAMMABLE

TOXIC

R 11

HIGHLY FLAMMABLE.

R 20/22

HARMFUL BY INHALATION AND IF SWALLOWED.

S 7

KEEP CONTAINER TIGHTLY CLOSED.

S 16

KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.

S 24

AVOID CONTACT WITH SKIN.

S 45

IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE  
IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).

TLV AND SOURCE

FOR METHYL ALCOHOL - SKIN:

ACGIH TLV-TWA: 200 PPM (260 MG/M3); STEL: 250 PPM (310 MG/M3).

OSHA PEL: 8 H TWA 200 PPM (260 MG/M3); STEL: 250 PPM (310 MG/M3).

FOR ETHYL ACETATE:

ACGIH TLV-TWA: 400 PPM (1440 MG/M3).

OSHA PEL: 8H TWA 400 PPM (1400 MG/M3).

FOR 4-METHYL-2-PENTANONE (METHYL ISOBUTYL KETONE):

ACGIH TLV-TWA: 50 PPM; STEL: 75 PPM.

OSHA PEL FINAL: 8H TWA 50 PPM (205 MG/M3); STEL: 75 PPM (300 MG/M3).

FOR HEPTANE:

ACGIH TLV-TWA: 400 PPM (1640 MG/M3); STEL: 500 PPM (2050 MG/M3).

OSHA PEL: 8H TWA 400 PPM; STEL: 500 PPM.

REVIEWS, STANDARDS, AND REGULATIONS

OEL=MAK

ACGIH TLV-NOT CLASSIFIABLE AS A HUMAN CARCINOGEN DTLVS\* TLV/BEI,1999

ACGIH TLV-TWA 1000 PPM DTLVS\* TLV/BEI,1999

IARC CANCER REVIEW:ANIMAL INADEQUATE EVIDENCE IMEMDT 44,35,1988

EPA FIFRA 1988 PESTICIDE SUBJECT TO REGISTRATION OR RE-REGISTRATION

FEREAC 54,7740,1989

MSHA STANDARD-AIR:TWA 1000 PPM (1900 MG/M3)

DTLVS\* 3,103,1971

OSHA PEL (GEN INDU):8H TWA 1000 PPM (1900 MG/M3)

CFRGBR 29,1910.1000,1994

OSHA PEL (CONSTRUC):8H TWA 1000 PPM (1900 MG/M3)

CFRGBR 29,1926.55,1994

OSHA PEL (SHIPYARD):8H TWA 1000 PPM (1900 MG/M3)

CFRGBR 29,1915.1000,1993

OSHA PEL (FED CONT):8H TWA 1000 PPM (1900 MG/M3)

CFRGBR 41,50-204.50,1994

OEL-AUSTRALIA: TWA 1000 PPM (1900 MG/M3), JAN1993

OEL-AUSTRIA: MAK 1000 PPM (1900 MG/M3), JAN1999

OEL-BELGIUM: TWA 1000 PPM (1880 MG/M3), JAN1993  
OEL-DENMARK: TWA 1000 PPM (1900 MG/M3), JAN1999  
OEL-FINLAND: TWA 1000 PPM (1900 MG/M3), STEL 1250 PPM (2400 MG/M3),  
JAN1999  
OEL-FRANCE: VME 1000 PPM (1900 MG/M3), VLE 5000 PPM, JAN1999  
OEL-GERMANY: MAK 1000 PPM (1900 MG/M3), JAN1999  
OEL-HUNGARY: TWA 1000 MG/M3, STEL 3000 MG/M3, JAN1993  
OEL-THE NETHERLANDS: MAC-TGG 500 PPM (950 MG/M3), JAN1999  
OEL-NORWAY: TWA 500 PPM (950 MG/M3), JAN1999  
OEL-THE PHILIPPINES: TWA 1000 PPM (1900 MG/M3), JAN1993  
OEL-POLAND: MAC(TWA) 1000 MG/M3, MAC(STEL) 3000 MG/M3, JAN1999  
OEL-RUSSIA: STEL 1000 MG/M3, JAN1993  
OEL-SWEDEN: NGV 500 PPM (1000 MG/M3), KTV 1000PPM (1900 MG/M3), JAN1999  
OEL-SWITZERLAND: MAK-W 1000 PPM (1900 MG/M3), JAN1999  
OEL-THAILAND: TWA 1000 PPM (1900 MG/M3), JAN1993  
OEL-TURKEY: TWA 1000 PPM (1900 MG/M3), JAN1993  
OEL-UNITED KINGDOM: TWA 1000 PPM (1950 MG/M3), SEP2000  
OEL IN ARGENTINA, BULGARIA, COLOMBIA, JORDAN, KOREA CHECK ACGIH TLV;  
OEL IN NEW ZEALAND, SINGAPORE, VIETNAM CHECK ACGIH TLV  
NIOSH REL TO ETHYL ALCOHOL-AIR:10H TWA 1000 PPM  
NIOSH\* DHHS #92-100,1992  
NOHS 1974: HZD 31500; NIS 430; TNF 157709; NOS 242; TNE 2088926  
NOES 1983: HZD 31500; NIS 334; TNF 86077; NOS 222; TNE 2069125; TFE  
1014002  
EPA GENETOX PROGRAM 1988, POSITIVE: RODENT DOMINANT LETHAL  
EPA GENETOX PROGRAM 1988, NEGATIVE: ASPERGILLUS-FORWARD MUTATION;  
SHE-CLONAL ASSAY  
EPA GENETOX PROGRAM 1988, NEGATIVE: CELL TRANSFORM.-RLV F344 RAT EMBRYO  
EPA GENETOX PROGRAM 1988, NEGATIVE: IN VITRO CYTOGENETICS-NONHUMAN;  
MAMMALIAN MICRONUCLEUS  
EPA GENETOX PROGRAM 1988, NEGATIVE: N CRASSA-ANEUPLOIDY; HISTIDINE  
REVERSION-AMES TEST  
EPA GENETOX PROGRAM 1988, NEGATIVE: IN VITRO SCE-HUMAN LYMPHOCYTES; IN  
VITRO SCE-HUMAN  
EPA GENETOX PROGRAM 1988, NEGATIVE: IN VITRO SCE-NONHUMAN; SPERM  
MORPHOLOGY-MOUSE  
EPA GENETOX PROGRAM 1988, NEGATIVE/LIMITED: CARCINOGENICITY-MOUSE/RAT  
EPA TSCA SECTION 8(B) CHEMICAL INVENTORY  
EPA TSCA SECTION 8(D) UNPUBLISHED HEALTH/SAFETY STUDIES  
EPA TSCA TEST SUBMISSION (TSCATS) DATA BASE, JANUARY 2001  
NIOSH ANALYTICAL METHOD, 1994: ETHANOL IN BLOOD, 8002  
NIOSH ANALYTICAL METHOD, 1994: ALCOHOLS I, 1400  
NTP CARCINOGENESIS STUDIES; ON TEST (TWO YEAR STUDIES), OCTOBER 2000

U.S. INFORMATION

4.7% METHANOL 67-56-1

1.0% METHYL ISOBUTYL KETONE 108-10-1

THESE PRODUCTS ARE SUBJECT TO SARA SECTION 313 REPORTING REQUIREMENTS.

SECTION 16. - - - - - OTHER INFORMATION- - - - -  
THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO  
BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. SIGMA, ALDRICH,  
FLUKA SHALL NOT BE HELD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLING  
OR FROM CONTACT WITH THE ABOVE PRODUCT. SEE REVERSE SIDE OF INVOICE OR  
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## 20.2 Silicone Oil AR 20 (Sigma-Aldrich product # 10836)

Valid 02/2003 - 04/2003

Fluka Chemical Corp.  
1001 West St. Paul  
Milwaukee, WI 53233 USA  
Tel: 414-273-3850

### M A T E R I A L S A F E T Y D A T A S H E E T

SECTION 1. - - - - - CHEMICAL IDENTIFICATION- - - - -  
    CATALOG #: 10836  
    NAME: SILICONE OIL AR 20, ~20 MPA.S  
SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - -  
    CAS #:NONE  
SECTION 3. - - - - - HAZARDS IDENTIFICATION - - - - -  
    DATA NOT AVAILABLE  
SECTION 4. - - - - - FIRST-AID MEASURES- - - - -  
    IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.  
    CALL A PHYSICIAN.  
    IF INHALED, REMOVE TO FRESH AIR. IF BREATHING BECOMES DIFFICULT,  
    CALL A PHYSICIAN.  
    IN CASE OF CONTACT, IMMEDIATELY WASH SKIN WITH SOAP AND COPIOUS  
    AMOUNTS OF WATER.  
    IN CASE OF CONTACT WITH EYES, FLUSH WITH COPIOUS AMOUNTS OF WATER  
    FOR AT LEAST 15 MINUTES. ASSURE ADEQUATE FLUSHING BY SEPARATING  
    THE EYELIDS WITH FINGERS. CALL A PHYSICIAN.  
SECTION 5. - - - - - FIRE FIGHTING MEASURES - - - - -  
    EXTINGUISHING MEDIA  
    WATER SPRAY.  
    CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.  
    SPECIAL FIREFIGHTING PROCEDURES  
    WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO  
    PREVENT CONTACT WITH SKIN AND EYES.  
    UNUSUAL FIRE AND EXPLOSIONS HAZARDS  
    EMITS TOXIC FUMES UNDER FIRE CONDITIONS.  
SECTION 6. - - - - - ACCIDENTAL RELEASE MEASURES- - - - -  
    WEAR RESPIRATOR, CHEMICAL SAFETY GOGGLES, RUBBER BOOTS AND HEAVY  
    RUBBER GLOVES.  
    ABSORB ON SAND OR VERMICULITE AND PLACE IN CLOSED CONTAINERS FOR  
    DISPOSAL.  
    VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.  
SECTION 7. - - - - - HANDLING AND STORAGE- - - - -  
    REFER TO SECTION 8.  
SECTION 8. - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - -  
    SAFETY SHOWER AND EYE BATH.  
    MECHANICAL EXHAUST REQUIRED.  
    WASH THOROUGHLY AFTER HANDLING.  
    AVOID INHALATION.  
    AVOID CONTACT WITH EYES, SKIN AND CLOTHING.  
    AVOID PROLONGED OR REPEATED EXPOSURE.

NIOSH/MSHA-APPROVED RESPIRATOR.  
 COMPATIBLE CHEMICAL-RESISTANT GLOVES.  
 CHEMICAL SAFETY GOGGLES.  
 KEEP TIGHTLY CLOSED.  
 STORE IN A COOL DRY PLACE.

SECTION 9. - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - -  
 APPEARANCE AND ODOR  
 LIQUID.

SECTION 10. - - - - - -STABILITY AND REACTIVITY - - - - -  
 STABILITY  
 STABLE.  
 INCOMPATIBILITIES  
 STRONG OXIDIZING AGENTS  
 HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS  
 CARBON MONOXIDE, CARBON DIOXIDE  
 HAZARDOUS POLYMERIZATION  
 WILL NOT OCCUR.

SECTION 11. - - - - - TOXICOLOGICAL INFORMATION - - - - -  
 ACUTE EFFECTS  
 MAY CAUSE SKIN IRRITATION.  
 MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.  
 MAY CAUSE EYE IRRITATION.  
 MAY BE HARMFUL IF INHALED.  
 MATERIAL MAY BE IRRITATING TO MUCOUS MEMBRANES AND UPPER  
 RESPIRATORY TRACT.  
 MAY BE HARMFUL IF SWALLOWED.  
 TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND  
 TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.

SECTION 12. - - - - - ECOLOGICAL INFORMATION - - - - -  
 DATA NOT YET AVAILABLE.

SECTION 13. - - - - - DISPOSAL CONSIDERATIONS - - - - -  
 CONTACT A LICENSED PROFESSIONAL WASTE DISPOSAL SERVICE TO DISPOSE OF  
 THIS MATERIAL.  
 DISSOLVE OR MIX THE MATERIAL WITH A COMBUSTIBLE SOLVENT AND BURN IN A  
 CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER.  
 OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.

SECTION 14. - - - - - TRANSPORT INFORMATION - - - - -  
 CONTACT FLUKA CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

SECTION 15. - - - - - REGULATORY INFORMATION - - - - -  
 EUROPEAN INFORMATION  
 CAUTION: SUBSTANCE NOT YET FULLY TESTED.

SECTION 16. - - - - - OTHER INFORMATION- - - - -  
 THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO  
 BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. SIGMA, ALDRICH,  
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## 20.3 Minimal Essential Medium (MEM) Buffer (Sigma-Aldrich product # M5650)

Valid 02/2003 - 04/2003

Sigma Chemical Co.  
P.O. Box 14508  
St. Louis, MO 63178 USA  
Tel: 314-771-5765

### M A T E R I A L S A F E T Y D A T A S H E E T

PRODUCT #: M5650  
NAME: MINIMUM ESSENTIAL MEDIUM EAGLE WITH  
EARLE'S SALTS AND AMINO  
ACIDS

WE ARE NOT AWARE OF ANY HAZARDS FOR THE ABOVE PRODUCT.  
THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO  
BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. SIGMA, ALDRICH,  
FLUKA SHALL NOT BE HELD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLING  
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## 20.4 Deionized (“D.I.”) Water

Valid 02/2003 - 04/2003

Fluka Chemical Corp.  
1001 West St. Paul  
Milwaukee, WI 53233 USA  
Tel: 414-273-3850

### M A T E R I A L S A F E T Y D A T A S H E E T

PRODUCT #: 17749  
NAME: WATER, FOR ANALYTICAL PURPOSES

WE ARE NOT AWARE OF ANY HAZARDS FOR THE ABOVE PRODUCT.  
THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO  
BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. SIGMA, ALDRICH,  
FLUKA SHALL NOT BE HELD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLING  
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## **21. Experiment Procedures Documentation**

### **21.1 Equipment Shipment to Ellington Field**

The apparatus, tools, and test liquids will be transported from Baltimore to Houston in the SUV of one of our teammates. It will be partially disassembled to fit in the car, and reassembled at Ellington Field. The apparatus does not require any special storage conditions, although we would prefer that it remain in a clean indoors environment with as little dust as possible. The dimensions of the apparatus are 23.64" x 52.92" x 55.27", so it will require an unobstructed volume of at least those dimensions for storage. Additional space is requested for storing the tools, syringes, and test liquids at Ellington Field; perhaps a few dozen square feet of floor space. The equipment will be brought to Ellington Field on the morning of Thursday, April 10, 2003.

### **21.2 Ground Operations**

After assembly of the basic apparatus, the test section rows and the corresponding polycarbonate covers will remain uninstalled. The test liquids, stored in screw top-sealed Lexan bottles, will be drawn manually into 30 mL syringes in quantities as specified in Table 6.1. Upon completion of syringe filling, the syringes will be mounted inside the test sections and sealed. Once all of the syringes are secured, the test section rows will be mounted to the apparatus, followed by mounting and sealing the polycarbonate covers to the test section rows. All of these assembly operations will be accomplished using the hand tools mentioned in Tool Requirements (Sec. 15). A thorough check of all fasteners, screws, and bolts will be performed before loading.

### **21.3 Loading**

A forklift and lifting pallet will be needed to load the STILLMix apparatus onto the KC-135. The team has enough people to safely lift the apparatus, so we will not require further assistance in manipulating it before and after loading.

### **21.4 Pre-Flight**

After the apparatus is brought onboard the airplane it will be bolted into place using the specified installation bolts provided by the RGO. The power cord for the surge protector will be inserted into the assigned power receptacle, but the surge protector itself will remain off. The power supply for the video camera will be plugged into the surge protector, but the camera will remain stowed.

## **21.5 Take Off / Landing**

For take off and landing, no special procedures will take place. The power for the surge protector will be checked to ensure that it is in the off position. Before landing, the camera will be stowed once again in its protective bag.

## **21.6 In-Flight**

Once airborne, the video camera will be installed into its mount and connected to its power supply. The surge protector will then be activated. Before the start of the first series of parabolas, the camera will be turned on and will begin recording. Video recording will be continuous from that point on; the only interruption will be the insertion of a new videotape after the first nine experiments are completed, probably coinciding with the completion of the outbound leg of the flight.

Before each parabolic maneuver, the camera mount will be positioned, using sliders, directly above the test section that will be used for that parabola. The camera will be at a set vertical distance from the test section, so we anticipate that there will be no need to refocus or adjust the camera in between parabolas. Upon achieving microgravity conditions, the two syringe plungers for that test section will be depressed manually by one of the flyers over the course of approximately 10 seconds. At the end of each parabola, the above process will be repeated.

## **21.7 Post-Flight**

All equipment will be offloaded from the aircraft. The polycarbonate covers from the test sections will be removed, as well as the syringes. The test section rows will be detached from the apparatus in order to facilitate cleaning. The covers, syringes, and test sections will be cleaned using a commercially available degreaser and water in the sink requested in Ground Support Requirements (Sec. 18). The components will be left to completely dry overnight and then dusted off using the pressurized air (also requested in Sec. 18) before reassembly the following day.

## **21.8 Offloading**

The apparatus will need to be offloaded using the forklift. After completion of the flight dates, the apparatus will be cleaned once more and partially disassembled to allow loading into our teammate's SUV and will then be transported back to Baltimore.

## 22. Bibliography

- 1 P.G. de Gennes, “Wetting: Statics and Dynamics,” *Rev. Mod. Phys.*, Vol. 57, No. 3, Part 1, July 1985.
- 2 Lopez, J., Miller, C.A., Ruckenstein, E., J. *Colloid Interface Sci.* 56 (1976), 460
- 3 C.R. Nave. *Surface Tension.* Atlanta: Georgia State University, 2000. 21 September 2002 <<http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html>>.
- 4 Dr. Laszlo Prokai. *PHA 5100, Surface/Interfacial Tension.* June 2002. Gainesville, FL: University of Florida. 21 September 2002 <<http://www.cop.ufl.edu/safezone/prokai/pha5110/tension.htm>>.
- 5 J. Lyklema. *Fundamentals of Interface and Colloid Science: Vol. III – Liquid-Fluid Interfaces.* London: Academic Press, 1991.
- 6 Committee on Microgravity Research, Space Studies Board, National Research Council. “Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies”. National Academy Press, 2000.
- 7 Fox, Robert W. and Alan T. McDonald. *Introduction to Fluid Mechanics.* 5th ed. New York: John Wiley & Sons, Inc., 1998.
- 8 Juvinall, Robert C. and Kurt M. Marshek. *Fundamentals of Machine Component Design.* 3rd ed. New York: John Wiley & Sons, Inc., 2000.
- 9 Reviewed Proceedings of the First International Symposium on Hydromechanics and Heat/Mass Transfer in Microgravity. “Hydromechanics and Heat/Mass Transfer in Microgravity”. Amsterdam: Gordon and Breach Science Publishers, 1992.
- 10 Tyrell, H.J.V. and K.R. Harris. *Diffusion in Liquids; A Theoretical and Experimental Study.* London: Butterworths, 1984.

## 23. Exceptions

The planning and operation of this experiment does not require or include any exceptions to RGO requirements or guidelines.