REDUCED GRAVITY AEROGEL FORMATION:

The Effects of Gravity on the Structure and Chemistry of Mesoscopic Particles in Sol-Gel Systems and the Subsequent Effects on the Structural and Optical Properties of Derived Aerogels

TEST EQUIPMENT DATA PACKAGE

Stephen Steiner, Principal Investigator
ZERO-G AEROGEL TEAM
Project ID: 2003-250

University of Wisconsin—Madison
Chemistry Department
c/o West Group
1101 University Ave.
Madison, WI 53706-1396

JANUARY 30, 2003

2. Quick Reference Sheet

Principal Investigator: Stephen Steiner

Contact Information:
Stephen Steiner
c/o West Group
1101 University Ave.
Madison, WI 53706-1396
(414) 732-5261
ssteiner@zerogaerogel.com

Experiment Title: Reduced Gravity Aerogel Formation: The Effects of Gravity on the Structure and Chemistry of Mesoscopic Particles in Sol-Gel Systems and the Subsequent Effects on the Structural and Optical Properties of Derived Aerogels

Flight Week: March 13 to March 22, 2003

Overall Assembly Weight: 107 lbs.

Assembly Dimensions (L x W x H): 30” x 36” x 36”

Proposed Floor Mounting Strategy: Straps

Gas Cylinder Requests: None

Overboard Vent Requests: Yes

Power Requirements: 115 VAC, 5.5 A

Flyer Names for Each Proposed Flight Day:

Day 1	**Day 2**
Stephen Steiner	David Meister
Mark Schneider	Christopher Wessing

Alternate: Emily Janicek

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4. Flight Manifest

Stephen Steiner
First Flight Date
Previous Flights: July 2001, April 2002

Mark Schneider
First Flight Date
Previous Flights: None

David Meister
Second Flight Date
Previous Flights: April 2002

Christopher Wessing
Second Flight Date
Previous Flights: None

Alternate
Emily Janicek
Previous Flights: None

5. Experiment Background

5.1 Overview

The experiment is testing the effects of gravity on the formation of nanostructures in bulk-scale sol-gel systems, how gravity influences the manner in which such nanostructures interconnect to form bulk-scale gel, and the subsequent effects on the physical, structural, and optical properties of aerogels derived from such gels. The aim is to develop a method of weightless material processing with the objective of enhancing the tailorability of gels, and thus aerogels, at the nanoscopic level. It is believed that the mean nanopore diameter and distribution of nanopore diameters within a gel (and subsequently an aerogel) can be controlled more effectively and to greater extremes in the absence of a gravitational pull. This could enable a process with the capabilities of producing aerogels with structural and optical properties not easily attainable otherwise, including the ability to control the light-scattering properties of aerogels, which are responsible for making transparent aerogels appear blue.

5.2 Introduction to Aerogel

Aerogel is a nanoporous, solid foam with many unusual physical and chemical properties. Aerogel is the lowest-density solid material that has ever been developed, and is, by definition, no more than 50% solid by volume, with the remaining volume filled with gas or evacuated space. Typically, aerogels range from 90 to greater than 99% air by volume in composition. Aerogels can be made from many substances, including metal oxides, carbon, plastics, and recently, metals. Silica aerogel, however, is by far the most researched type of aerogel.

5.2.1 Properties of Aerogel

Aerogels, with such extreme low densities and high porosities, have many unusual characteristics. Typical silica aerogels range in density from 0.1 g cm^{-3} to 0.001 g cm^{-3}. The internal surface area of a typical silica aerogel (determined by Brunauer-Emmet-Teller nitrogen adsorption) ranges anywhere from 200 m^2 g^{-1} to 2 000 m^2 g^{-1}. With such high internal surface areas, aerogels are excellent materials for energy dampening applications, including trapping of high-momentum particles, acoustic isolation, and thermal insulation. Silica aerogel is also very strong for its density—a typical silica aerogel can withstand up to 2 000 times its weight in applied force across its surface. Its high internal surface area also makes aerogel an ideal material for surface chemistry applications, including catalytic converters, chromatography, desalination of water, capacitor electrodes, and nanoscale engineering.

To put these figures into perspective, here are a few popular analogies. An inch-thick piece of silica aerogel is as effective an insulator as a stack of 30 panes of window glass. A block of silica aerogel the size of an average man would weigh approximately one pound, but at the same time, would be able to support the weight of a small sub-compact car. These comparisons clearly depict the remarkable potential aerogel has for commercial and industrial applications.

Silica aerogel, although transparent, exhibits a characteristic blue-violet cast as a result of Rayleigh scattering within its internal structure. With its superior insulating ability and high optical transparency, aerogel would otherwise be an ideal material for transparent superinsulation in windows, telescopes, and spacecraft. It is therefor desirable to develop processing techniques for producing transparent, non-blue aerogels for applications requiring high optical transparency.

5.2.2 Production of Aerogel

Overview

Aerogels are made from gels. A gel is a colloidal system in which a network of interconnected solid particles spans the volume of a liquid medium. A gel is composed of a porous solid matrix interspersed with a liquid component. The solid particle matrix gives the gel its rigidity, whereas the liquid component gives the gel its density. The nanoscopic pores in a gel, or nanopores, typically range anywhere from 5 to 250 nm in diameter.

If the liquid in a gel is removed by evaporation, the solid particle matrix that gives the gel its rigidity will collapse to form a hard, dense material. As the liquid evaporates from the pores of the gel, liquid closes in to fill the vacant space. As this occurs, capillary forces draw branches of the gel's solid matrix inward. Weak hydrogen interactions can occur between the surfaces of matrix branches, causing them to adhere. The result is an irreversible collapse of the matrix into a dense solid. If the gel consists of a silica matrix and an organic solvent such as ethanol, for example, it will form high-purity silica glass upon evaporation.

It is possible, however, to extract the liquid from a gel without causing the solid particle matrix to collapse. The result is the isolation of the gel's solid matrix from its liquid component, forming a low-density, nanoporous solid with nearly the same volume of the original gel. This material is called aerogel.

Preparation of Gels by Sol-Gel Polymerization

Aerogels are made from gels. Metal oxide gels can be formed by sol-gel polymerization of a metal alkoxide in a liquid solvent. Such gels are typically called alcogels. Silica alcogels are produced through reaction of a silicon alkoxide, such as tetramethoxysilane (TMOS) or tetraethoxysilane (TEOS), with water in a cosolvent such as methanol or ethanol. The reaction involves three chemical steps resulting in the formation of the gel matrix:

$\equiv\text{Si-OR} + H_2O \rightleftharpoons \equiv\text{Si-OH} + \text{ROH}$ **Hydrolysis** **(1)**

$\equiv\text{Si-OH} + \text{ROH} \rightleftharpoons \equiv\text{Si-O-Si}\equiv + \text{ROH}$ **Alcohol Condensation** **(2)**

$\equiv\text{Si-OH} + H_2O \rightleftharpoons \equiv\text{Si-OH} + \text{ROH}$ **Water Condensation** **(3)**

Gelation begins as silicon alkoxide molecules interconnect to form small, oligomeric species of a few monomer units. These oligomeric species further expand and/or interconnect with other monomeric and oligomeric species to form mesoscopic clusters. These mesoscopic clusters eventually interconnect to form a bulk-scale gel matrix that spans the entire volume of the liquid medium. Looking at a gel's solid particle matrix under a microscope, it can be seen that it is comprised of interconnected, but discrete, clusters.

Once an alcogel has formed, it can be soaked in a pure solvent to remove excess water, catalyst, and unreacted species from the gel. This ensures that back reactions do not weaken the gel's structure, and purifies the gel for production of aerogel.

Supercritical Drying

After an alcogel has been purified, it can be made into aerogel. This can be done a number of ways, the most common of which being supercritical extraction.

Supercritical extraction utilizes special properties possessed by supercritical fluids to produce aerogel. A supercritical fluid is a substance beyond its critical point—the temperature and pressure beyond which a substance cannot be condensed to a liquid phase by further increase in pressure. Supercritical fluids possess many properties expected of gases, including expansion to fill the volume of a container and compressibility, but at the same time, also exhibits many properties similar to those of liquids, including relatively high density and good thermal conductivity. Supercritical fluids can even dissolve substances that would otherwise be insoluble in the fluid's liquid phase. Unlike liquids, however, they exhibit no capillary forces.

When a gel is dried by evaporation, its collapse is primarily due to capillary forces drawing the gel's solid particle matrix inward. By bringing the liquid in the gel to its critical point, however, the liquid in the gel can be extracted as a supercritical fluid without causing any capillary action within the gel. The supercritical fluid can then diffuse out of the gel's solid particle matrix like a gas. Once the system is depressurized, the supercritical fluid (which at this point exists throughout the gel and its surroundings) reverts to a gas. The result is the effective replacement of the gel's liquid component with gas throughout the gel's matrix, leaving behind a low-density nanoporous foam. This material is aerogel.

Conditions for supercritical extraction depend on the properties of the liquid component of the gel. The critical point of ethanol, for example, is 514.0 K at 60.567 atm.[1] This requires the use of a high-pressure vessel that can withstand the pressures and temperatures required to supercritically extract ethanol from the gel. Pressurized ethanol is dangerously explosive near its critical point, however, and is undesirable as a liquid for supercritical extraction. Instead, a safer, non-flammable liquid can be used to do supercritical extraction—carbon dioxide. In this technique, called the Hunt process, the gel's liquid component is exchanged with liquid carbon dioxide, enabling safe, low-temperature, inexpensive supercritical drying, since the critical point of

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[1] Taken from Table of Critical Constants, *CRC Handbook of Chemistry and Physics*, p. 6-53.

carbon dioxide is only 304.13 K at 72.786 atm.[2] Since liquid carbon dioxide does not exist at atmospheric pressure, a pressure vessel is required for both soaking and supercritical extraction.

Procedure for Hunt Process Supercritical Drying

The gel is first placed in a pressure vessel under liquid. This is to protect the gel during pressurization. The vessel is sealed and cooled to approximately 278 K (0ºC). Once cooled, the vessel is pressurized to the vapor pressure of carbon dioxide (appoximately 50 atm) with carbon dioxide from a siphon tank. At this point, liquid carbon dioxide siphons into the vessel. The initial protecting liquid can then be drained off.

The gel is allowed to soak in liquid carbon dioxide until all of the gel's original liquid component has been removed. Liquid carbon dioxide is periodically flushed through the vessel to wash out liquid built-up as it removed from the gel. After the gel has been soaked and purified, it can be supercritically dried. To do this, the vessel is slowly heated past the critical point of carbon dioxide, releasing pressure during heating to maintain the vessel's pressure at approximately 80 atm. The vessel is heated past 313 K (40ºC) to 320 or 330 K and allowed to stay at those conditions for several hours (depending on the size of the gel). The vessel is then slowly cooled and depressurized to ambient conditions over the course of several hours by leaking pressure to the surroundings. Once ambient conditions have been reached, the vessel can be opened.

Non-Supercritical Drying

Although supercritical drying is the most effective way of producing aerogels, non-supercritical methods can also be used to extract liquid from a gel, however, only with considerable shrinking.

The surface of a silica alcogel's solid matrix is lined with hydroxyl groups. These hydroxyl groups engage in weak hydrogen bonding with the gel's liquid component, as well as with each other. If the liquid component of the gel is evaporated, capillary forces draw the branches of the gel's matrix close to each other, allowing these hydroxyl groups to adhere, pulling the matrix inward. The hydroxyl groups can be replaced, however, with non-polar groups (such as trimethylsilyl groups) which exhibit significantly reduced interactions. The result is lesser collapse of the gel's matrix during evaporation, allowing for the production of aerogel without supercritical extraction.

5.2.3 Origins of Rayleigh Scattering in Aerogels

Although highly transparent, bulk samples of silica aerogels (along with other non-opaque aerogels) appear blue when viewed in white light. This phenomenon is a result of Rayleigh scattering of short wavelengths by the aerogel's nanoporous interior. An aerogel's porous matrix consists of interconnected nanoscopic particles 5 to 25 nm in diameter forming pores with a range of diameters anywhere from 5 to 250

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[2] *CRC Handbook of Chemistry and Physics*, p. 6-52.

nm. Most of the nanopores within an aerogel fall somewhere between 5 and 50 nm in diameter and do not scatter visible light. Nanopores within the aerogel matrix with diameters between 50 to 250 nm are large enough to interfere with short-wavelength light, specifically blue, violet, and ultraviolet. It is these pores that cause the majority of Rayleigh scattering in aerogel. As a result, blue, violet, and ultraviolet light are more easily scattered than other colors, giving rise to the characteristic blue-violet cast aerogels exhibit. As our eyes are more sensitive to blue light than to violet, the bulk material appears to be blue.

5.3 Effects of Gravity on Gel Formation

Gravity is almost always ignored when it comes to chemical systems, simply because its effects are so much lesser in magnitude than the quantum interactions that govern most chemical behavior. Systems involving molecular-sized particles experiencing Brownian motion typically experience only a negligible effect from gravity. Contrapositively, bulk-scale systems are heavily influenced by gravity, and experience only negligible effects from the forces that govern Brownian motion. But at what point do we say something is "bulk scale" and no longer "molecular" in size? Where do Newtonian forces like weight and buoyancy "switch on" and does Brownian motion "switch off?"

To be truthful, there is no clear threshold differentiating the two realms. Somewhere between "big molecule" and "microparticle" lies the mesoscopic domain, where both Brownian motion and gravity have a say.

Particles in the mesoscopic realm are molecular in nature, but large enough to experience weight and buoyancy. They are governed generally by Brownian motion, diffusing through a medium like a small molecule would, but much slower, and more drowsily. Mesoscopic particles experience drag as they barge through smaller molecules in solution, and do not have the free, unhindered ability to diffuse like small molecules.

At the same time, mesoscopic particles will not rapidly settle to the bottom of their containers like bulk-scale particles, and do not easily sort themselves out according to relative densities. But their motion is still affected by these tendencies, and thus mesoscopic particles in solution behave and interact much differently than smaller molecules in solution, as they are governed by both Brownian and Newtonian forces.

Vanderhoff et al. demonstrated that emulsion polymerization of latexes in microgravity results in better monodispersity, increased uniformity, and reduced coagulation.[3] Noever et al. have proposed that buoyancy-driven fluid flow dramatically affects micro- and nanostructures formed in sol-gel systems just before gelation, and that these eddies are "frozen" as imperfections in the gel's matrix.[4,5] It

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[3] Vanderhoff J. W.; El-Aasser, M. S.; Micale, F. J.; Sudol, E. D.; Tseng, C. M.; Sheu, H. R. *Polym. Prepr.* 1987, 28, 455; *Mater. Res. Soc. Symp. Proc.* 1987, 87, 213.

[4] Noever, D. A. *Microgravity Sci. Technol.* 1994, 3, 14.

[5] Zhu, J. X.; Li, M.; Rogers, R.; Meyer, W.; Ottewill, R. H.; STS-73 Space Shuttle Crew; Russel, W. B.; Chaikin P. M. *Nature* 1997, 387, 883.

would be expected then that formation of sol-gel structures in microgravity would result in more uniform gel matrix.

In a silica sol-gel system, gelation starts with the formation of oligomeric silica species. As these species grow to form more complex nanostructures, they begin to attain considerable mass and thus begin to experience more the effects of gravity. As polymerization continues, silica clusters evolve. These clusters join together to form the gel's solid matrix. When these clusters interconnect, they form relatively large pores between them, unlike the small and uniform pores within the clusters formed by Brownian-motion-governed monomers and oligomers. In a gravitational field, these clusters deviate from ideal molecular behavior and construction as they traverse this Brownian-Newtonian interface. Gravitational effects alter the manner in which these particles grow, affecting their structures and how they are structurally able to interact once they have formed, as well as how the clusters themselves move. If it were possible to remove the gravitational effects of weight and buoyancy during the formation and interconnection of these mesoscopic particles, it might be possible to enable a pseudo-Brownian motion throughout the entire formation of the gel, all the way to the bulk realm. It is the hypothesis of the principal investigator that this would result in not only a more uniform gel, but in a gel comprised of the types of tight, Brownian-derived, small-pored nanostructures possible at the molecular scale throughout the volume of the bulk material. From this, gels formed in reduced gravity should exhibit an overall smaller mean diameter of nanopores, a narrower distribution of nanopore diameters, visibly observable differences in the substructures of the gel's matrix, and possibly increased strength. Aerogels derived from such gels would exhibit reduced Rayleigh scattering when compared to aerogels produced from gels formed in the presence of a gravitational pull, since they would possess fewer nanopores of sufficient size to cause Rayleigh scattering. This would imply that forming gels in microgravity would enable the nanoscopic control required to produce the precursor material needed for transparent, non-blue aerogels.

5.4 Previous Reduced Gravity Aerogel Experiments

A number of attempts at forming aerogels in microgravity have been conducted, but none have resulted in conclusive data.

Hunt et al. conducted a series of experiments starting on the KC-135A and eventually on a shuttle flight. Their KC-135A experiment measured the light-scattering properties of silica Stober particles, which are microscopic silica clusters. They reported an apparent difference in properties when compared to Stober particles grown in the presence of a gravitational pull, but were unable to derive any conclusive data. Another experiment conducted on a sounding rocket resulted in actual bulk-scale gel samples that were supercritically dried and analyzed. They reported a difference based on transmission electron microscopy, and apparently higher internal surface areas than aerogels formed in the presence of a gravitational pull, but they were unable to conclude any useful results on if microgravity would result in reduced Rayleigh scattering. An experiment was eventually flown on a shuttle flight and operated by Senator John Glenn, but the group's research objectives have changed since the start of that project and the alcogels produced from the flight have not yet been supercritically dried.

Smith et al. conducted a space-flight experiment on the growth of Stober particles and found space-grown samples of Stober particles resulted in low-density gels, where ground-based samples remained in suspension.[6] This implies that gravity hinders ideal formation of gel substructures, and results in a growth pattern that ultimately terminates the gel clusters' size, while also affects their structure in such a way that their surfaces are less able to interconnect than an idealized Brownian-only system would allow.

Two notable problems have presented themselves in the evolution of these experiments. The first is achieving microgravity. Since microgravity is only possible through a limited number of venues, the research in this area is limited. The second, and possibly more challenging problem, is being able to reliably, reproducibly, and effectively form bulk-scale gels for analysis within the time frame of the microgravity environment without destroying the effects of microgravity.

Previous experiments on the KC-135A have been limited by gelation times, which typically are longer than the 23 seconds of microgravity achievable by the aircraft. Some experiments have implemented heat as a method of increasing gel times, but it is the opinion of the principal investigator that in doing so, microscopic thermal currents are introduced into the gel, overtaking the effects of growing the gel in microgravity. The equipment employed by Hunt et al. aboard their space shuttle experiment was a modified device used for growing protein crystals in microgravity. The device uses intense vibration to channel liquids to a central mixing chamber where they would mix from the vibrations. It is the opinion of the principal investigator that this allows overtakes the subtle effects of growing gels in microgravity, since vibration would introduce mechanical currents into the gels and also form micro-eddies that would interfere with the production of the gels' nanostructures.

5.5 Experiment Objective

The objective of the experiment is to form bulk samples of silica alcogels in a microgravity environment aboard the KC-135A Reduced Gravity Laboratory to determine the effects of gravity on the formation of substructures within silica alcogels and how those effects propagate into the structural and optical properties of subsequently derived silica aerogels. We have developed a novel rapid gelation technique that allows us to completely form bulk-scale gels in microgravity within the amount of time microgravity can be produced on the KC-135A and control exactly how long gelation will require. We have refined our technique as a result of our previous experiments to use safer, milder reagents that we have shown to be effective in producing gels in microgravity aboard the KC-135A. This technique allows us to trap the effects of microgravity in a gel structure without requiring a space flight. Using this information, it is believed that conclusive data on the effects of gravity on

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[6] Smith, D. et al. "Effect of Microgravity on the Growth of Silica Nanostructures," *Langmuir*, 2000, 16, 10055-10060.

mesoscopic systems will be obtained, and that it can be determined if producing aerogels from gels grown in microgravity is a possible means for reducing Rayleigh scattering in silica aerogels. The experiment will attempt to determine if microgravity can be used as a possible means of reliably controlling the properties of aerogels at the nanoscopic level.

5.6 Description of Follow-Up Flight

This is the third trial of our experiment.

Our first trial in July 2001 was a proof-of-concept step of the experiment, establishing that it was possible to use our rapid gelation technique to form gels aboard the KC-135A. The experiment lacked the level of engineering required to reliably produce the quality of gels required for rigorous analysis, however.

Our second trial in April 2002 successfully produced a small number of silica alcogels suitable for scientific analysis. We established the first engineering specifically designed for performing sol-gel chemistry in microgravity and showed it to be effective, despite initial operational difficulties. Although we were able to fully form several gels in microgravity, we were unable gather enough data from the gels to perform a complete analysis.

This trial of the experiment will utilize our third generation designs for performing sol-gel chemistry in microgravity, along with improved vibrational dampening systems and more reliable equipment. In addition, we will be implementing a modified chemical reaction using milder reagents than in our past two trials, which will result in more effective gel formation and a significantly reduced hazard.

6. Experiment Description

6.1 Overview

The objective of the experiment is to form bulk samples of silica alcogels in a microgravity environment aboard the KC-135A Reduced Gravity Laboratory to determine the effects of gravity on the formation of substructures within silica alcogels and how those effects propagate into the structural and optical properties of subsequently derived silica aerogels. It is believed that by forming alcogels in microgravity, it will be possible to produce aerogels with a lower mean nanopore diameter, narrower distribution of nanopore diameters, and more uniform structure than aerogels producing in the presence of a gravitational pull. In doing so, it is believed that it may be possible to produce aerogels that exhibit reduced Rayleigh scattering of visible light.

6.2 Experiment Methodology

The experiment will form silica alcogels in microgravity aboard the KC-135A Reduced Gravity Laboratory. Since only 23 seconds of microgravity is available per parabola, the gel time for the reaction must be within that time limit. This is to ensure the effects of microgravity are trapped within the gel matrix when it forms, and that it is completely formed when it reenters a gravitational pull. Alcogels will be formed by mixing two solutions in microgravity, resulting in the formation of a gel within 15 seconds of mixing.

The experiment will produce 25 alcogels per flight.

Liquids will be degassed prior to flight to prevent formation of coin bubbles in alcogels as they form.

All equipment is heavily dampened against vibration to ensure a suitable microgravity environment.

Gels will be formed in sealed, airtight molds to prevent air bubbles from being trapped in the gel as it forms and to ensure uniformity.

Acceleration will be closely monitored with an accelerometer.

The experiment will conduct the following tests, varying gel density and gel time required to produce the gels:

Table 6.1 Experiment Layout

	15-second gelation	**20-second gelation**
Low-density formula	4 alcogels	
Moderate density formula	15 alcogels	4 alcogels
High-density formula	4 alcogels	

The experiment will be repeated on the second flight.

6.3 Accompanying Ground-Based Experiments

The experiment will be repeated on the ground using the same equipment and the same techniques used in microgravity. These gels will be used as controls for data analysis.

Both the microgravity-formed and the control alcogels will be purified, treated with hexamethyldisilazane (to waterproof them) and later supercritically dried by the Hunt process.

6.4 Data Analysis

The aerogels will be analyzed for the following properties by various techniques:

- Pore structure from TEM
- Mean pore diameter from TEM and gas analysis
- Distribution of pore diameters from TEM
- Chain length from TEM
- Cluster size from TEM
- Internal surface area by Brunauer-Emmet-Teller nitrogen adsorption surface area determination
- Density by volumetric techniques
- Transparency and Rayleigh scattering properties by spectrophotometry
- Tensile strength
- Modulus of compression

6.5 Expected Results

It is believed that aerogels produced from alcogels formed in microgravity will exhibit a significantly lower mean nanopore diameter, a narrower distribution of nanopore diameters centered around that mean, reduced Rayleigh scattering in the visible region, significantly increased Rayleigh scattering in the ultraviolet region, and stronger mechanical properties. In addition, it is believed that the substructures in such aerogels will be more uniform than the substructures of aerogels produced from gels formed in a gravitational pull, and that the presence of large clusters in the aerogel matrix will be reduced.

7. Equipment Description

7.1 Overview

To produce silica alcogels in microgravity, a base solution containing silicon alkoxide must be mixed with a catalyst solution containing water and ammonium hydroxide. The equipment is designed to accurately measure, aspirate, and dispense catalyst into a set of volume expandable molds which are pre-filled with base solution. Upon injection of catalyst into a base-filled mold, a gel will form. All equipment and molds are contained within a double-layered polycarbonate aluminum-frame glove box. The glove box is then housed in a foam-padded open aluminum frame that serves to dampen the equipment from vibration.

7.2 Injection Apparatus and Molds

Injection Apparatus and Diffusion Needle

The injection apparatus uses a 10.0-mL polyethylene syringe to aspirate and dispense liquid. The syringe is attached to a linear actuator that pushes and pulls the syringe's piston. The syringe is equipped with a standard male Luer connector which then interfaces with the injection system's plumbing.

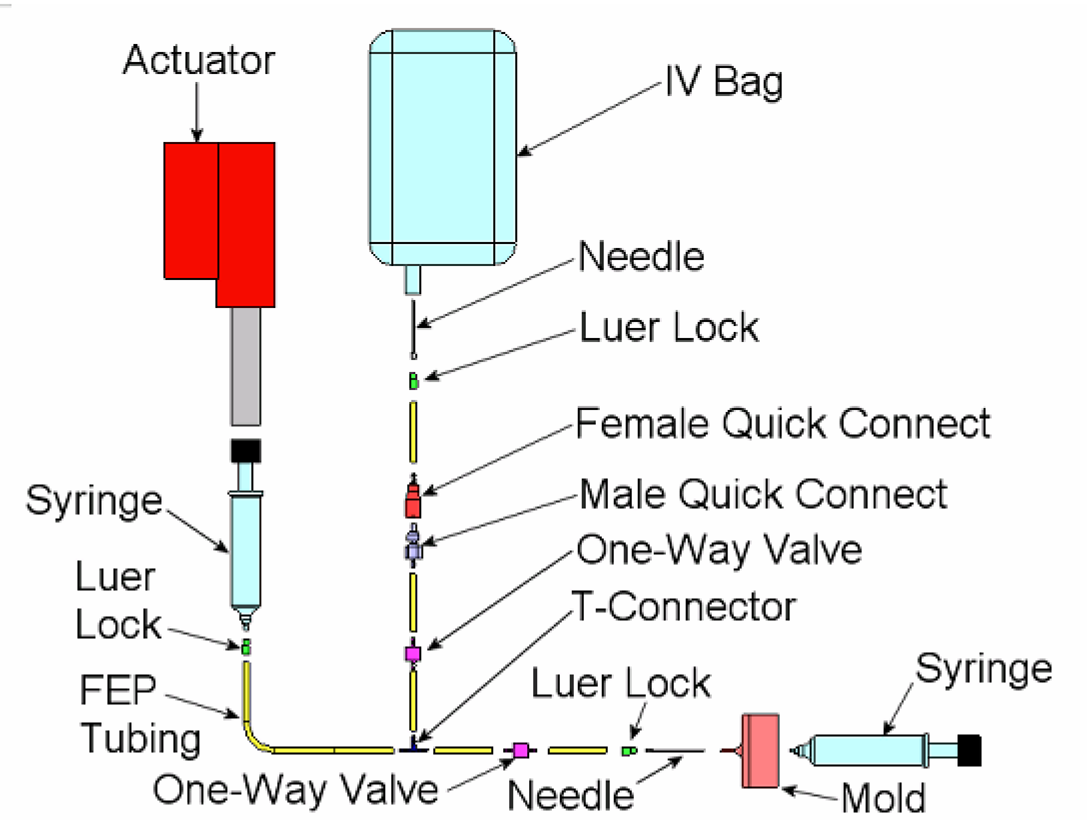


Figure 7.1 Exploded diagram of injection system with mold

The system's plumbing is comprised of fluorinated ethylene/propylene copolymer (FEP) tubing connected by polypropylene barb connectors., the system branches off in two directions from the syringe: through a three-way tee to a polypropylene intravenous delivery bag in one direction (used to contain the catalyst solution), and out to a needle in the other.

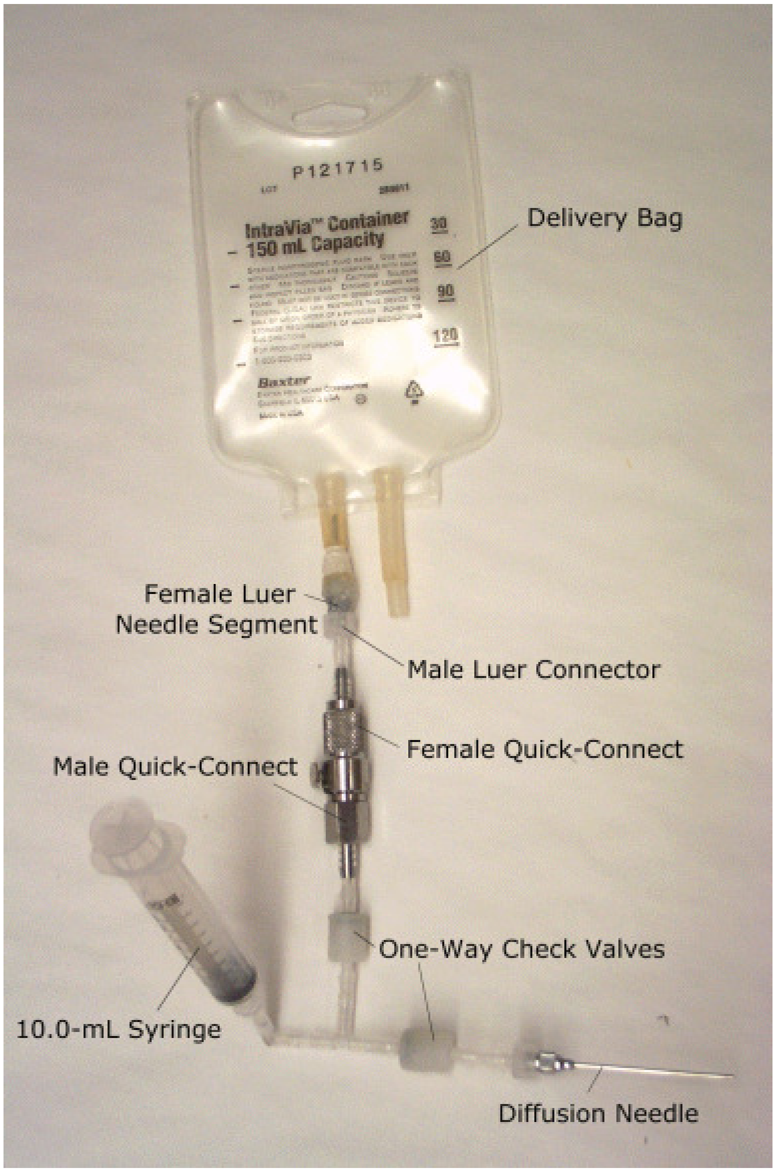


Figure 7.2 Photograph of injection system. The syringe can be rotated.

The intravenous delivery bag has a capacity of 150 mL and is filled with catalyst solution prior to flight. Through one of the spigots of the delivery bag is epoxied a segment of a rounded-off steel Luer needle. The needle segment is then sealed at the spigot by silicone caulk. The needle segment has a female Luer connection and interfaces with the injection system's plumbing through a polypropylene male Luer-to-barb connector, joined to a stainless steel spring-loaded quick-connect by FEP tubing. This quick-connect serves as a convenient means for attaching delivery bags to and detaching used delivery bags from the system, while providing a no-flow safety mechanism when it is not interfaced. This prevents liquid from dripping out when the bag is not connected the injection system and prevents air from being drawn into the injection system if it is improperly interfaced. The quick-connect interfaces with the opposite quick-connect on the injection system. Liquid drawn through the quick-connect into the injection system passes through a polypropylene one-way liquid check valve. This prevents liquid from flowing into the delivery bag, only allowing liquid to be drawn out from it.

Between the three-way connection at the center of the injection system and the needle is placed a second one-way check valve, ensuring that liquid can only be injected out through the needle, and that liquid and air cannot be aspirated in through the needle.

Connected to this check valve is a 16-gauge, 2-inch, stainless steel Luer needle. The needle has a sealed, blunt tip, with four small orthogonal holes around the needle's circumference, approximately 1/4 inch from the end of the needle. The needle serves as a device to efficiently diffuse catalyst into the base-filled molds.

Volume Expandable Molds

The molds have the ability to expand in volume upon injection of catalyst. This allows for air-free gel formation and ensures no pressure builds up inside.

Each mold has a cylindrical polypropylene base, 5.0 mL in volume. In the rim of this base are four orthogonal bolt holes and an indent in which a Viton o-ring sits. Into this base is bolted a polypropylene lid. The lid is equipped with a small rod segment with a channel for the diffusion needle to penetrate through. A rubber septum is epoxied over this rod segment to seal the mold and still allow penetration by the needle.

On the bottom of the mold's base is a female Luer connector. To this is attached a 10.0-mL polyethylene syringe to accommodate for the increase in volume when catalyst liquid is injected.

When the diffusion needle penetrates the septum of the mold, it is pushed to the bottom of the mold's base where the four orthogonal holes on the needle are aligned with the center cross-sectional plane of the mold.

All materials in the mold are compatible with both the base solution and catalyst solution.

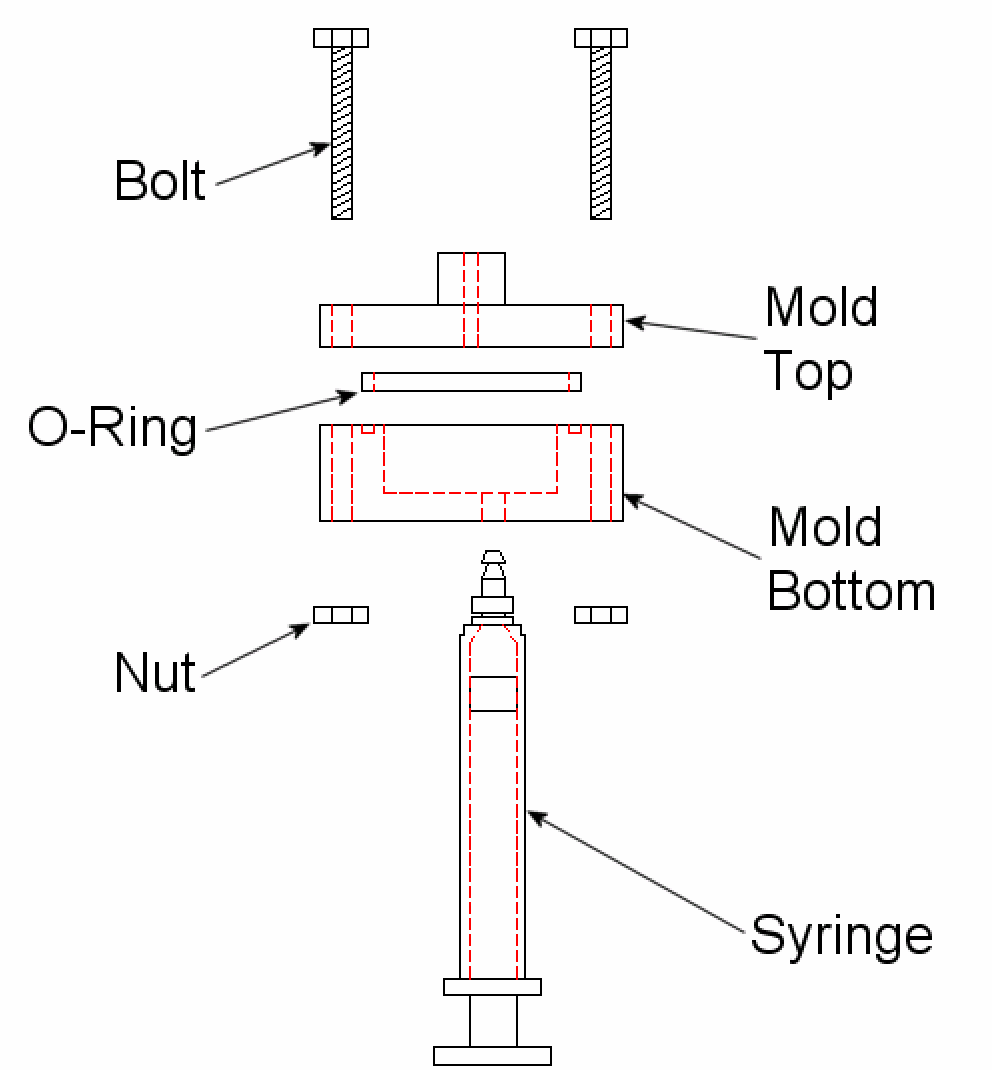


Figure 7.3 Diagram of volume expandable mold.

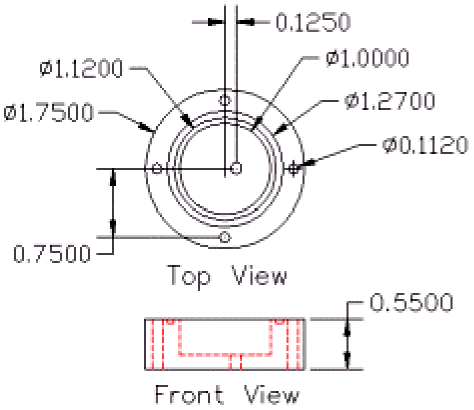


Figure 7.4 Mold Base Dimensions

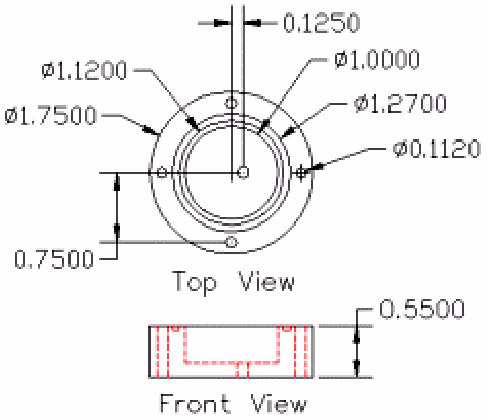


Figure 7.5 Mold Lid Dimensions

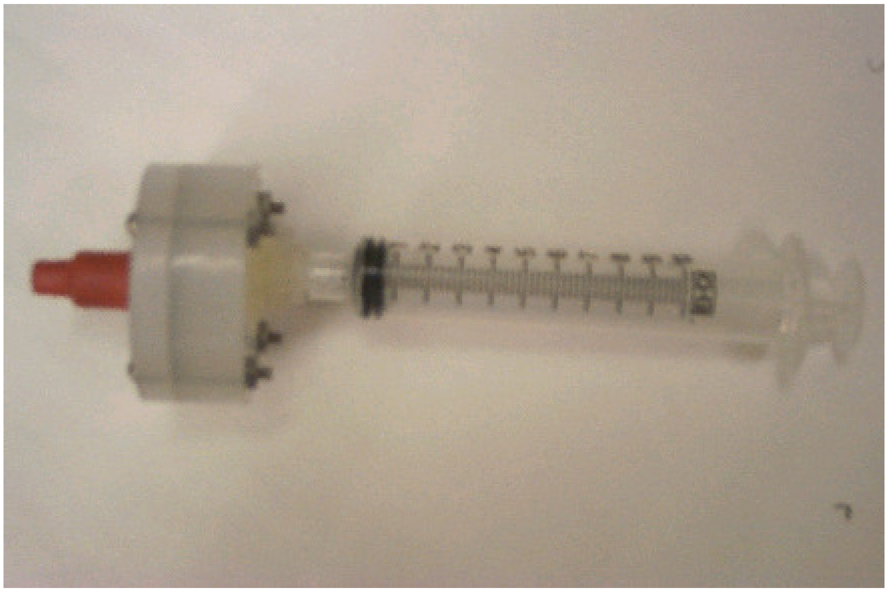


Figure 7.6 Photograph of volume expandable mold

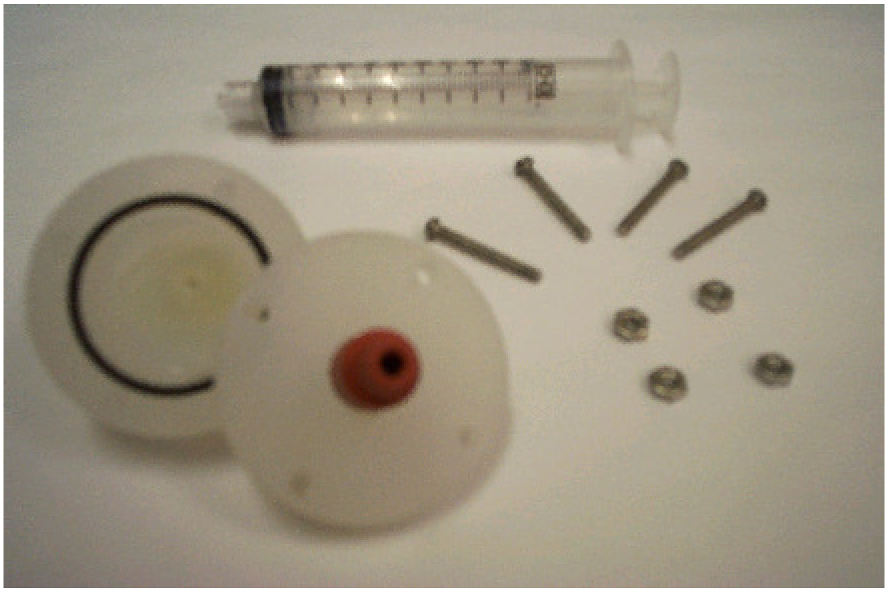


Figure 7.7 Photograph of disassembled volume expandable mold

Mold Racks

The mold rack system is designed to contain the molds by providing a tight-fitting foam docking system, dampening the molds from vibration and maximizing storage space.

Each rack is composed of a foam structure comprised of several layers of foam cut-outs glued together. This foam structure is then adhered to a polycarbonate sheet which is used to bolt the rack into the containment box (see Section 7.5).

A mold is inserted into the rack by lining it up with the channel in the foam structure and, while holding the syringe on the mold, pushing it backwards into the channel and pulling it down into a hole. This provides vibrational dampening of stowed molds, a secure hold for the molds, and optimum utilization of space.

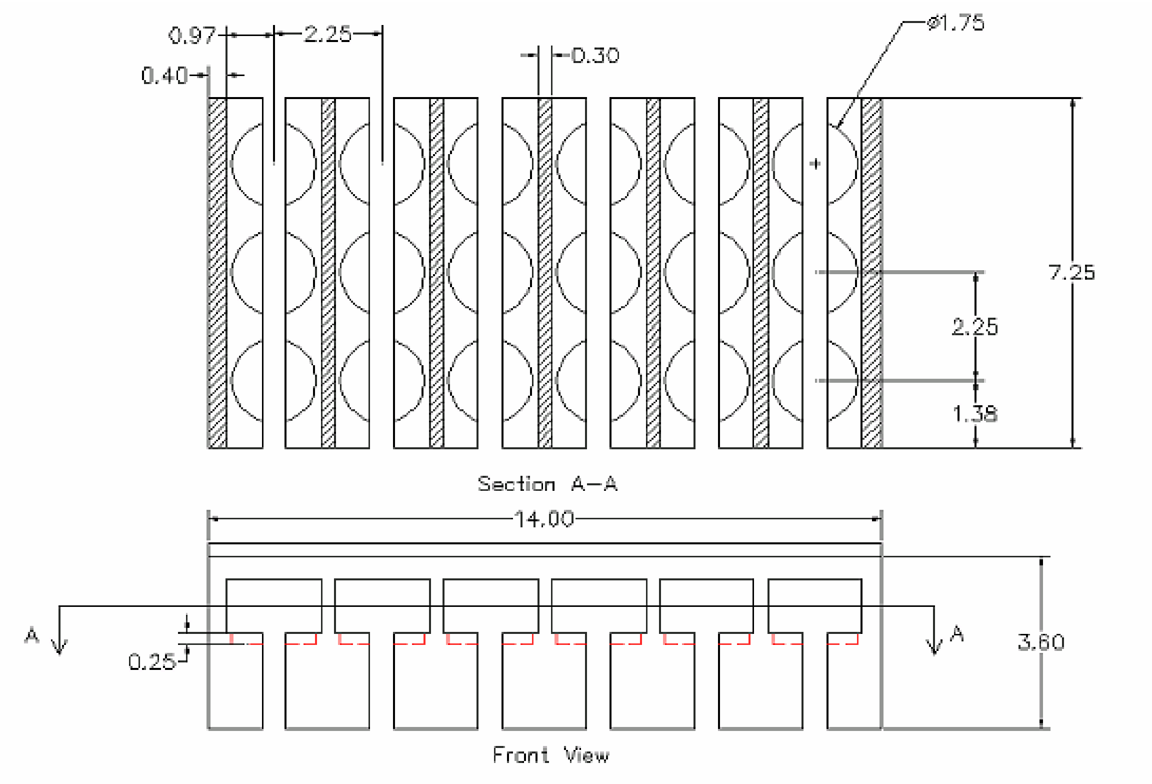


Figure 7.8 Mold Rack Design

7.3 Actuator and Actuator Control

The syringe is operated by a linear actuator that pushes and pulls the syringe's piston. The actuator is a Warner Electric Electrak 1 Elite linear actuator, providing up to 25 lbs. of force at 2.0 A. The electrical system only provides 800 mA of current, meaning the actuator is limited to approximately 10 lbs. of force. At the end of the actuator's piston is a through-hole into which two screws are screwed. Copper wire is then tied around these screws and around the head of the syringe's piston to connect the two components.

The actuator is mounted with a bolt running through its top and into the aluminum frame of the containment box, and is held in place on its body between the backs of two aluminum L-beams.

The actuator is controlled by an interface relay driven by the parallel port on the computer. The interface has two separate relay circuits connecting to the actuator—one providing positive current to the actuator's leads and one providing negative current. This allows for bi-directional control of the actuator piston. As a safety mechanism to prevent overheating, the computer cannot instruct the actuator to go both up and down at the same time.

The actuator is equipped with a feedback potentiometer that changes resistance with the stroke length of the actuator's piston. The resistance on the potentiometer is monitored by the computer and used to precisely control the movement of the actuator for aspirating and dispensing specific volumes of liquid.

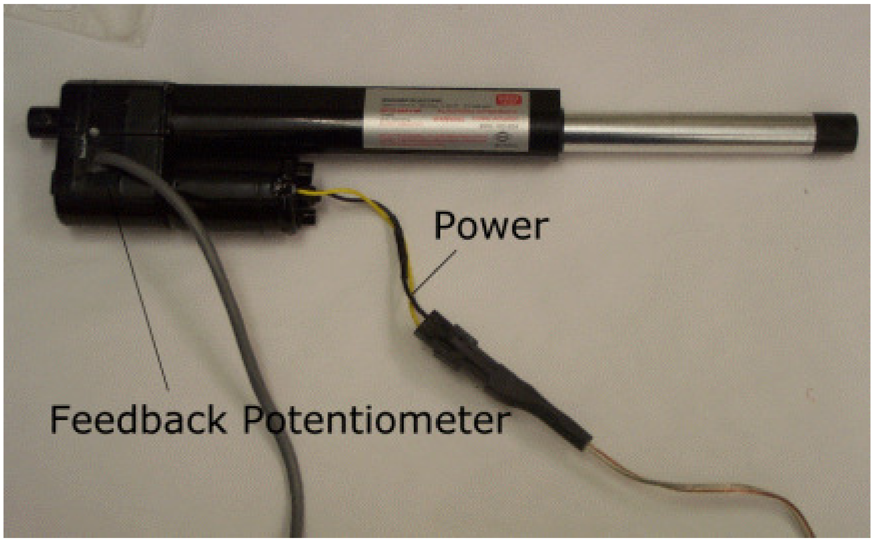


Figure 7.9 Linear Actuator

7.4 Computer Controls and Data Acquisition System

The computer is equipped with two devices for interfacing with the equipment.

The first device is the parallel port relay, which contains the CMOS-driven electromechanical relays for the actuator as well as control circuitry for two four-digit seven-segment LED displays in the box. The actuator relays are tripped when logic is high on pins 8 (instructing the actuator to move up) and 9 (instructing the acutator to move down) of the parallel port. This is controlled by a program on the computer. A data signal is sent out pins 4 through 7 containing a string of numbers to be display on the LED displays in the box. One LED display shows the current volume of liquid in the syringe (derived from the resistance on the actuator's feedback potentiometer) and the other displays the current acceleration (measured by an accelerometer). Pins 2 and 3 are reserved for diagnostics and power lights.

The second device is the LabJack USB (Universal Serial Bus) data acquisition system. The LabJack converts analog signals (such as voltage running through the actuator's feedback potentiometer) into 12-bit digital signals that can be processed by the computer. Connected to the LabJack are an accelerometer and the feedback potentiometer on the actuator. Information from the LabJack is fed to the control program for controlling the actuator.

Figure 7.10 Parallel port interface box

7.5 Containment Box

The containment box is designed to house all equipment and reagents required to perform the experiment while providing a versatile working environment and effective containment of any liquid or vapor leaks that may occur.

The containment box is composed of an aluminum frame assembled from 1 1/2-inch aluminum L-beams. Shelving and support structures in the box are made with L-beams bolted into the frame of the box. On both the inside and outside of the L-beams are bolted 1/4-inch thick polycarbonate sheets. This provides two layers of containment with approximately 1/8" between. In the front of the box are two butyl rubber gloves that extend into the box. These gloves are ring-clamped and sealed to flanged steel rings on the outside of the box. On the inside of the box is sealed a pair of arm-length latex gloves that fit tightly around the butyl rubber gloves. This provides two levels of containment when working with the gloves.

The inside of the box can be accessed through a two-stage door in the front of the box. The outer section of this door is hinged and latches shut. The latches are locked by caribbeaner clips. This outer door has a rubber gasket similar to those used in refrigerator units and provides an airtight seal for the box. The inner section of the door is a polycarbonate panel that clips into place by a set of four metal strips around the perimeter of the door. This inner panel also has a rubber gasket and also provides an airtight seal. The outer door and inner panel together provide two layers of containment while allowing access to the inside of the box if necessary. The box is not to be opened during flight.

On the side of the containment box are embedded BNC electrical connectors. These connectors are used to connect the electronics inside the containment box with the computer interfaces outside. The connectors are sealed with silicon caulk to ensure no liquid can leak through them. In the back of the box is an off-board vent spigot for drawing vapor or liquid out of the box.

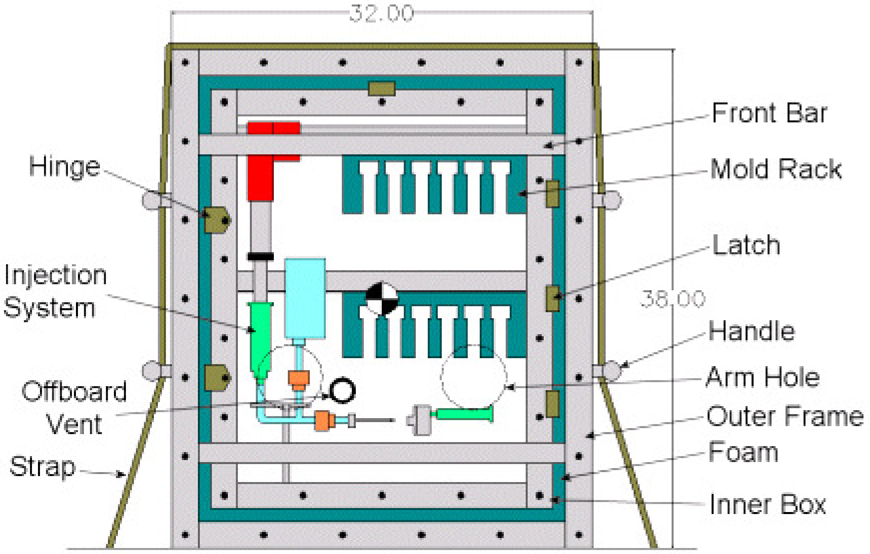


Figure 7.11 Containment box

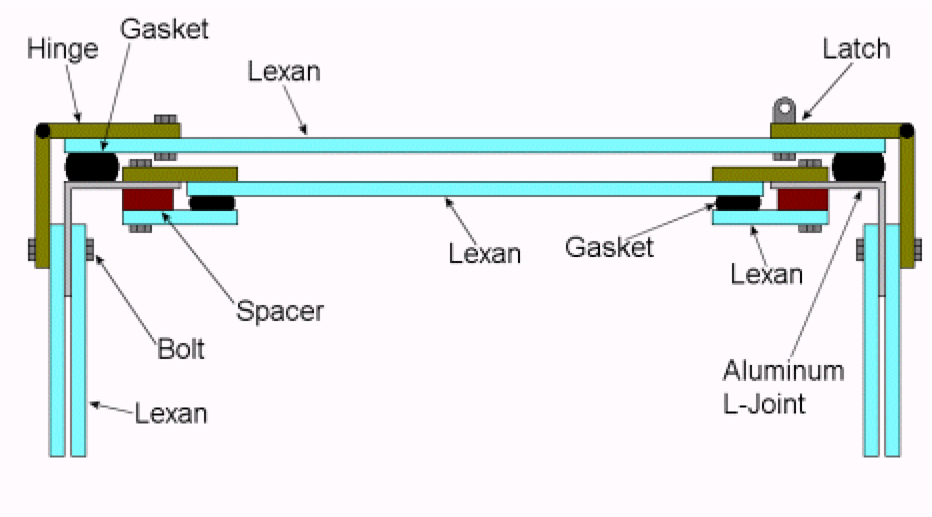


Figure 7.12 Door Schematic

7.6 Vibrational Isolation Frame

The entire containment box fits inside a foam-padded, open aluminum frame. This provides vibrational damping for the entire system.

The frame is constructed of bolted aluminum L-beams and aluminum flats. The sides of the frame hinge upward, clamping inward on the containment box. A lid is then fitted over the top of the sides and latched (see Figure 7.13).

There is no ledge on the front side of the frame in order to allow the doors to be opened while the box is mounted in the frame. To prevent the box from being able to slide out the front of the frame (despite the tight clamp from the frame and the tight fit from the foam), steel bars can be mounted across the front of the frame. On the

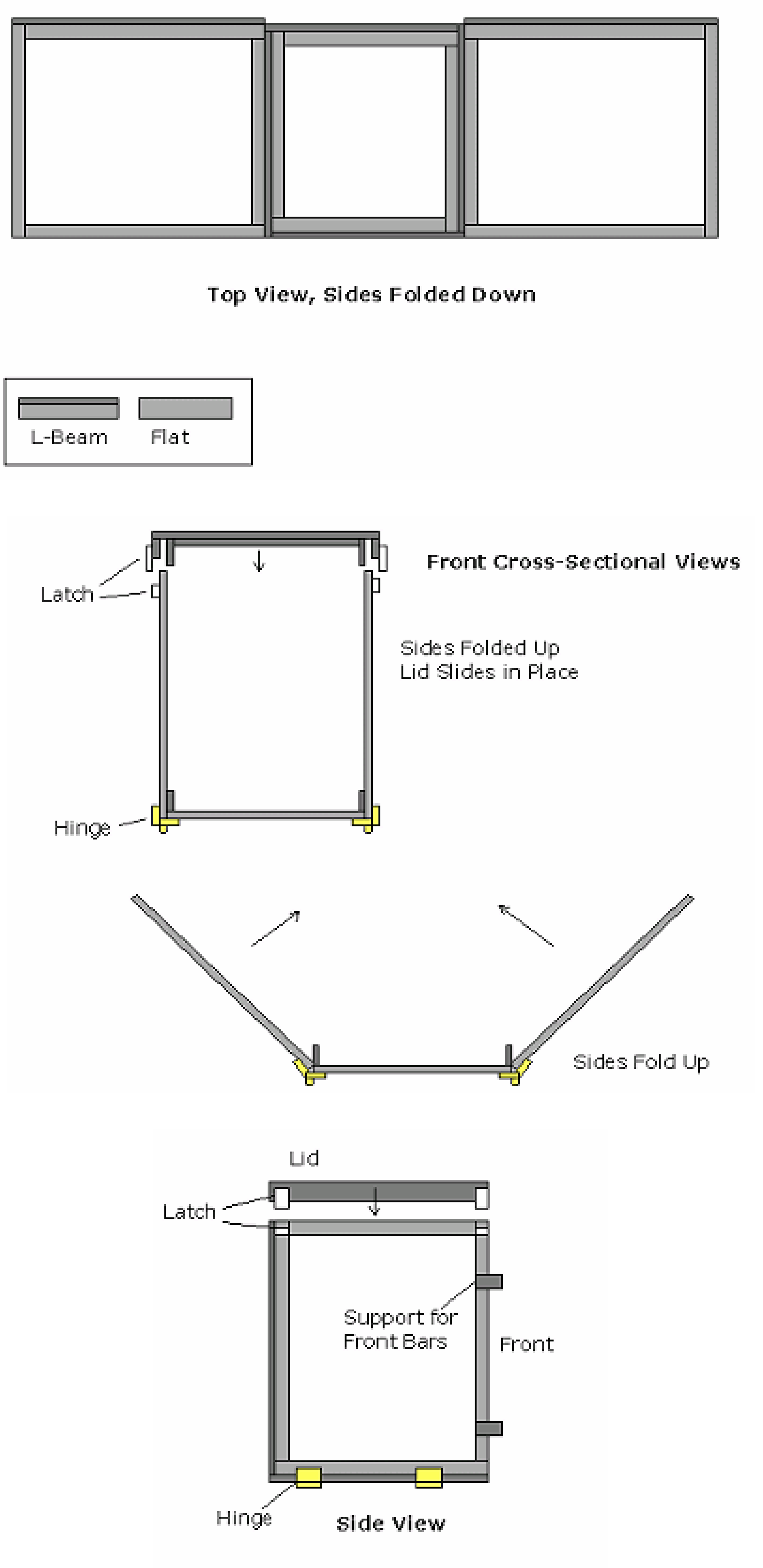


Figure 7.13 Description of vibrational damping frame (foam not shown)

sides of the front of the frame are supports for holding a foam-padded steel bar. The steel bar is drilled through on the ends for clipping caribbeaner clips through.

7.7 Equipment Layout

The equipment operator and computer operator both require straps. The equipment should be laid out as shown in Figure 7.14.

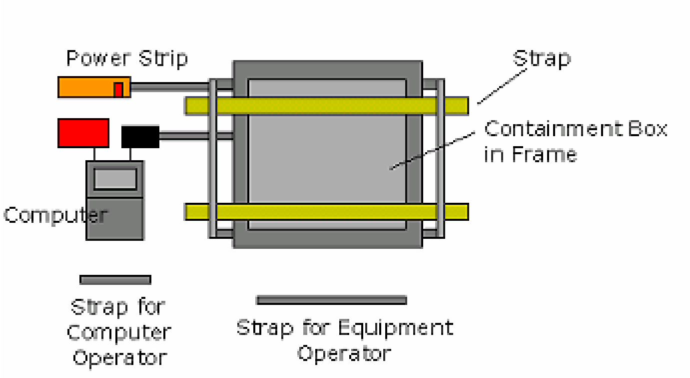


Figure 7.14 Equipment Layout

7.8 Outreach Experiments

We would like to bring aboard a sealed plastic bottle containing a small amount of water and a small amount of vegetable oil to demonstrate how liquids behave in microgravity for our outreach video.

7.9 Equipment Weights

Table 7.1 Equipment Weights

Component	**Weight**
Containment Box in Frame	100 lbs.
Computer	6 lbs.
Parallel Port Box	0.5 lbs.
LabJack	0.5 lbs.
Total Equipment Weight	**107 lbs.**

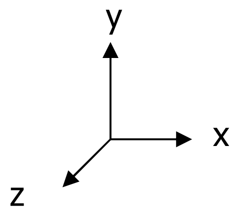
8. Structural Analysis

8.1 Overview

The experiment equipment has been designed and built to withstand all G-load specifications required by NASA's Reduced Gravity Student Flight Opportunities Program. Calculations are first performed to show that the apparatus is securely fastened to the floor of the KC-135A. This portion also includes a floor load analysis describing how the equipment will not exceed the allowable load in flight. Next, a structural analysis of the inner box indicates that the internal components will be isolated from the fuselage of the aircraft. Lastly, calculations are shown proving that the inner box will be fully contained within the outer aluminum frame. For purposes of G-load calculations, it will be assumed that the right-hand side of the equipment will face towards the front of the aircraft. Free-body diagrams (FBD's) and induced G-loads are included for all calculations. Critical factors of safety (FS) show that the equipment is safe for all persons and aircraft components aboard the KC-135A.

8.2 Centers of Gravity

Center of gravity calculations use a 3-D right-handed coordinate system with the "origin" located at the bottom-left-rear corner of the outer aluminum frame. Individual component weights and positions relative to the origin are used to calculate the center of gravity (CG) for the inner box and the entire system. All dimensions are shown in inches.



The total weight (at 1 G) of the inner box with internal components is 100 lbs. The total weight of the internal components is less than 10 lbs. The outside edges of the inner box have dimensions 26 x 32 x 32 (width, height, depth). After considering left-right and front-back symmetry as well as the 2-inch foam layer between the inner box and the outer frame, it can be seen that the CG_x and CG_z of the inner box with all internal components are located at 15 (26/2 + 2) and 18 (32/2 + 2) inches, respectively. CG_y is a slightly more complicated calculation. The inner box has more weight towards the top due to the linear actuator and increased amount of aluminum angles. The actuator weighs 2 lbs. and the aluminum weighs 3 lbs. in 1 G with an average height of about 25. The rest of the internal components (5 lbs.) have relative top-bottom symmetry. The vertical center of gravity is calculated as follows:

$CG_y = (5*25 + 5*18 + 90*18) / 100 = 18.35$

Hence, the CG of the inner box with all internal components is (15, 18.35, 18).

The center of gravity of the entire apparatus is required for calculations to show that the equipment will be securely fastened to the aircraft under all G-load specifications. The weight of the outer frame including foam is 40 lbs. with dimensions 30 x 36 x 36 (w, h, d). After considering total symmetry of the outer frame, the CG is (15, 18, 18).

Below are the calculations of the CG for the entire system (*i.e.,* outer frame + inner box + internal components):

CG_x = [15*100 + 15*40] / 140 = **15 inches**
CG_y = [18.35*100 + 18*40] / 140 = **18.25 inches**
CG_z = [18*100 + 18*40] / 140 = **18 inches**

Here it can be seen that the center of gravity for the entire system is located at (15, 18.25, 18).

The weight of the equipment will be assumed to be concentrated at the center of gravity for all moment and factor of safety calculations.

8.2.1 9 G's Forward

Under an induced gravity of 9 G's forward, the entire system will experience a weight of 1,260 lbs. (140*9). The reaction force to this weight in the horizontal direction will be provided by two 2-inch wide cargo straps attached to the handles of the outer frame (bolted to the aircraft with 3/8-inch steel bolts). Summing the forces in the x-direction it can be seen that the straps will each need to provide a reaction force of 630 lbs. in the negative x-direction. Each strap is capable of supplying 5,000*cos (72°) = 1,545 lbs. This results in a factor of safety of 2.45 for the entire apparatus in 9 G's forward in the horizontal direction. Taking the moments about the point (0, 0, 18) it can be seen that the reaction moment for each strap will need to be 1,260*18 / 2 = 11,340 in-lbs. The straps are each capable of providing a moment of 5,000*sin (72°) * 5 = 23,780 in-lbs. This results in a factor of safety of 2.1. Thus, the equipment will remain static under 9 G's forward.

8.2.2 3 G's Aft

Under an induced gravity of 3 G's aft, the entire system will experience a weight of 420 lbs. (140*3). The reaction force to this weight will be provided by two 2-inch wide cargo straps attached to the handles of the outer frame (bolted to the aircraft by 3/8-inch steel bolts). Summing the forces in the x-direction it can be seen that the straps will each need to provide a reaction force of 210 lbs. in the positive x-direction. Each strap is capable of supplying 5,000*cos (72°) = 1545 lbs. This results in a factor of safety of 7.36 in the horizontal direction for the entire apparatus in 3-G's aft. Taking moments about the position (36, 0, 18) it can be seen that each strap will need to provide a reaction moment of 420*18 / 2 = 3,780 in-lbs. Each strap is capable of supplying a 5,000*sin (72°)*5 = 23,780 in-lbs. This results in a factor of safety of 6.29.

8.2.3 6 G's Down

While experiencing an induced gravity of 6 G's down, the equipment will experience an induced weight of 840 lbs. The area of the bottom of the equipment is 7.5 ft^2. This maximum in-flight stress on the fuselage would be 112 lbs./ft^2. This is well below the maximum allowable in-flight floor loading specification of 200 lbs./ft^2. This is a factor of safety of 1.79.

Therefore, our experiment does not need to be provided floor shoring to satisfy the g-load specifications in the 6 G's down situation.

8.2.4 2 G's Lateral

The equipment will experience an induced weight of 280 lbs. in the lateral direction. To avoid translational motion in the z direction, the outer frame will need to be ratcheted down with enough force so that the frictional force generated against the aircraft foam is significantly greater than the 280 lbs. of induced force. If the case were to rotate, the cargo straps would need to counter the moment induced about the position (18, 0, 0). The moment that needs to be countered would be 280*18 = 5,040 in-lbs. The tether strap going over the top of the outer frame would need to provide a force of 5,040 / 36 = 140 lbs. Since the strap is capable of providing a force of up to 5,000 lbs., the factor of safety for 2 G's in the lateral direction is 35.7.

8.2.5 2 G's Up

Under an induced gravity of 2 G's up, the weight of the equipment will be 280 lbs. This weight will be countered by reaction forces provided by the straps over the top of the outer frame. Each strap is capable of providing up to 5,000*sin (72^o) = 4,755 lbs. of force when in tension. This results in a factor of safety of 4,755*2 / 280 = 34.

8.3 Summary of Apparatus Attachment to Fuselage of KC-135A

Factor of safety calculations for the entire system shows that the equipment will remain in static equilibrium for all G-load specifications. The use of two cargo straps will provide sufficient reaction forces to secure the apparatus to the fuselage of the KC-135A.

Table 8.1: Summary of FS calculations for fastening the equipment under all G-load specifications. Forces and moments shown are the reactions that need to be provided by one cargo strap.

Case	Force (lbs.)	Force FS	Moment (in-lbs.)	Moment FS
9 G's forward	630	**2.45**	11,340	**2.10**
3 G's aft	210	**7.36**	3,780	**6.29**
6 G's down	420	**1.79**	N/A	**N/A**
2 G's lateral	Need more info (see text)		5,040	**35.7**
2 G's up	140	**34**	N/A	**N/A**

8.4 Structural Integrity of Internal Components inside the Inner Box

The inner glove box is designed to sufficiently withstand any loads imposed by the internal components on its frame. Three of the four sides are bolted to the aluminum framework by a series of 18 1/4-inch steel bolts. The cross-sectional area of each bolt is 0.0312 in^2 and the effective bearing area being stressed in any of the horizontal directions (forward, aft, lateral) is 0.562 in^2. The shear strength of polycarbonate is 7,000 psi. Therefore, these sides will be able to withstand 3,930 lbs. from internal loading.

The outer polycarbonate door on the inner box is fastened to the aluminum framing by 2 steel hinges and 4 steel locks. It will be assumed that the critical bearing stress for the outer door of the inner box will be held by the steel locks which are attached by significantly smaller bolts than the hinges (which use 8 1/4-inch steel bolts). Each lock has two 1/8-inch diameter steel bolts. Therefore, there is effectively 8 bolts (1/8-inch diameter each, effective total bearing area = 0.125 in^2) holding the outer front panel on. The total weight (at 1 G) of all internal hardware components is 10 lbs.

The inner door panel of the inner box is held by four aluminum latches that utilize mechanisms similar to lavatory stall doors. The total effective bearing area of these latches is 0.25 in^2. Yield strength for the aluminum is 19,000 psi.

It should be noted that there are two layers of polycarbonate along the sides of the glove box. Ultimate structural failure would require both layers to break. This is extremely unlikely to happen, even under 9 G's.

The top and bottom of the inner box each consist of two 1/4-inch sheets of polycarbonate fastened to the aluminum framing with 12 1/4-inch steel bolts. The effective bearing area is 0.375 in^2.

A table is included that describes the factors of safety for loading induced from internal components to the walls of the inner box.

Table 8.2: Containment summary of internal components inside the inner box.

Case	Induced Force (lbs.)	Structural Strength of Box (lbs.)	Factor of Safety
9 G's forward	90	3,930	**43.6**
3 G's aft	30	3,930	**131**
6 G's down	60	2,625	**43.8**
2 G's lateral left	20	3,930	**196**
2 G's lateral right outer door	20	8,75	**43.8**
2 G's lateral right inner door	20	4,750	**237**
2 G's up	20	2,625	**131**

Factor of safety calculations indicate that the inner glove box is capable of containing all possible internally induced loads. All internal components will be isolated from the fuselage of the KC-135A.

8.5 Structural Integrity of Inner Box Inside the Outer Aluminum Frame

Factor of safety calculations show that the inner box will be fully contained within the outer aluminum frame under all necessary G-load conditions. The aluminum angles for the outer frame have 2.5 x 2.5-inch legs and will provide sufficient support to contain the inner box.

Shear Stress = F/A

Table 8.3: Summary of FS calculations for shear stress of the outer frame under loading imposed from the inner box.

Case	Induced Stress (psi)	Structural Strength of Outer Frame (psi)	Shear Factor of Safety
9 G's forward	200	19000	95
3 G's aft	66.7	19000	285
6 G's down	185	19000	103
2 G's lateral	44.5	19000	427
2 G's up	44.5	19000	427

Bending Stress = M*Y/I

M = maximum bending moment = Induced load * 1/2 max. length = F * 18
Y = 1/2 width of bending area = 0.5 inches
I = moment of inertia = 1/12 bh^3 = 0.25 in^4

Table 8.4: FS associated with bending of outer aluminum frames from load induced from inner box.

Case	Induced Stress (psi)	Structural Strength of Outer Frame (psi)	Bending Factor of Safety
9 G's forward	8,100	19,000	**2.35**
3 G's aft	2,700	19,000	**7.04**
6 G's down	5,400	19,000	**3.52**
2 G's lateral	1,800	19,000	**10.6**
2 G's up	1,800	19,000	**10.6**

9. Electrical Analysis

9.1 Schematic

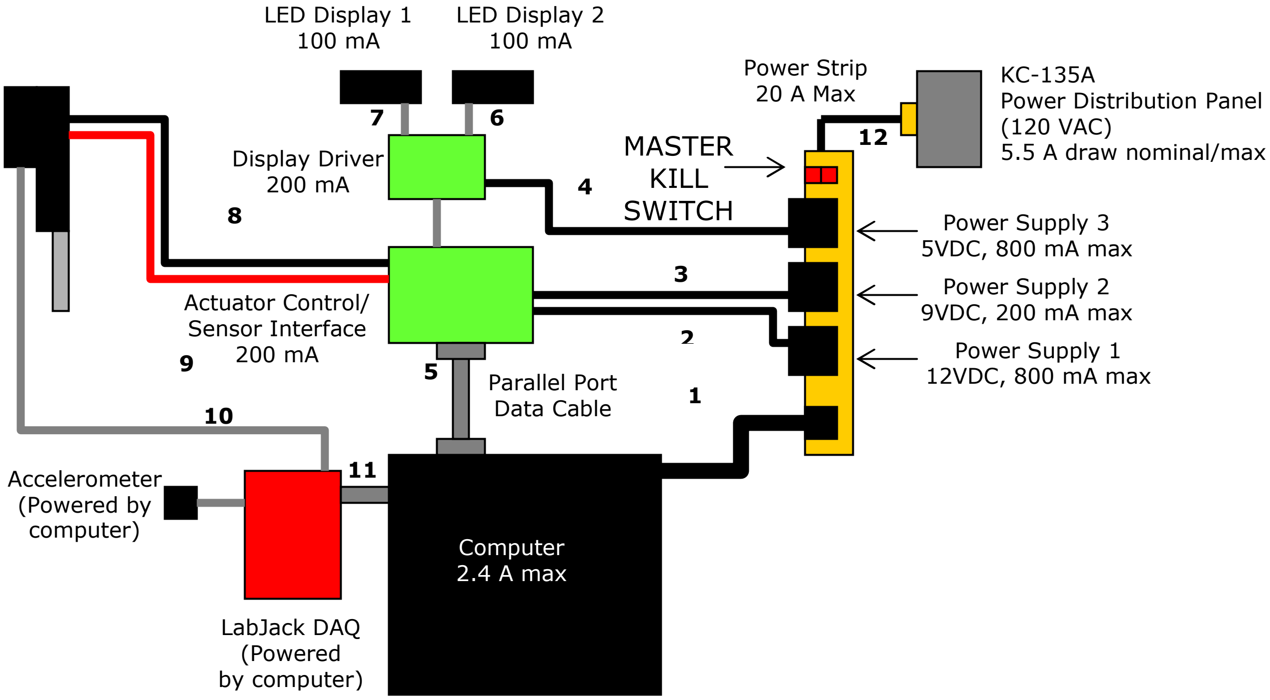


Figure 9.1 Electrical schematic

9.1.1 Equipment Description

The electrical system consists of the following:

- UL-Listed Power Strip
- IBM Pentium 166 MHz Laptop Computer
- LabJack Digital/Analog Data Acquisition USB Device
- Analog Accelerometer
- Warner Electric ELEKTRAK 1 ELITE Linear Actuator with Deluxe Feedback Potentiometer **(9)**
- Parallel Port Interface to Control Actuator
- Display Driver Circuit Powered by Parallel Port Interface
- 7-segment LED Displays Powered by Parallel Port Interface

9.2 Load Tables

Power Source Details	**Load Analysis**
Name : Power Strip **(12)**	Power Supply 1 **(2)** - 0.8 Amps
Voltage : 115VAC, 60Hz	Power Supply 2 **(3)** - 0.2 Amps
Wire Gauge : 12	Power Supply 3 **(4)** - 0.8 Amps
	Computer **(1)** - 2.4 Amps (max)
Max Output Current: **20 Amps**	Total Current Draw : **4.2 Amps**

Power Source Details	**Load Analysis**
Name : Power Supply 1 **(2)**	Actuator **(8)** (wire gauge 16) - 0.1 – 0.7 Amps (under anticipated load)
Voltage : 12VDC	
Wire Gauge : 18	
Max Output Current: **0.8 Amps**	Total Current Draw : **0.7 Amps** (max)

Power Source Details	**Load Analysis**
Name : Power Supply 2 **(3)**	Actuator Control - 0.1 – 0.2 Amps
Voltage : 9VDC	
Wire Gauge : 12	
Max Outlet Current: **0.2 Amps**	Total Current Draw : **0.2 Amps** (max)

Power Source Details	**Load Analysis**
Name : Power Supply 3 **(4)**	LED Display 1 **(7)** - 0.1 Amps
Voltage : 5VDC	LED Display 2 **(6)** - 0.1 Amps
Wire Gauge : 18	Display Driver – 0.2 Amps
Max Output Current: **0.8 Amps**	Total Current Draw : **0.4 Amps**

9.3 Electrical Kill Switch

The electrical equipment can be disengaged by switching the MASTER KILL SWITCH on the power strip. The resulting power loss will disable the actuator, but the computer and data acquisition systems will continue to run off of the computer's back-up battery. The experiment can still be conducted by disconnecting the plastic syringe from the actuator and manually operating it.

9.3.1 Emergency Shutdown Procedure

In the event of an emergency, the MASTER KILL SWITCH will be flipped and the equipment will stop operating. The computer will go to back-up power and can be turned off by sliding its power switch.

10. Pressure Vessel Certification

10.1 Overview

The system uses an actuator-driven syringe that utilizes slight pressure differentials to aspirate up to 10.0 mL of liquid from an intravenous delivery bag and dispense it into a volume expandable mold. Both the delivery bag and molds are volume expandable and collapsible, so no pressure can build up in any component during nominal operation. The system cannot aspirate more than 10.0 mL at a time, and each mold can expand up to 10.0 mL in volume by its volume expandable syringe.

The system is comprised of a polyethylene syringe, 1/8-inch diameter fluorinated ethylene/propylene copolymer (FEP) tubing, 1/8-inch diameter polypropylene barbed connections, standard polypropylene barb-to-Luer lock connections, one-way liquid check valves, and the four-directional diffusion needle (see Equipment Description). The system has been classified as Category A by JSC Personnel.

10.2 Schematic and Description

Consult the Equipment Description for a more detailed description of the injection apparatus.

The system is driven by an actuator that pushes and pulls the piston on a polyethylene syringe. The actuator cannot extend the syringe fully down, nor can it pull it fully out. When the piston on the syringe is pulled, liquid is drawn from an airtight intravenous delivery bag filled with catalyst solution. The actuator pulls the syringe up to a certain distance, pulling liquid from the bag, through a one-way check valve and into the syringe. When the actuator pushes down on the syringe, liquid is dispensed through the second check valve and out through the diffusion needle.

The catalyst bag is connected to the injection system by a standard metal quick-connect. The quick-connect does not permit liquid to flow unless it is interfaced with the opposite gender quick-connect. This is a safety mechanism to prevent the catalyst bag from dripping and to prevent the injection system from aspirating air.

10.3 MAWP Table

Component MAWP are provided by their manufacturers.

Component	**MAWP**
Syringe needles	2,000 psi
Polyethylene syringes	100 psi
FEP tubing	200 psi
One-way check valves	Negligible
Metal Quick-connects	250 psi

MAWP for entire system: 25 psi

This is calculated by dividing the 25 lbs. of force the actuator can exert by the surface area of the end of the syringe's piston (approximately 1 square inch). This could only be reached if all of the pressure release points were blocked and the actuator were pushing down. This case has been prevented by the design of several pressure release points within the system. Any high pressure in the system would be resolved by volume expansion of the syringe in the mold. In the rare case that built-up pressure is attained, pressure would be released through where the tubing is fit onto the barb joints. This would release liquid into the box, but the liquid would be contained by two layers of polycarbonate.

11. Laser Certification

No lasers are used in the experiment.

12. Parabola Details and Crew Assistance

The first two parabolas will be used for the researchers to acclimate to reduced gravity. The remaining 28 reduced gravity parabolas will be used to form gels with the experimental equipment. No crew assistance is requested.

13. Institutional Review Board

No institutional review board certification is required for this project.

14. Hazard Analysis

The equipment has been designed with great care keeping safety in mind. Using solutions to problems we have encountered in the past with previous equipment, we believe that we have thoroughly ensured safety while maximizing functionality with this design.

Hazard Number: 1

Hazard Title: Risk of fire in cabin of KC-135A

Hazard Description: Fire in the cabin poses a heath hazard to the flight test personal, could damage the KC-135A aircraft and flight systems.

Hazard Causes:

1) Ethanol and tetramethoxysilane are used and are highly flammable, if solutions containing them came into contact with an open flame or spark, they could ignite
2) Actuator sparks from an overload in power supply
3) Wiring insulation degradation
4) Computer sensor interface or power strip sparks
5) Computer sensor interface or power strip fails, causing overload in actuator, potentially damaging dispensing apparatus and releasing flammable solvent

Hazard Controls:

1) All chemicals used aboard the KC-135A are triply-contained
2) Injection apparatus is secured inside box so that no parts can come lose and potentially break

3) Actuator cannot be extended far enough to completely depress injection apparatus syringe so as to prevent over extension and possible breakage
4) Actuator is computer-controlled and computer-monitored to ensure proper operation
5) The actuator automatically locks if overheated or overloaded
6) Computer sensor interface is shielded by plastic box preventing any liquids or vapors from entering
7) Computer sensor interface is properly grounded and well-insulated to prevent sparks
8) Electronics are protected from power surge by a fuse in the power strip
9) All AC adapters reside outside of the containment box
10) Wiring is enamel-insulated and resistant to the solutions used in the containment box (including alcohols and alkoxides)
11) A Master Kill Switch is located on the experiment power strip to deactivate all power in the event of an emergency
12) Power strip is UL-listed and unlikely to spark or malfunction
13) Containment box is equipped with an off-board vent to draw out any liquid globules or vapor as they would be generated, preventing flash-point vapor pressure from building up and preventing liquid contact with electronics
14) Fire extinguisher located on the aircraft

Hazard Number: 2

Hazard Title: Structural failure of the apparatus

Hazard Description: The apparatus cracks or breaks, releasing debris into cabin, which could result in personal injury to the flight test personal and potentially damage to the aircraft

Hazard Causes:

1) The actuator becomes loose in the inner box, during induced gravity phase the actuator could crack polycarbonate walls
2) Storage restraint of apparatus fails
3) Stress concentrations at bolt-polycarbonate interface

Hazard Controls:

1) Actuator is firmly secured to the frame of the apparatus, and bolted into aluminum angles
2) Polycarbonate is very durable and highly impact-resistance, not susceptible to stress corrosion
3) Apparatus will be restrained by two straps, each having a maximum tensile strength of 5,000 lbs. See Structural Analysis for all factors of safety associated with the experiment

Hazard Number: 3

Hazard Title: Injury to Person

Hazard Description: Flight test personnel and experimenter are at risk of person injury, resulting in skin lacerations, cuts, bruises, or broken bones.

Hazard Causes:

1) Carabeaneer clips on outer door fail, the door swings open.
2) Carabeaneer clips are loose in cabin
3) Experimenter's gloves tear exposing hand to injection needle
4) Injury from contact with injection needle
5) Injury from sharp edges and corners of apparatus
6) Stowage restraint of apparatus fails; apparatus becomes loose in cabin

Hazard Controls:

1) The outer door is secured by multiple carabineer clips
2) The outer door will be tested pre-flight
3) All carabineer clips will be secured during flight
4) The experimenter's gloves are made of 1/16"-thick butyl rubber; resistant to punctures
5) The experimenter's gloves are double-layered
6) The injection needle is thick (16 gauge) and blunt with a closed tip
7) All edges and corners of the apparatus are foam-padded
8) The apparatus will be restrained by two straps, which each has a maximum tensile strength of 5,000 lbs. See Structural Analysis for factors of safety
9) Straps will be latched into the floor and tightened down by JSC personnel
10) All bolts will be tightened and checked prior to flight

Hazard Number: 4

Hazard Description: Damage occurs to test equipment inside inner box.

Hazard Causes:

1) Molds vibrate loose from containment system, damage occurs to test equipment in 2 G's
2) Actuator comes loose in inner box

Hazard Controls:

1) A foam-padded rack is used to stow molds from which molds must be snapped out, pushed up, and then slid out. This three-step removal ensures that no mold can come lose
2) The foam in the mold containment system is tight enough to secure the molds
3) Mold containment system will be tested pre-flight
4) Actuator is firmly secured by the frame of the apparatus and is bolted into an aluminum L-beam

Hazard Number: 5

Hazard Title: Damage to KC-135A aircraft

Hazard Description: Damage occurs to the KC-135A aircraft.

Hazard Cause: Stowage restraint of apparatus fails; apparatus becomes loose in cabin

Hazard Controls: Apparatus will be restrained by two straps which each has a maximum tensile strength of 5,000 lbs. See Structural Analysis

Hazard Number: 6

Hazard Title: Health hazards could result from a toxic chemical leak in cabin.

Hazard Description: Tetramethoxysilane (TMOS) is toxic. Catalyst solution contains ammonium hydroxide, which is corrosive. Unconfined liquids pose health hazards including, but not limited to, danger of contact with eyes and skin, inhalation, or ingestion.

Hazard Causes:

1) Polycarbonate containment layers crack
2) Leak occurs at BNC connectors
3) Inner door fails
4) Clips on inner door fail
5) Door gaskets fail to seal
6) Gloves tear
7) Off-board vent failure

Hazard Controls:

1) All chemicals are triply contained while on the KC-135
2) There is caulk around the BNC connectors
3) Inner door will be tested prior to flight and has multiple support clips
4) Clips will be tested prior to flight
5) The door gaskets will be pressure-tested prior to flight
6) The gloves are double-layered
7) Gloves are thick butyl rubber

8) Off-board vent will be tested by JSC personnel prior to flight and will remove vapor leaks
9) Only small amounts of chemicals are present in the box and are all contained by sealed plastic containers. Ammonium hydroxide solution is mostly ethanol and water and only contains a few drops of ammonium hydroxide solution per 10 mL.

Hazard Number: 7

Hazard Title: Health hazards could result from a toxic chemical leak in the box.

Hazard Description: Tetramethoxysilane (TMOS) is toxic and ammonium hydroxide is corrosive. Unconfined liquids pose health hazards including, but not limited to, danger of contact with eyes and skin, inhalation, or ingestion.

Hazard Causes:

1) Syringe piston comes out of mold
2) Excess catalyst solution is injected into mold
3) Catalyst solution is injected without a mold being present
4) Mold comes apart from loose bolts
5) Septum comes off mold or leaks, allowing base solution and/or catalyst solution to leak out
6) O-ring on mold does not seal
7) Luer locks, barb connections, or tubing segments fail
8) Catalyst bag is punctured
9) Catalyst bag becomes dislodged

10) FEP tubing fails
11) Actuator connection to injection syringe fails
12) Injection syringe cracks

Hazard Controls:

1) Only a small volume of base solution will be used (5 mL per mold)
2) All chemicals are triply contained
3) An off-board vent is installed to vent off any chemical leaks in the inner box
4) The volume expansion syringe on the mold is the same size as the aspiration syringe, it is impossible to inject more catalyst solution than the mold can hold
5) The automated injection system controls can be manually overridden
6) Bolts on molds will be tightened
7) All bolts will be checked for tightness prior to flight
8) Septa are epoxied in place
9) All Luer locks are screwed onto the threaded end of syringes and epoxied to connecting tubing
10) All Luer locks will be tested prior to flight
11) Catalyst bag is sealed with RTV and secured inside a small plastic box
12) Plastic box for catalyst bag will be screwed into the aluminum frame of the containment box

13) All plastics used in the system have been carefully chosen to be compatible with the reagents being used

14) One-way check valves are installed to prevent back-flow of liquid

15) Actuator and injection syringe are bolted/securely clamped in place

16) Injection syringe and molds are contained within double-layered polycarbonate containment box

Hazard Number: 8

Hazard Title: Gloves are torn.

Hazard Description: Exposes user to potentially dangerous chemicals, debris, chemicals, and diffusion needle

Hazard Causes:

1) Glove material is punctured by excessive load by user
2) Laceration of material from sharp object from inside the box
3) Puncture from diffuser needle

Hazard Controls:

1) Gloves are made of thick butyl rubber are extremely difficult to puncture or even tear
2) Gloves are chemically resistant
3) Butyl gloves are fit inside a second layer of arm-length latex gloves to provide two layers of containment. The second layer of gloves is sealed to the inside of the containment box.

4) No sharp objects are present in the box
5) Diffusion needle is wide, blunt, and closed-tip and is unable to puncture gloves or skin

Hazard Number: 9

Hazard Title: Electrical or computer failure causes uncontrolled operation of actuator and induces excessive mechanical stress

Hazard Description: Damage to equipment or person

Hazard Causes:

1) Loose electrical connection
2) Static discharge shorts out circuitry
3) Accidental activation of function.

Hazard Controls:

1) Equipment is deactivated when connection to computer is lost
2) Master Kill Switch is located on power switch outside of the box to cut power to all systems, including computer and electronics

15. Tool Requirements

All tools for ground maintenance will be contained in a composite tool kit with Styrofoam cutouts for ease of inventory evaluation. All tools will have UW initials written in permanent marker for identification. This will provide a quick means of discovering missing tools and minimize the risk of tools causing foreign object damage (FOD) to aircraft. Extra bolts, nuts, and washers will be contained in sealable plastic bags. In addition, all paper and plastic sheet products will be closely tracked to prevent any FOD to aircraft.

1. Standard flathead and Phillips screwdriver
2. (1) roll duct tape
3. (1) roll of resin core solder
4. Soldering iron
5. Needle nose pliers
6. (2) packs of epoxy
7. (2) tubes of fire-resistant gasket material
8. (1) English wrench set
9. Electric screwdriver/drill kit
10. (1) Hacksaw
11. Spare bolts, washers, nuts, hinges, and locks

16. Photo Requirements

16.1 Photographer

A photographer is requested to photograph the researchers operating the experiment and the equipment.

16.2 Videographer

A videographer is requested to videotape the experiment.

16.3 Down-Link

No down-link is required.

16.4 Camera Poles

No camera poles are requested.

17. Aircraft Loading

We will be requiring a forklift to carry the experiment box onto the KC-135A. When the forklift reaches the level of the entrance to the aircraft, two people will be needed to carry the box aboard the aircraft. There will be 2 handles on either side of the box so that the 2 people can lift the equipment.

Assembly Weight: 100 lbs.
Footprint: 36” x 36”
Load: 100 lbs/1,296 in^2 = 0.077 psi

18. Ground Support Requirements

Power Requirements:

Standard 120 VAC 60 Hz power is required for testing equipment.

Hazardous Substance Requirements:

Storage for absolute ethanol, tetramethoxysilane, and 0.4 M ammonium hydroxide/water/ethanol solution is needed. We will provide labeled plastic bottles for storing solutions.

Access to Building 993 During Non-business Hours:

Access to Building 993 is not requested during non-business hours.

Pressurized Gas Requirements:

The experiment has no pressurized gas requirements.

General Tool Requests:

No general tool requests.

19. Hazardous Materials

The experiment requires the use of several chemical reagents.

19.1 Chemical Requirements

Catalyst Solution (used in-flight and stored in hazardous materials cabinet)

Description: 0.4 M ammonium hydroxide in 40% water 60% ethanol solution
Hazard: Slightly basic alcohol solution could be toxic if ingested
Containment: Liquid is contained within sealed, air-free, commercially-obtained polypropylene intravenous delivery bags. Liquid is contained within injection apparatus during nominal operation and is further contained by the containment box's two separate sealed polycarbonate layers.
Controls: Solution is only slightly basic and poses little health risk. Smell is only recognizable as ethanol. Containment box is equipped with an off-board vent to purge the equipment of any liquid or vapor leak as it would form. Containment box has two latched gasket-sealed refrigerator-style doors that are locked during flight to prevent liquid or vapor from escaping into the cabin if it should evolve. All materials used in the equipment are compatible with solution.

Base Solution (used in-flight and stored in hazardous materials cabinet)

Description: Tetramethoxysilane in ethanol.
Hazard: Toxic: Targets lungs, blood, kidneys. Lachrymator. Readily hydrolyzed.
Containment: Solution is loaded into sealed polypropylene volume expandable molds (see Equipment Description) prior to flight. Molds are housed in the mold rack inside the containment box. Molds are contained within double-walled polycarbonate containment box.
Controls: Molds are sealed by a Viton o-ring and are bolted shut. Molds are thoroughly inspected prior to flight. Containment box is equipped with an off-board vent to purge the equipment of any liquid or vapor leak as it would form. Containment box has two latched gasket-sealed refrigerator-style doors that are locked during flight to prevent liquid or vapor from escaping into the cabin if it should evolve. All materials used in the injection system, containment box, and molds are compatible with solution.

Tetramethoxysilane (stored for use only on the ground)
Description: Tetramethoxysilane $(CH_3O)_4Si$.
Hazard: Toxic: Targets lungs, blood, kidneys. Lachrymator. Readily hydrolyzed.
Containment: Reagent is stored in sealed glass bottle in the hazardous materials cabinet in the hangar.

20. Material Safety Data Sheets

Material Safety Data Sheet for Tetramethoxysilane

Valid 05/2001 - 07/2001

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

MATERIAL SAFETY DATA SHEET

SECTION 1. - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - - -
CATALOG #: 87682
NAME: TETRAMETHOXYSILANE
SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -
CAS #: 681-84-5
MF: C4H12O4SI
EC NO: 211-656-4
SYNONYMS
METHYL SILICATE (ACGIH) * SILICIC ACID, METHYL ESTER OF ORTHO- *
TETRAMETHOXYSILANE * TETRAMETHYL SILICATE * TETRAMETHYLSILIKAT (CZECH)
* TL 190 *
SECTION 3. - - - - - - - - - - HAZARDS IDENTIFICATION - - - - - - - - -
LABEL PRECAUTIONARY STATEMENTS
FLAMMABLE
HIGHLY TOXIC (USA)
TOXIC (EU)
TOXIC BY INHALATION.
CAUSES BURNS.
TARGET ORGAN(S):
EYES
KIDNEYS
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE
IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF
WATER AND SEEK MEDICAL ADVICE.
WEAR SUITABLE PROTECTIVE CLOTHING, GLOVES AND EYE/FACE
PROTECTION.
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 SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.
CALL A PHYSICIAN IMMEDIATELY.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL
RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
ASSURE ADEQUATE FLUSHING OF THE EYES BY SEPARATING THE EYELIDS
WITH FINGERS.
SECTION 5. - - - - - - - - - FIRE FIGHTING MEASURES - - - - - - - - - -
EXTINGUISHING MEDIA
CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.
WATER MAY BE EFFECTIVE FOR COOLING, BUT MAY NOT EFFECT EXTINGUISHMENT.
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.
UNUSUAL FIRE AND EXPLOSIONS HAZARDS
FLAMMABLE LIQUID.
VAPOR MAY TRAVEL CONSIDERABLE DISTANCE TO SOURCE OF IGNITION AND

FLASH BACK.
CONTAINER EXPLOSION MAY OCCUR UNDER FIRE CONDITIONS.
FORMS EXPLOSIVE MIXTURES IN AIR.

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

EVACUATE AREA.
SHUT OFF ALL SOURCES OF IGNITION.
WEAR SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES.
COVER WITH AN ACTIVATED CARBON ADSORBENT, TAKE UP AND PLACE IN CLOSED CONTAINERS. TRANSPORT OUTDOORS.
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.
FACESHIELD (8-INCH MINIMUM).
USE ONLY IN A CHEMICAL FUME HOOD.
SAFETY SHOWER AND EYE BATH.
USE NONSPARKING TOOLS.
DO NOT BREATHE VAPOR.
DO NOT GET IN EYES, ON SKIN, ON CLOTHING.
WASH THOROUGHLY AFTER HANDLING.
DISCARD CONTAMINATED CLOTHING AND SHOES.
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: 120 - 122 C
MELTING POINT: -4 C
FLASHPOINT 78.8 F
26 C
VAPOR PRESSURE: 274.527 MMHG
SPECIFIC GRAVITY: 1.032
VAPOR DENSITY: 5.25 G/L

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

STABILITY

STABLE.

CONDITIONS TO AVOID

MAY DECOMPOSE ON EXPOSURE TO MOIST AIR OR WATER.

INCOMPATIBILITIES

OXIDIZING AGENTS
ACIDS
BASES

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS

CARBON MONOXIDE, CARBON DIOXIDE
SILICON OXIDE
METHANOL

HAZARDOUS POLYMERIZATION

WILL NOT OCCUR.

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

ACUTE EFFECTS

WARNING: AVOID EYE CONTACT BECAUSE TETRAMETHYL ORTHOSILICATE UNDERGOES HYDROLYSIS READILY, PRODUCING METHANOL WHICH CAUSES IRREVERSIBLE BLINDNESS.
CONTACT WITH MOISTURE LIBERATES METHANOL. INGESTION OF METHANOL MAY CAUSE BLINDNESS, NAUSEA, HEADACHE, VOMITING, GASTROINTESTINAL UPSET, DIZZINESS, IRREGULAR BREATHING, WEAKNESS, CONFUSION, DROWSINESS, UNCONSCIOUSNESS, AND DEATH.
MATERIAL IS EXTREMELY DESTRUCTIVE TO TISSUE OF THE MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT, EYES AND SKIN.
INHALATION MAY RESULT IN SPASM, INFLAMMATION AND EDEMA OF THE LARYNX AND BRONCHI, CHEMICAL PNEUMONITIS AND PULMONARY EDEMA.
SYMPTOMS OF EXPOSURE MAY INCLUDE BURNING SENSATION, COUGHING, WHEEZING, LARYNGITIS, SHORTNESS OF BREATH, HEADACHE, NAUSEA AND VOMITING.
TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND

TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.
MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.
CAN CAUSE BLINDNESS.
TOXIC IF INHALED.
MAY BE HARMFUL IF SWALLOWED.

CHRONIC EFFECTS
TARGET ORGAN(S):
EYES
KIDNEYS
LUNGS

RTECS #: VV9800000
SILICIC ACID, TETRAMETHYL ESTER

TOXICITY DATA

IPR-RAT LD50:100 MG/KG	85JCAE -,1222,1986
IPR-MUS LD50:250 MG/KG	CBCCT* 2,56,1950
SKN-RBT LD50:17 ML/KG	AMIHBC 4,119,1951
ORL-MAM LD50:1 GM/KG	GISAAA 39(4),86,1974

TARGET ORGAN DATA
SENSE ORGANS AND SPECIAL SENSES (OTHER EYE EFFECTS)
LUNGS, THORAX OR RESPIRATION (ACUTE PULMONARY EDEMA)
KIDNEY, URETER, BLADDER (CHANGES IN TUBULES)
MUSCULO-SKELETAL (OTHER CHANGES)

ADDITIONAL INFORMATION
IHL-RAT LC50:0.4 MG/L/4H

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 FLUKA CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

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

EUROPEAN INFORMATION
FLAMMABLE
TOXIC
R 1
FLAMMABLE
R 23
TOXIC BY INHALATION.
R 34
CAUSES BURNS.
S 16
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.
S 45
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).
S 26
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE.
S 36/37/39
WEAR SUITABLE PROTECTIVE CLOTHING, GLOVES AND EYE/FACE PROTECTION.

REVIEWS, STANDARDS, AND REGULATIONS
OEL=MAK
ACGIH TLV-TWA 1 PPM DTLVS* TLV/BEI,1999
MSHA STANDARD:AIR-CL 5 PPM (30 MG/M3)
DTLVS* 3,169,1971
OSHA PEL (CONSTRUC):8H TWA 5 PPM (30 MG/M3)
CFRGBR 29,1926.55,1994
OSHA PEL (SHIPYARD):8H TWA 5 PPM (30 MG/M3)
CFRGBR 29,1915.1000,1993
OEL-AUSTRALIA: TWA 1 PPM (6 MG/M3), JAN1993
OEL-BELGIUM: TWA 1 PPM (6 MG/M3), JAN1993

OEL-DENMARK: TWA 1 PPM (6 MG/M3), JAN1999
OEL-FINLAND: TWA 5 PPM (30 MG/M3), STEL 10 PPM (60 MG/M3), JAN1999
OEL-FRANCE: VME 1 PPM (6 MG/M3), JAN1999
OEL-JAPAN: OEL 1 PPM (6 MG/M3), JAN1999
OEL-THE NETHERLANDS: MAC-TGG 1 PPM (6 MG/M3), JAN1999
OEL-NORWAY: TWA 1 PPM (6 MG/M3), JAN1999
OEL-SWITZERLAND: TWA 1 PPM (6 MG/M3), JAN1999
OEL-UNITED KINGDOM: TWA 1 PPM (6.3 MG/M3), STEL 5 PPM (32 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 METHYL SILICATE-AIR:10H TWA 1 PPM
NIOSH* DHHS #92-100,1992
EPA TSCA SECTION 8(B) CHEMICAL INVENTORY
EPA TSCA TEST SUBMISSION (TSCATS) DATA BASE, JANUARY 2001

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 PACKING SLIP FOR ADDITIONAL TERMS AND CONDITIONS OF SALE.

Material Safety Data Sheet for Absolute Ethanol

Valid 11/2002 - 01/2003

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

MATERIAL SAFETY DATA SHEET

SECTION 1. - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - - -
CATALOG #: 02860
NAME: ETHANOL, ACS, ABSOLUTE, 'A15 O'
SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -
CAS #: 64-17-5
MF: C_2H_6O
EC NO: 200-578-6
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)
IRRITANT
IRRITATING TO EYES, RESPIRATORY SYSTEM AND SKIN.
TARGET ORGAN(S):
NERVES
LIVER
KEEP CONTAINER TIGHTLY CLOSED.
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE.
WEAR SUITABLE PROTECTIVE CLOTHING.
HYGROSCOPIC
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 NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IN CASE OF CONTACT, IMMEDIATELY WASH SKIN WITH SOAP AND COPIOUS AMOUNTS OF WATER.
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES.
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.
USE WATER SPRAY TO COOL FIRE-EXPOSED CONTAINERS.
UNUSUAL FIRE AND EXPLOSIONS HAZARDS
VAPOR MAY TRAVEL CONSIDERABLE DISTANCE TO SOURCE OF IGNITION AND FLASH BACK.
CONTAINER EXPLOSION MAY OCCUR UNDER FIRE CONDITIONS.

FLAMMABLE LIQUID.
EMITS TOXIC FUMES UNDER FIRE CONDITIONS.

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

WEAR RESPIRATOR, CHEMICAL SAFETY GOGGLES, RUBBER BOOTS AND HEAVY RUBBER GLOVES.
COVER WITH DRY-LIME, SAND, OR SODA ASH. PLACE IN COVERED CONTAINERS USING NON-SPARKING TOOLS AND TRANSPORT OUTDOORS.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.
EVACUATE AREA.
SHUT OFF ALL SOURCES OF IGNITION.

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

REFER TO SECTION 8.

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

SAFETY SHOWER AND EYE BATH.
USE NONSPARKING TOOLS.
MECHANICAL EXHAUST REQUIRED.
WASH THOROUGHLY AFTER HANDLING.
WASH CONTAMINATED CLOTHING BEFORE REUSE.
AVOID BREATHING VAPOR.
AVOID CONTACT WITH EYES, SKIN AND CLOTHING.
AVOID PROLONGED OR REPEATED EXPOSURE.
NIOSH/MSHA-APPROVED RESPIRATOR.
COMPATIBLE CHEMICAL-RESISTANT GLOVES.
CHEMICAL SAFETY GOGGLES.
KEEP CONTAINER CLOSED.
KEEP AWAY FROM HEAT, SPARKS, AND OPEN FLAME.
STORE IN A COOL DRY PLACE.
HANDLE AND STORE UNDER NITROGEN.

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

PHYSICAL PROPERTIES

BOILING POINT: 78 C
FLASHPOINT 62F
16.66C
SPECIFIC GRAVITY: 0.794
SWISS POISON CLASS: FREI

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

STABILITY

STABLE.

INCOMPATIBILITIES

PROTECT FROM MOISTURE.
ALKALI METALS
AMMONIA
OXIDIZING AGENTS
PEROXIDES

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS

NATURE OF DECOMPOSITION PRODUCTS NOT KNOWN.

HAZARDOUS POLYMERIZATION

WILL NOT OCCUR.

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

ACUTE EFFECTS

CAUSES SKIN IRRITATION.
MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.
CAUSES EYE IRRITATION.
MAY BE HARMFUL IF INHALED.
MATERIAL IS IRRITATING TO MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT.
MAY BE HARMFUL IF SWALLOWED.
CAN CAUSE CNS DEPRESSION.
NARCOTIC EFFECT
DAMAGE TO THE HEART
TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.
LC
LD

CHRONIC EFFECTS

TARGET ORGAN(S):
NERVES
LIVER

HEART
THIS PRODUCT IS OR CONTAINS A COMPONENT THAT IS NOT CLASSIFIABLE AS TO ITS CARCINOGENICITY BASED ON ITS IARC, ACGIH, NTP OR EPA CLASSIFICATION.

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 EMBYRO 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 - - - - - - - - -

CONTACT A LICENSED PROFESSIONAL WASTE DISPOSAL SERVICE TO DISPOSE OF THIS MATERIAL.
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 FLUKA CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

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

EUROPEAN INFORMATION
EC INDEX NO: 603-002-00-5
HIGHLY FLAMMABLE
IRRITANT
R 11
HIGHLY FLAMMABLE.
S 7
KEEP CONTAINER TIGHTLY CLOSED.
S 16
KEEP AWAY FROM SOURCES OF IGNITION - NO SMOKING.

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

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 PACKING SLIP FOR ADDITIONAL TERMS AND CONDITIONS OF SALE.

Material Safety Data Sheet for Ammonium Hydroxide (used in high dilution)

Valid 11/2002 - 01/2003

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

MATERIAL SAFETY DATA SHEET

SECTION 1. - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - - -
CATALOG #: 318612
NAME: AMMONIUM HYDROXIDE, VOLUMETRIC STANDARD,
5.0N SOLUTION IN WATER
SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -
CAS #: 1336-21-6
MF: H_5NO
EC NO: 215-647-6
HAZARDOUS INGREDIENTS
CONTAINS AMMONIUM HYDROXIDE, CHEMICAL ABSTRACTS REGISTRY NUMBER 1336-21-6.
SECTION 3. - - - - - - - - - - HAZARDS IDENTIFICATION - - - - - - - - -
LABEL PRECAUTIONARY STATEMENTS
CORROSIVE
HARMFUL IF SWALLOWED.
CAUSES BURNS.
LACHRYMATOR.
IN CASE OF CONTACT WITH EYES, RINSE IMMEDIATELY WITH PLENTY OF WATER AND SEEK MEDICAL ADVICE.
WEAR SUITABLE PROTECTIVE CLOTHING, GLOVES AND EYE/FACE PROTECTION.
IN CASE OF ACCIDENT OR IF YOU FEEL UNWELL, SEEK MEDICAL ADVICE IMMEDIATELY (SHOW THE LABEL WHERE POSSIBLE).
REFRIGERATE BEFORE OPENING.
SECTION 4. - - - - - - - - - - FIRST-AID MEASURES- - - - - - - - - - -
IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.
CALL A PHYSICIAN.
DO NOT INDUCE VOMITING.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IN CASE OF SKIN CONTACT, FLUSH WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES. REMOVE CONTAMINATED CLOTHING AND SHOES. CALL A PHYSICIAN.
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
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 SELF-CONTAINED BREATHING APPARATUS, RUBBER BOOTS AND HEAVY RUBBER GLOVES.
COVER WITH DRY LIME OR SODA ASH, PICK UP, KEEP IN A CLOSED CONTAINER AND HOLD FOR WASTE DISPOSAL.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.
EVACUATE AREA.
SECTION 7. - - - - - - - - - - HANDLING AND STORAGE- - - - - - - - - - -

REFER TO SECTION 8.

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

SAFETY SHOWER AND EYE BATH.
USE ONLY IN A CHEMICAL FUME HOOD.
WASH CONTAMINATED CLOTHING BEFORE REUSE.
DISCARD CONTAMINATED SHOES.
WASH THOROUGHLY AFTER HANDLING.
DO NOT BREATHE VAPOR.
DO NOT GET IN EYES, ON SKIN, ON CLOTHING.
AVOID PROLONGED OR REPEATED EXPOSURE.
NIOSH/MSHA-APPROVED RESPIRATOR.
COMPATIBLE CHEMICAL-RESISTANT GLOVES.
CHEMICAL SAFETY GOGGLES.
FACESHIELD (8-INCH MINIMUM).
KEEP TIGHTLY CLOSED.
STORE IN A COOL DRY PLACE.

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

APPEARANCE AND ODOR
CLEAR COLORLESS LIQUID
PHYSICAL PROPERTIES
FLASHPOINT NONE
SPECIFIC GRAVITY: 0.965

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

STABILITY
STABLE.
INCOMPATIBILITIES
COPPER, COPPER ALLOYS
GALVANIZED IRON
ZINC
HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS
NITROGEN OXIDES
AMMONIA
HAZARDOUS POLYMERIZATION
WILL NOT OCCUR.

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

ACUTE EFFECTS
MATERIAL IS EXTREMELY DESTRUCTIVE TO TISSUE OF THE MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT, EYES AND SKIN.
INHALATION MAY RESULT IN SPASM, INFLAMMATION AND EDEMA OF THE LARYNX AND BRONCHI, CHEMICAL PNEUMONITIS AND PULMONARY EDEMA.
SYMPTOMS OF EXPOSURE MAY INCLUDE BURNING SENSATION, COUGHING, WHEEZING, LARYNGITIS, SHORTNESS OF BREATH, HEADACHE, NAUSEA AND VOMITING.
CAUSES BURNS.
MAY BE HARMFUL IF ABSORBED THROUGH THE SKIN.
LACHRYMATOR.
MAY BE HARMFUL IF INHALED.
MATERIAL IS EXTREMELY DESTRUCTIVE TO THE TISSUE OF THE MUCOUS MEMBRANES AND UPPER RESPIRATORY TRACT.
HARMFUL IF SWALLOWED.

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 ALDRICH CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.

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

EUROPEAN INFORMATION
EC INDEX NO: 007-001-01-2
CORROSIVE
R 34
CAUSES BURNS.

SECTION 16. - - - - - - - - - - OTHER INFORMATION- - - - - - - - - - -

THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO

21. Experiment Procedures

21.1 Equipment Shipping Method

Equipment, reagents, and electronics will be brought to Ellington Field by van. No equipment will be shipped through commercial couriers. Equipment will be dropped off on Thursday, March 13, 2003.

21.2 Ground Operations

The experiment containment box will be tested upon arrival at Ellington Field. The containment box will be connected to the computer and electronics and tested for correct operation. Test molds will be loaded with base solution and injected with catalyst from the injection system to ensure the equipment is suitable to produce gels and is free from leaks and mechanical defects. Standard 120VAC power is required.

21.3 Loading

The equipment will be loaded onto the KC-135A by forklift. Once on board, the equipment will be strapped to the floor of the aircraft by JSC personnel.

21.4 Pre-Flight

Due to chemical considerations, molds will be loaded into the containment box on the mornings of the flights. The containment box is designed for quick, easy loading access and can be latched and locked for take-off.

21.5 Take-Off/Landing

The computer, DAQ, and electronics interfaces will need to be stowed during take-off and landing. There are no power requirements during take-off and landing.

21.6 In-Flight

1. At the start of the flight, the equipment operator “Mario” is strapped in front of the equipment box and prepares to operate in the box. The computer operator “Luigi” is strapped in front of the computer and ready to operate the equipment.

2. Prior to each reduced gravity parabola, Mario takes a mold from the mold rack and attaches it to the diffusion needle. Luigi instructs the injection system to aspirate a specific volume of liquid.

3. Upon initiation of microgravity, the computer operator instructs the injection apparatus to inject catalyst into the attached mold.

4. Upon completion of injection, Mario disconnects the mold from the injection system and gives it two hard shakes. This breaks up any eddies formed from incomplete diffusion. The mold is then placed in a special container where it remains until entry into gravity. A gel forms in the mold within 15 seconds of injection.

5. Upon entry into gravity, Mario takes the mold and places it into a vacant slot in the mold rack.

6. Steps 2 through 5 are repeated for each reduced gravity parabola.

21.7 Post-Flight

The computer, electronics, and molds used on the first flight are off-loaded. New molds will be loaded on the morning of the second flight.

21.8 Offloading

The equipment will be off-loaded by forklift. All equipment will be taken from Ellington Field by van.

22. Bibliography

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Campbell, J. A. in *Chemical Systems: Energetics, Dynamics, Structure*. (1977)

Chemical Rubber Company, *CRC Handbook of Chemistry and Physics,* 83rd ed. (2002)

Hrubesh, Lawrence W. and Poco, John F. "Processing and Characterization of High Porosity Aerogels," *Lawrence Livermore National Laboratory Pre-print.* (1994)

Hunt, Arlon. Telephone Interview. (20 May 2001)

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Smith, D. et al. "Effect of Microgravity on the Growth of Silica Nanostructures," *Langmuir*, 2000, 16, 10055-10060.

Tillotson, T. M. and Hrubesh, L. "Transparent Ultralow-density Silica Aerogels Prepared by a Two-Step Sol-Gel Process." *Reports from Third International Symposium on Aerogels, Warzburg, Germany*. (1991)

Vanderhoff J. W.; El-Aasser, M. S.; Micale, F. J.; Sudol, E. D.; Tseng, C. M.; Sheu, H. R. *Polym. Prepr.* 1987, 28, 455; *Mater. Res. Soc. Symp. Proc.* 1987, 87, 213.

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