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The Construction and Characterization of a Large Volume Wilson Cloud Chamber Utilizing Orthogonal
Cameras for Image Capture

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Thesis submitted to the faculty of Idaho State University
in partial fulfillment of the requirements
for the degree

Master of Science
in
Nuclear Science & Engineering

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To the Graduate Faculty:

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Dedication

In dedication to my most wonderful wife, you have stuck by my side and supported me all these years. I couldn't have done this without you.

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The Construction and Characterization of a Large-Volume Expansion Cloud Chamber Utilizing Orthogonal Cameras for Image Capture

Cody A Womack

Abstract

This paper describes the steps taken and the issues to overcome during the construction process of an expansion cloud chamber. This cloud chamber was built for the purpose of attaching video cameras to a computer for use in tracking radiation cloud trails and determining the source of the radiation.

The main chamber pieces did not have to be constructed from basic resources, as the main chamber was a project originally developed by the Idaho National Laboratory. The project was suspended due mainly to funding issues. Nevertheless, the chamber still required assembly, and construction of a structure to support all of the parts to the chamber. A cabinet was constructed to support the cloud chamber as well as contain the air compressors required to run the chamber. A computer mounting section was added to conveniently locate a computer for running the camera software. During the construction process, it was desirable to keep in mind the need to develop an operating procedure.

After final construction of the chamber, it was necessary to characterize the chamber and determine the appropriate level of alcohol for use as the supersaturating vapor. By testing the chamber with varying levels of ethyl alcohol, it was determined that the most suitable level was 63% ethyl alcohol.

Chapter 1. Introduction*

Motivation & Objectives

Cloud chambers were among the first devices used to detect radioactive particles, and have been critical in many discoveries in physics, including the discovery of the positron. Since the initial invention of the cloud chamber scientific research, especially radiation detection, has turned to more sophisticated instruments. Sometimes these more sophisticated instruments are better adept to measure the amount of radiation in a location, and less able to pinpoint the specific location in space of the source of radiation. For those measurements involving a source location, researchers typically use a large array of individual detectors to determine the origin.

A cloud chamber not only detects radiation, but shows the path through space that the radiation ion takes. Researchers in the past have used cameras looking into a cloud chamber at orthogonal angles to pinpoint the precise location in space the particle originated. Yet, the position of the origin point required lengthy calculations, and was not able to be quickly determined. With today's computing power, recording cameras can be connected straight to a computer with tracking software that can be used to calculate the specific origin of a radioactive particle in a cloud chamber in a timely manner. Therefore, the purpose of this project was to build and test a functional, on-demand cloud chamber for the use of tracking particle origins.

One such avenue of research would be tracking the origins of neutrons, much like the neutron hodoscope previously used at the Transient Reactor Test Facility (TREAT)¹. The hodoscope was a device used to track the path of sub-atomic particles (in the case of TREAT, neutrons). It accomplished this by reading the output of a two-dimensional array of neutron detectors aimed at a neutron source through pinhole collimators. With this method, it was able to track a moving source in two dimensions. In the TREAT experiments the objective was to be able to image the fuel movement during extreme power excursions by the fast fission neutron response of the hodoscope array. It is feasible that a cloud chamber can be used to replace the hodoscope, and track the origin of neutrons without the use of collimators.

Background

Brief History of Cloud Chambers

In the late 1800s and early 1900s, atmospheric researchers were investigating the development of cloud drop formation on dust particles in the air. The majority of researchers felt that dust particles had to be present as condensation nuclei for any cloud formation. Despite this perception, physicist and meteorologist C.T.R. Wilson showed that under certain circumstances, a cloud could form in the absence of any dust particles. In running experiments with water vapor in his expansion chamber, and with dust

* For references in this chapter, see references 2 & 4

present, Wilson saw that even a small expansion produced a thick cloud. Upon subsequent expansions, he saw the clouds that formed become less dense, as the droplets that formed around dust particles carried the dust to the bottom of the chamber. Eventually, he saw no cloud formations, as the air was free of dust. Wilson didn't see anything form until the expansion ratio was between 1.25 and 1.37. Within this range he saw only a few drops form, and after 1.37 he again saw a thick cloud form. This discovery led Wilson to try to determine what might be causing the formation of the drops and cloud, as there were no dust particles in the air to act as condensation nuclei. During this research, Wilson discovered that when a radioactive source was brought near the chamber instead of forming the few drops within the range of 1.25 and 1.37, a thick cloud formed. J.J. Thomson, the credited discoverer of the electron, discovered that a cloud would form in the same expansion range in the presence of an x-ray beam. These experiments, along with others, led Wilson to realize that the clouds forming within this range were using charged ions from ionizing radiation as the condensation nuclei. This discovery allowed Wilson to develop his namesake cloud chamber in 1911 for use in the research of ionizing radiation. The Wilson Cloud Chamber was also called the Pulsed Cloud Chamber, as it could be "pulsed" or operated on demand.

Physics of Cloud Formation

Concerning the formation of atmospheric clouds, assume there is a specific volume of air fully saturated with water vapor. This volume of air is raised through the atmosphere by various mechanisms. As it rises up, the pressure decreases, and the volume of air expands adiabatically. Due to this expansion, the temperature drops and the volume of air can no longer hold the same amount of water vapor; this is called supersaturation. This supersaturated state is an unstable one, and any perturbation will cause the excess water vapor to condense and separate out from the rest of the vapor. In the atmosphere, the excess vapor typically condenses, or nucleates, on dust particles.

The cloud chamber that Wilson designed operated on a similar principle regarding cloud formation. It contains a volume of air saturated with some type of vapor (Wilson started with simple water vapor, but tested many others). This volume is suddenly expanded by mechanical means, and the pressure and temperature fall. This causes the volume to become supersaturated with the vapor. If there is no dust in this environment, it will remain supersaturated until some perturbation acts upon it. If a particle of ionizing radiation passes through, it will strip electrons off of any molecules or elements in its path causing ions to form. The vapor will nucleate on these ions, just like the vapor nucleates on the dust in the atmosphere during cloud formation in nature. Since the ions only form in the path of the radiation, it allows the radiation path to become visible.

If a mixture of liquids is used as a source of the vapor, instead of water, then the supersaturation will also vary with the composition of the mixture. To calculate what this supersaturation would be, it is first assumed that the atmosphere within the chamber is comprised of non-condensable gas, at pressure P_g , along with a vapor from the mixture of the liquids which is at a pressure P_1 .

Starting with the ideal gas law:

$$P_1 V_1 = nRT_1. \quad (1)$$

The number of moles of the vapor would be the mass of the vapor divided by the molecular weight. Substituting this, gives:

$$P_1 V_1 = \left(\frac{M_1}{M} \right) RT_1. \quad (2)$$

With M_1 as the mass of the vapor in volume V_1 and M is the molecular weight of the vapor, in grams.

If the volume of the chamber were expanded suddenly, from V_1 to V_2 , the temperature will fall from T_1 to T'_2 , where T'_2 can be calculated by the adiabatic equation:

$$\frac{T_1}{T'_2} = \left(\frac{V_2}{V_1} \right)^{\gamma-1}, \quad (3)$$

which is sometimes written as:

$$PV^\gamma = \text{constant}. \quad (4)$$

The prime notation of T'_2 in equation (3) indicates that this is the temperature after the expansion, but before the condensation of the vapor. Also, γ is the ratio of specific heat at constant pressure to the specific heat at constant volume for each of the gases within the chamber (if only one gas is present, $\gamma = C_p/C_v$).

The pressure of the vapor immediately after expansion is given by:

$$P'_2 V_2 = \left(\frac{M_1}{M} \right) RT'_2. \quad (5)$$

Again, the prime notation indicates that this is after the expansion, but before the vapor condenses within the chamber.

The vapor within the chamber, at this point, is at an unstable equilibrium. It is supersaturated, holding more vapor than it is able to, at the temperature T'_2 . The excess vapor precipitates in the chamber, reducing the mass of vapor in the gaseous mixture from M_1 to M_2 . A stable equilibrium is reached, and the vapor pressure drops to the saturation pressure for the lower temperature T_2 . As condensation is an exothermic process, the temperature T_2 is slightly higher than the temperature T'_2 . With this drop in temperature and pressure, the equation would now read:

$$P_2 V_2 = \left(\frac{M_2}{M} \right) RT_2, \quad (6)$$

with M_2 being the mass of the vapor after expansion and condensation. Naturally, this would be lower than M_1 .

The supersaturation produced from the expansion of the chamber would be the ratio of the vapor density after expansion and before condensation, to the density of the saturated vapor at the temperature T_2 , shown below in Eqn. 9.

The first of these two values, the vapor density after expansion and before condensation, is simply the mass of the vapor before expansion divided by the volume after expansion.

$$\rho'_2 = \frac{M_1}{V_2}. \quad (7)$$

The second of these, the saturation density at temperature T_2 , would be the same equation; however the mass term would be the mass of the vapor after condensation:

$$\rho_2 = \frac{M_2}{V_2}. \quad (8)$$

Supersaturation is the ratio of the two:

$$S = \frac{\rho'_2}{\rho_2} = \frac{M_1}{M_2} = \frac{P_1 V_1 T_2}{P_2 V_2 T_1}. \quad (9)$$

If the equations (7) and (8) are solved for M_1 and M_2 , respectively, and are inserted into equation (9), the supersaturation term will be:

$$S = \frac{(P'_2/T'_2)}{(P_2/T_2)}. \quad (10)$$

If the small difference between T_2 and T'_2 can be disregarded, then $T'_2 = T_2$. Placing this into the adiabatic equation (3) and rearranging would give:

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1}. \quad (11)$$

Substituting this into the supersaturation equation (10) would give:

$$S = \frac{P_1}{P_2} \left(\frac{V_1}{V_2} \right)^{\gamma}. \quad (12)$$

Assuming $1 + \epsilon$ to be the ratio of the final volume to initial volume, otherwise known as the expansion ratio, then the supersaturation would be:

$$S = \frac{P_1}{P_2} \left(\frac{1}{1 + \epsilon} \right)^\gamma. \quad (13)$$

For mixtures of a vapor and a gas, as is the case in a cloud chamber, the specific heat ratio, γ is calculated with the following equation:

$$\frac{1}{\gamma - 1} = \frac{1}{\gamma_g - 1} * \frac{P_g}{\pi} + \frac{1}{\gamma_v - 1} \frac{P_v}{\pi}, \quad (14)$$

where P_v and P_g are the partial pressures of the vapor and gas, respectively, γ_v and γ_g the corresponding γ 's, and $\pi = P_v + P_g$, the total pressure.

For more than one liquid used as vapor, saturating a non-condensable gas (as is the case when using both water and ethanol in air), γ is given by:

$$\frac{1}{\gamma - 1} = \frac{1}{\gamma_g - 1} * \frac{P_g}{\pi} + \frac{1}{\gamma'_v - 1} \frac{P'_v}{\pi} + \frac{1}{\gamma''_v - 1} \frac{P''_v}{\pi}. \quad (15)$$

This shows how γ , and therefore the supersaturation S may vary with the partial pressures of the vapor and the gas, and the corresponding specific heat ratios. The partial pressures and specific heat ratios can vary with the nature of gas and vapor used, and with the initial temperature and pressure. Consequently, the supersaturation may vary depending on these conditions.

Chapter 2. Chamber Construction

Beginning Construction

This cloud chamber began as a project at the Idaho National Laboratory (INL), with the possibility of being used for many different research avenues. Most of these were related to the determination of the location of a radiation source. Some parts and material were procured by the original researchers, but the project was discontinued. Once the project was resumed, the only major items on location were the main chamber, piston/filter chamber, chamber supports, pistons, and cameras. (See Figure 2).

The first item to be considered during construction and assembly was the cabinet/chamber support frame. Of the many different designs deliberated, the end result was limited by the available material. To construct the cabinet and chamber support frame, aluminum modular framing was used, along with aluminum sheeting. A cuboid structure with supporting cross pieces was assembled from the modular framing, with the aluminum sheeting used for the cabinet walls. Important areas in the frame and cabinet were an area on top for mounting the chamber supports, a cabinet area to hold the air compressors, and an area to serve as a computer server rack. (See Figure 1).

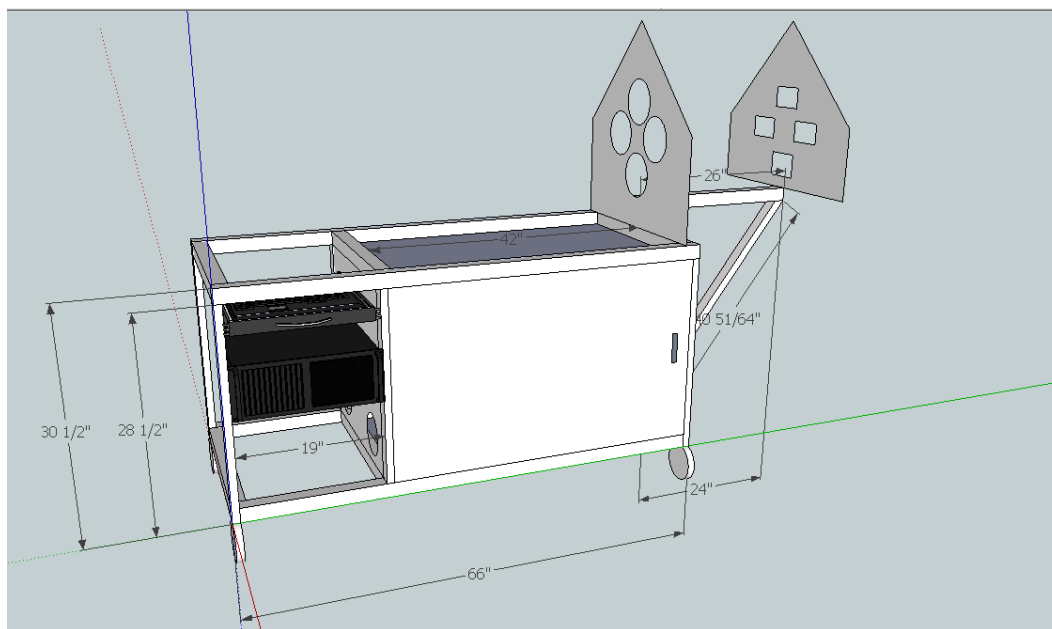


Figure 1. Early model of the cloud chamber support frame and air compressor cabinet. Note the server rack to the left, and a proposed brace piece to the right.

Additionally seen in Figure 1 are early ideas for the cabinet frame that required a brace piece to support the pneumatic actuators. Despite these early designs, a brace piece was not added as it was unclear if the brace would be necessary. Aluminum panels were used for the cabinet walls and doors. All pieces were powder-coated to protect the metal, and to help eliminate sharp edges. The entire cabinet structure was then assembled. (See Figures 2 & 3)

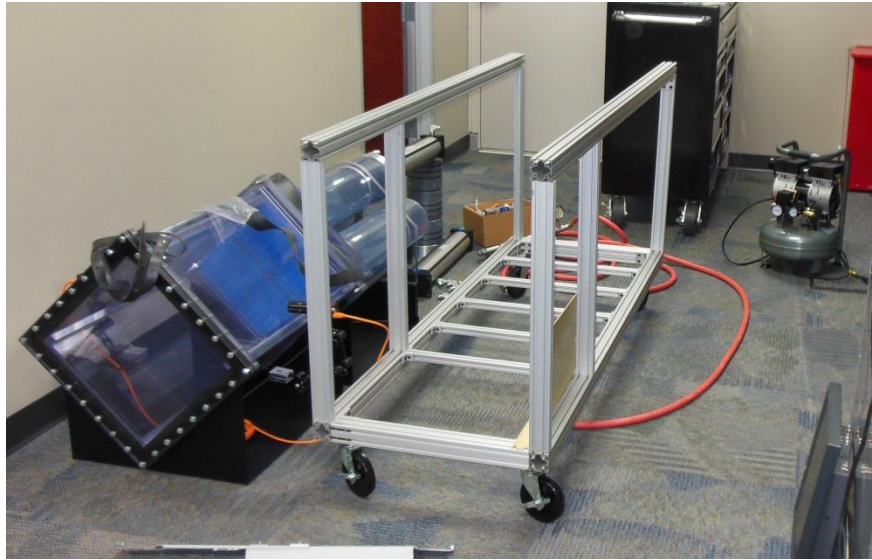


Figure 2. Early hand construction of the frame (right), with chamber and other items mentioned above (left).



Figure 3. Partway through cabinet construction.

The cooling fans were originally intended to have an intake on the lower left side of the compressor cabinet, and an exhaust on the upper right side (see Figure 4). After the installation of the power supply in the rackmount area of the frame, there was no longer enough room for the intake fans. These were subsequently moved to the rear of the cabinet, in approximately the area where each compressor would be placed (see Figure 5). Each fan had circular fan blades mounted inside a square frame, such as those used for desktop computers. Instead of trying to cut square holes for the entire fan frame, a circular hole, the area the size of the fan blades, was punched for airflow and the frames of the fans were mounted to the cabinet wall. The fans have a minimum total airflow of 104 cubic feet per minute, and the cabinet had an estimated 17.5 cubic feet of volume. The selected fans could move the entire cabinet's worth of air slightly under six times a minute, or once every 10 seconds.

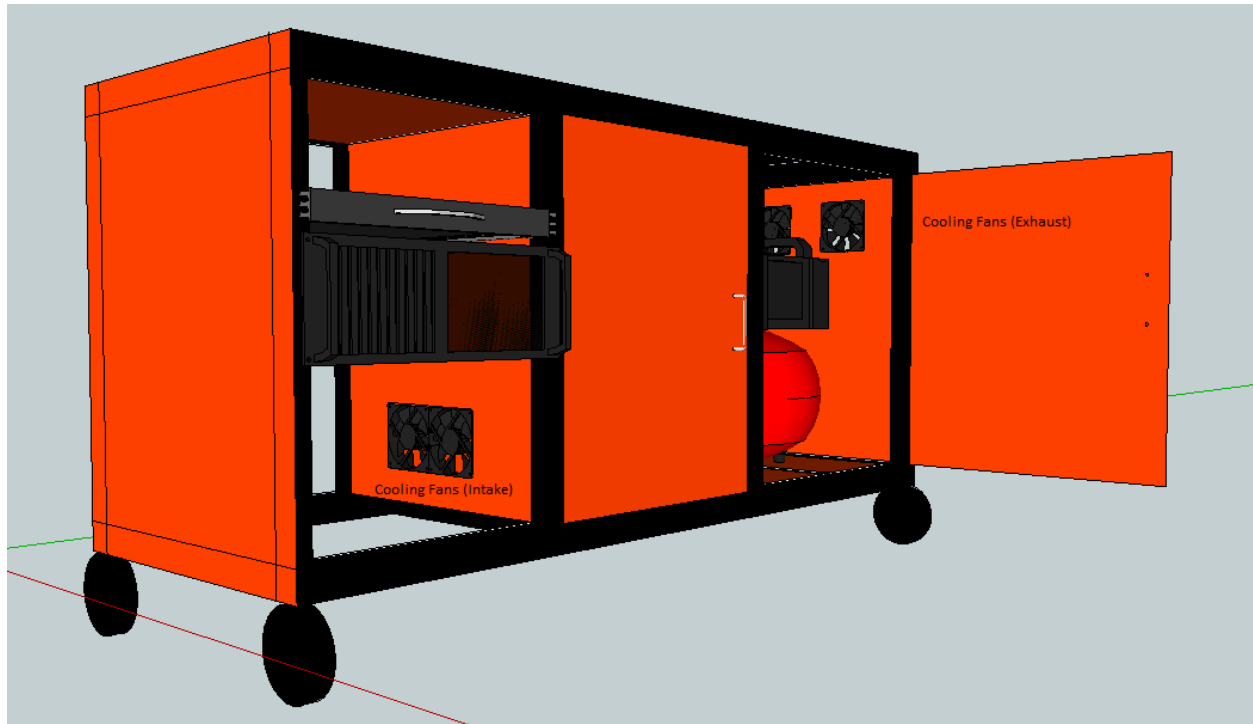


Figure 4. Early positions of the cooling fans.

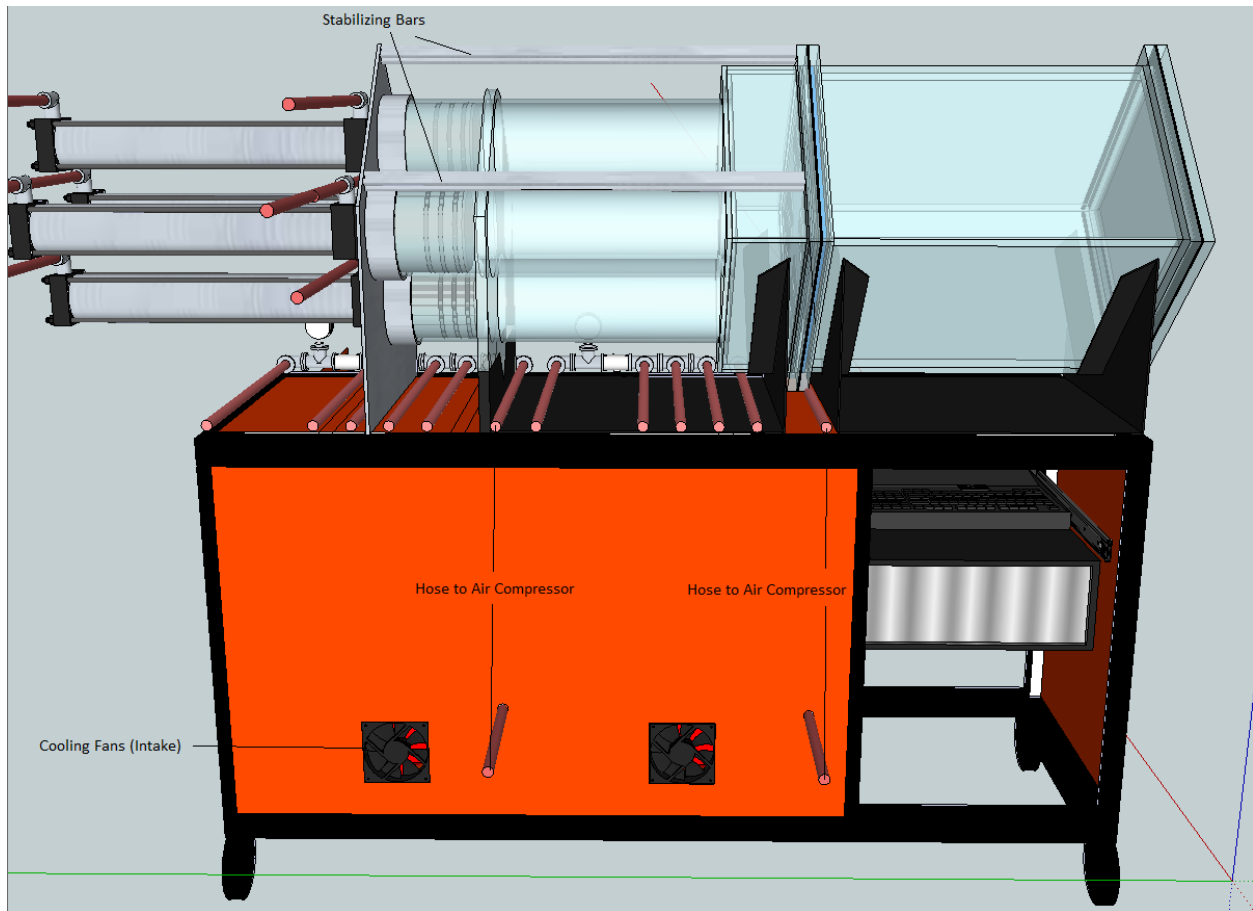


Figure 5. Finalized position of the cooling fans.

In order to drive the pistons, two manifolds were constructed leading from two separate air compressors to the pneumatic actuators. One manifold led to one end of the actuators, in order to push the pistons forward; the other manifold led to the other end of the actuators, in order to pull the pistons back. The movement of the cylinder piston within the actuator causes air to be pushed through the alternate manifold, necessitating the need for a valve to release the excess air (see Figures 6, 7, & 8).

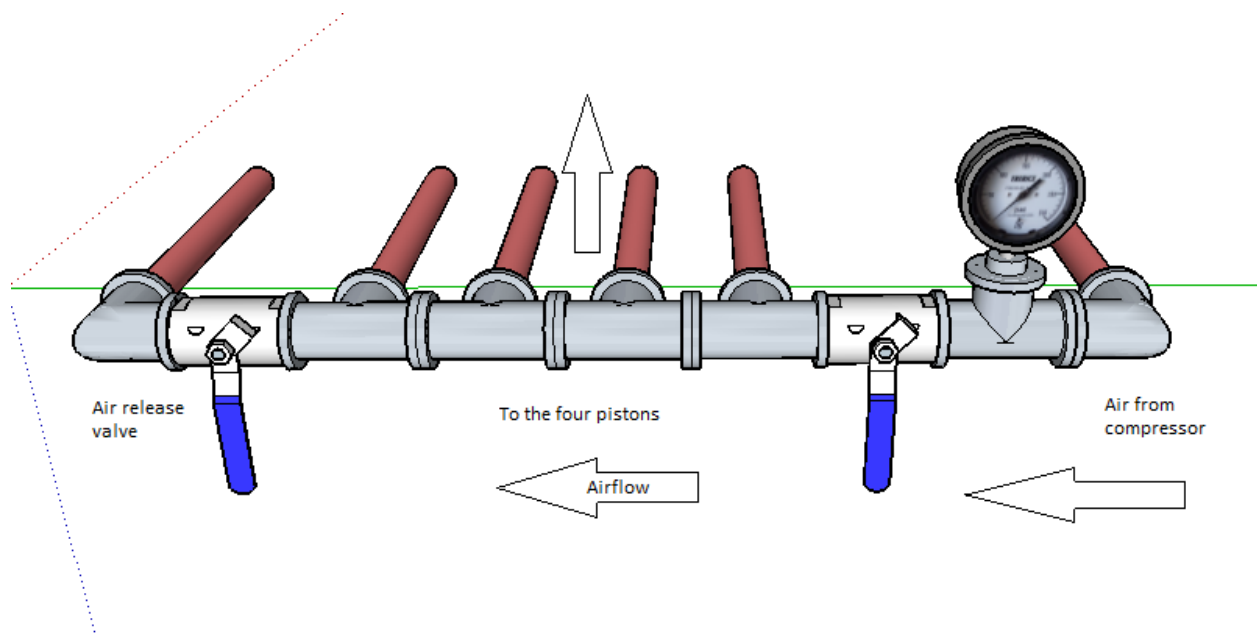


Figure 6. Manifold airflow diagram. Working position.

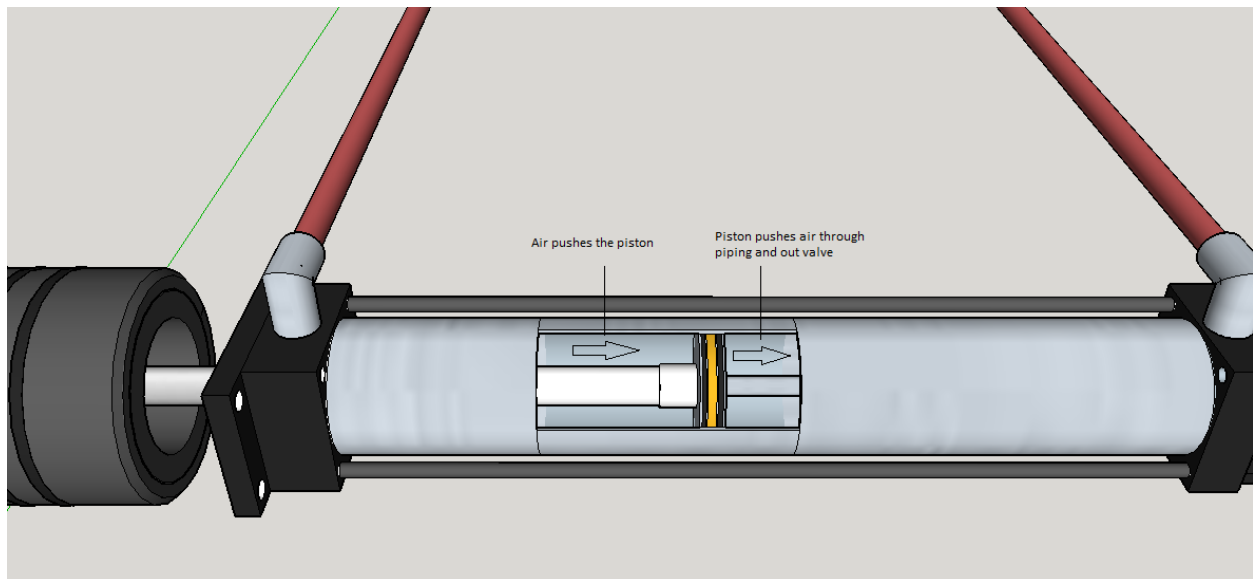


Figure 7. Piston airflow diagram.

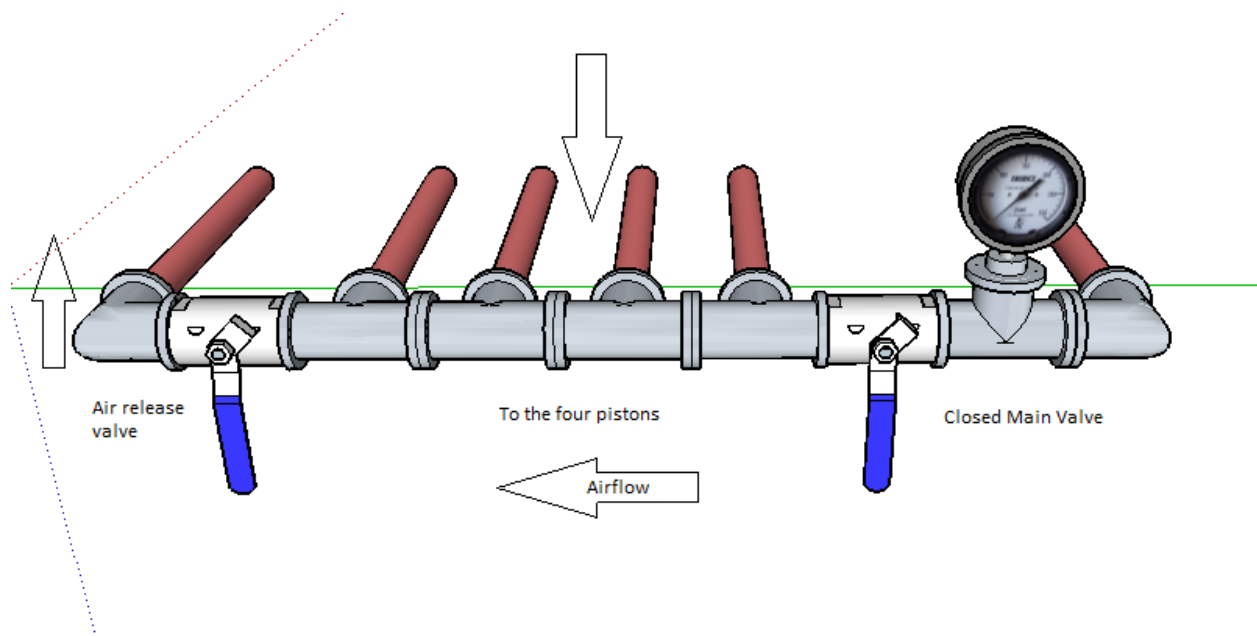


Figure 8. Manifold airflow diagram. Passive position.

After the manifolds were completed, they were installed along with the support structures for the chamber pieces (see Figure 9). It was at this stage that a support structure for the pneumatic actuators was decided upon and installed. The original chamber had no means of attaching the actuators to the assembly, or holding the pistons in place in the chamber tubes. It was necessary to develop some method to support and attach the actuators. An early version of supporting brackets was seen previously in Figure 1. An alternate early version of a supporting plate included a plate framed by some 80/20 aluminum rods with brace pieces attaching to the cabinet frame (see Figure 10). However, it was found after initial construction of the frame, that neither of these early ideas were needed; the weight of the actuators could be supported by attaching a rod extending from the support plate directly to the cloud chamber. Later testing revealed the need for additional side supporting rods, due to torquing of the plate when the pistons were being run in and out of the system (see Figures 11 & 12).



Figure 9. Chamber and frame with mounted manifolds and black chamber supports.

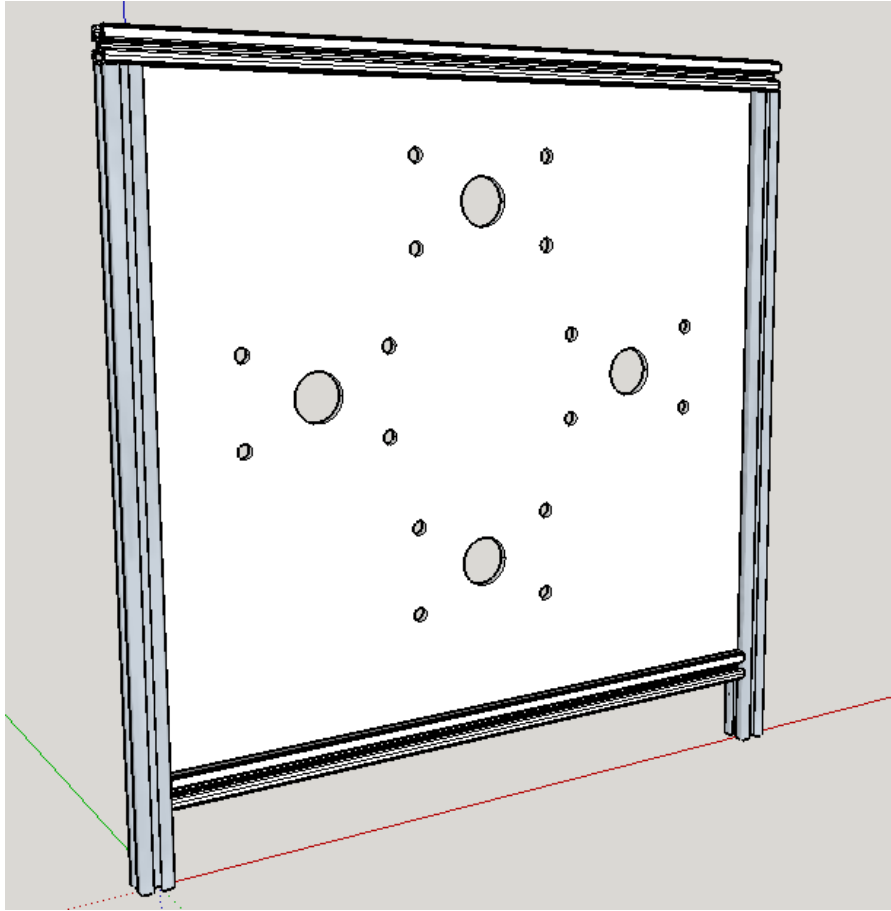
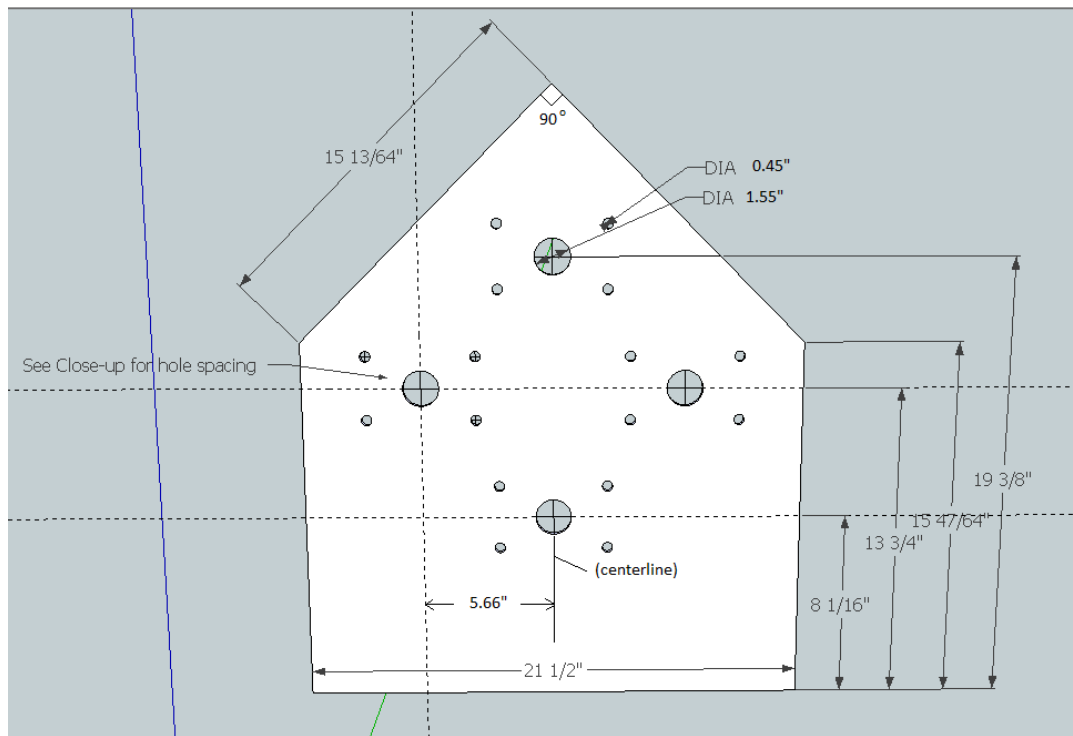


Figure 10. Early piston support plate design.



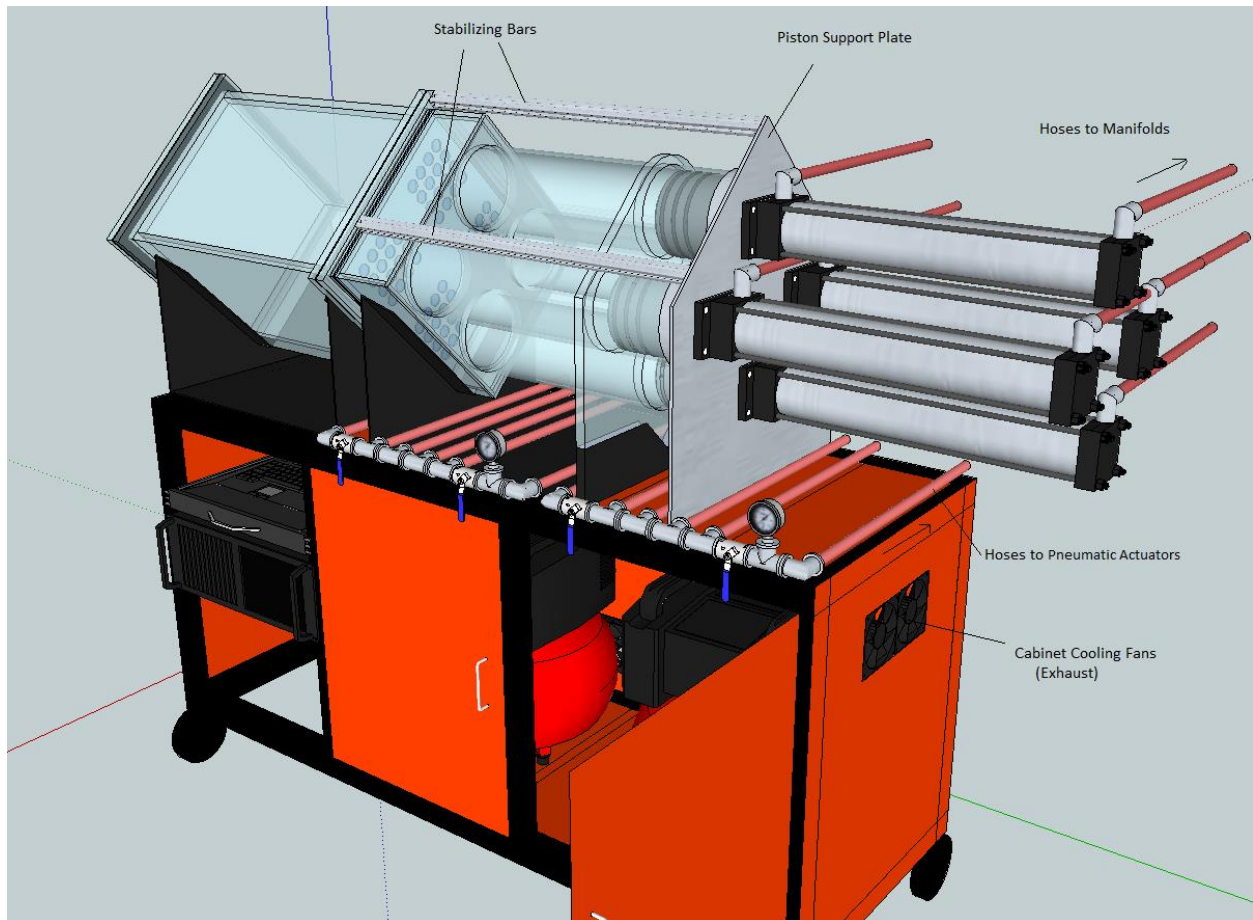


Figure 12. Model of the cloud chamber and cabinet, illustrating the piston support plate and stabilizing bars.

Project Delays

As with most projects, some issues arose that created delays.

One issue involved the wheels for the cabinet and frame. The original wheels attached to the frame were single-bolt casters, one to each corner. These wheels were given with the assurances that they would support the weight of the chamber and cabinet frame. The wheels performed admirably when they only needed to support the weight of the cabinet, but once the weight of the chamber was added, the bolts started to bend slightly. It was clear that the wheels could not support the combined weight. New swivel casters were procured that needed to be attached through 4 screw holes rather than a single bolt, more than capable of supporting the combined weight of the cabinet and chamber. The main issue with attaching the new wheels was the fact that the cabinet frame was already powder-coated; including the small blocks to which the previous wheels were attached. These small blocks were obstructing the ability to attach the new casters to the frame. The blocks were removed by cutting through the powder coating, and detaching them from the frame. The new casters could attach to the

frame with only 3 of the 4 attachment points on the caster plate. Therefore quarter inch thick scrap aluminum plates were cut and mounted to the frame, and the new casters attached to the plates.

Once the new wheels were attached, the chamber and pistons were mounted to the cabinet and frame. At that point, a previous undetected error was discovered. As can be seen in Figures 13 & 14, the piston heads originally created for the INL project had a steel plate insert to connect to the actuator shaft. However, the steel plate inserts were not properly constructed. These were originally designed as a stainless steel hex nut welded to a circular carbon steel plate. The heat from the welding process caused the carbon steel plate to warp, and the stainless steel nuts had been welded slightly off center. This resulted in the nuts being both off center and crooked, and they were not able to be attached to the actuator shafts. New inserts were designed, and were precision-machined from a solid aluminum cylinder (See Figures 15 & 16).

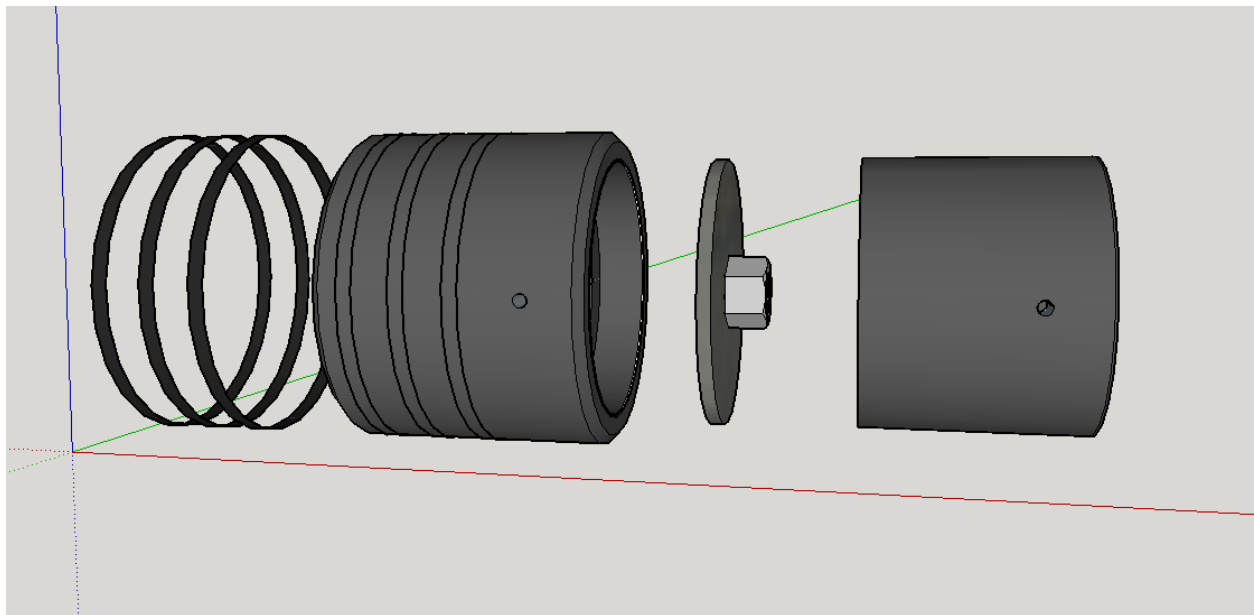


Figure 13. Exploded view of the piston head, showing the old connecting plate was supposed to attach to the pneumatic actuator rods.

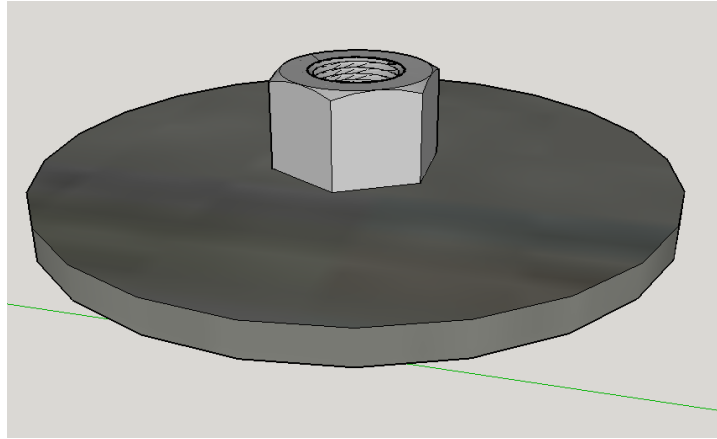


Figure 14. Close-up model of the previous ill-made attachment plates

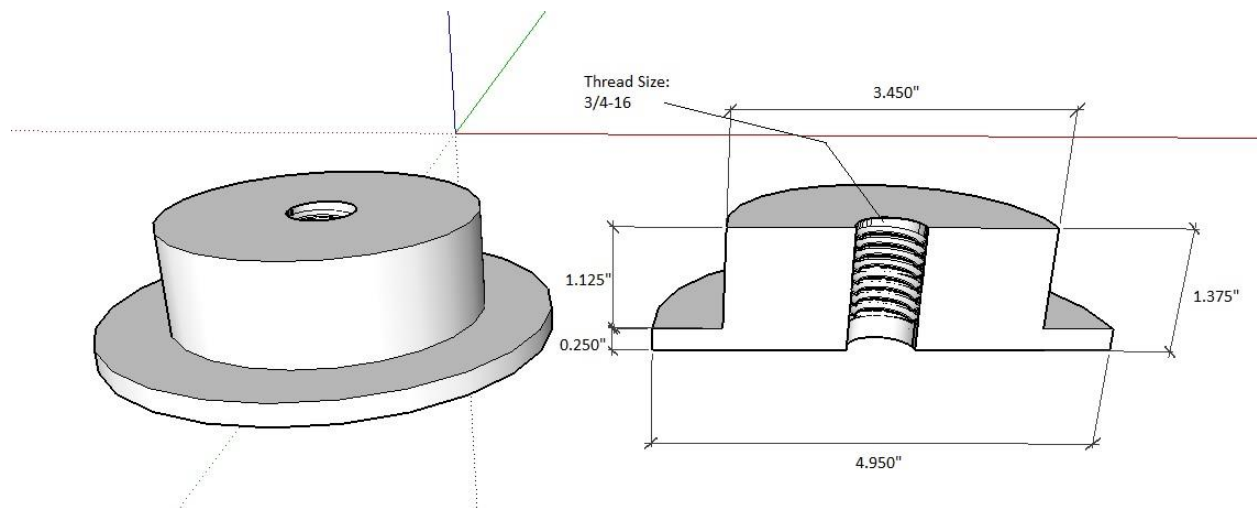


Figure 15. Close-up model of the new attachment inserts machined from a solid cylinder of aluminum.

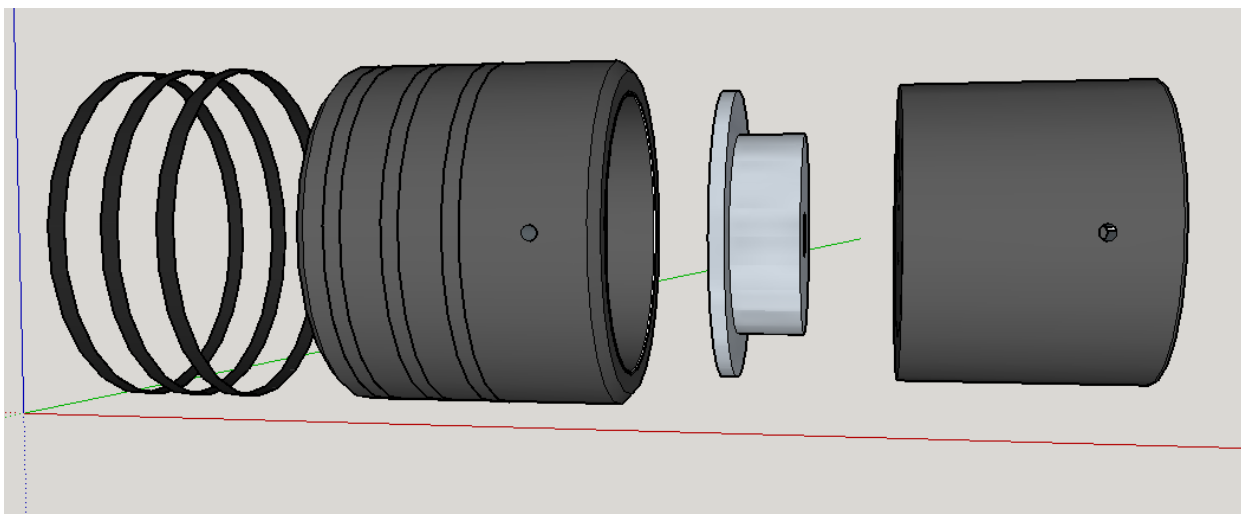


Figure 16. Exploded view of the piston head, showing the new inserts to attach to the pneumatic actuator rods.

After the new inserts were machined, the pistons and chamber were reassembled. Silicone grease was used as a lubricant for the pistons. The Material and Safety Data Sheet (MSDS) of the specific lubricant used can be found in Appendix E.

During the first test after reassembly of the chamber, in an attempt to pull a vacuum, the chamber was found to have multiple air leaks from previous lack of use. The leaks were sealed with a clear silicone caulking that required 24 hours between each application and subsequent testing of the chamber. During the process of testing, an improper seal was discovered between the two chamber sections, as the spacing and number of bolts between the two halves were not adequate for providing a sufficient seal. New bolt holes were drilled connecting the two sides, providing a better seal with the rubber gasket. It was realized that any seals would rupture before the 7 psi check valve would break in a conceivable instance of positive chamber pressure; the 7 psi check valve was replaced with a 0.5 psi check valve.

Once the leaks were sealed, a preliminary test was made using isopropyl alcohol and no radiation source. A mixture of 70% isopropyl alcohol and 30% water resulted in a thick cloud, proving that the chamber was capable of reaching a supersaturated state. This test showed that an absorbent material was needed to allow for better evaporation of the alcohol. The absorbent material chosen was felt; this material required support on each side so that a fully saturated piece could remain upright against the sloped side of the chamber. An addition was added to the liquid fill valve, so that the felt could be uniformly saturated. This addition mainly consisted of a PVC pipe with evenly spaced holes, spanning the full length of the fabric.

Aluminum bars of modular framing were added to the each side of the main chamber to use as attachments for the orthogonal cameras. The cameras were Stingray model F-504 cameras from Allied Vision Technologies, with low-distortion wide-angle lenses. At full resolution, the cameras had a framerate of only 9 frames per second (fps). At lower resolutions, framerates of up to 15 fps could be achieved. The software provided for image capture was a demonstration model of Unibrain Fire-i recording software.

To effectively test alpha and beta radiation, an access port and internal source holder were required as a method of inserting a radiation source directly into the chamber. An irrigation pipe plug was used as an access port. A hole was cut into the face of the chamber to insert sources, which could then be sealed with the plug. A simplified source holder was constructed out of available materials. It consisted of a main bracket and an interchangeable source holder attached at any point along its length. Due to the interchangeable nature of the source holder, it was capable of holding many different types of sources, including needle sources, button sources, and sources required to be threaded onto a screw, sometimes called an “add-a-source”. See Appendix B for parts and operation of the source holder, and see Appendix C for alternate versions of the access port and source holder.

The chamber then was moved from the Idaho Falls facility to the Pocatello campus. At the time, the Pocatello location did not have an outlet to meet the amperage requirements to use both of the air compressors along with the the computer and cooling fans. Modifications had to be made to the air tubing in order to reduce the power load, by using only one compressor. The second compressor would be able to be added again, if the proper power requirements are met.

In Pocatello, a light source was needed to provide adequate lighting for illumination of the cloud trails, yet did not give too much glare for the cameras through the chamber wall. To meet this end, some LED strip lighting was mounted onto a foam board, with a viewport cut in the middle. Since the lighting was underneath the foam board, and placed directly against the polycarbonate, it cut down dramatically on the glare compared to the regular room lighting. Furthermore, the LED light strips would not produce excessive heat against the polycarbonate surface of the chamber.

Chapter 3. Experimentation

Once lighting was installed, and the system was capable of running on the available power, the chamber was tested to determine the optimal dilution of alcohol to achieve ion cloud trails. For these experiments an alpha emitting Americium-241 source was used.

Chamber Testing

According to Table 1, the formation of a cloud in the chamber depends on the expansion ratio of the chamber, and varies with the alcohol percentage. The chamber has limits of the expansion ratio as to when ions cause cloud droplets to form, and when a dense cloud forms inside. These will be called the lower and upper limits, respectively. Using schematics and careful measurements of the main chamber and piston tubes, the expansion ratio is simply the ratio of expanded volume (pistons drawn completely out) and non-expanded volume (pistons fully inserted). The ratio of these volumes was calculated to be 1.19. Plotting the values from Table 1, the alcohol content required for the expansion ratio to fall between the ion limit and the cloud limit would be around 8% ethanol. Pure ethyl alcohol was diluted with distilled water to 8% ethanol content, and was added to the chamber through the liquid fill valve. Tests completed using an alpha source and this solution of ethyl alcohol, had negative results, i.e. no cloud trails were formed.

TABLE I-8. Cloud and ion limits with different compositions.

% of C ₂ H ₅ OH		Expansion ratio		% of C ₂ H ₅ OH		Expansion ratio	
by weight	by volume	without field (ion limit)	with field (cloud limit)	by weight	by volume	without field (ion limit)	with field (cloud limit)
00.0	00.0	1.251	1.276	58.3	63.0	1.101	1.113
9.3	11.	1.155	1.174	67.8	73.	1.105	1.114
24.9	30.	1.115	1.130	73.4	77.	1.100	1.112
44.2	49.	1.110	1.112	83.9	87.	1.114	1.128
50.4	57.	1.098	1.107	90.0	92.	1.119	1.132
52.8	59.	1.103	1.114	96.0	96.	1.142	1.158
				100.0	100.	1.152	1.172

Table 1. Ion and Cloud limits of the expansion ratio by weight and volume of ethyl alcohol. (Gupta & Ghosh, 1946)

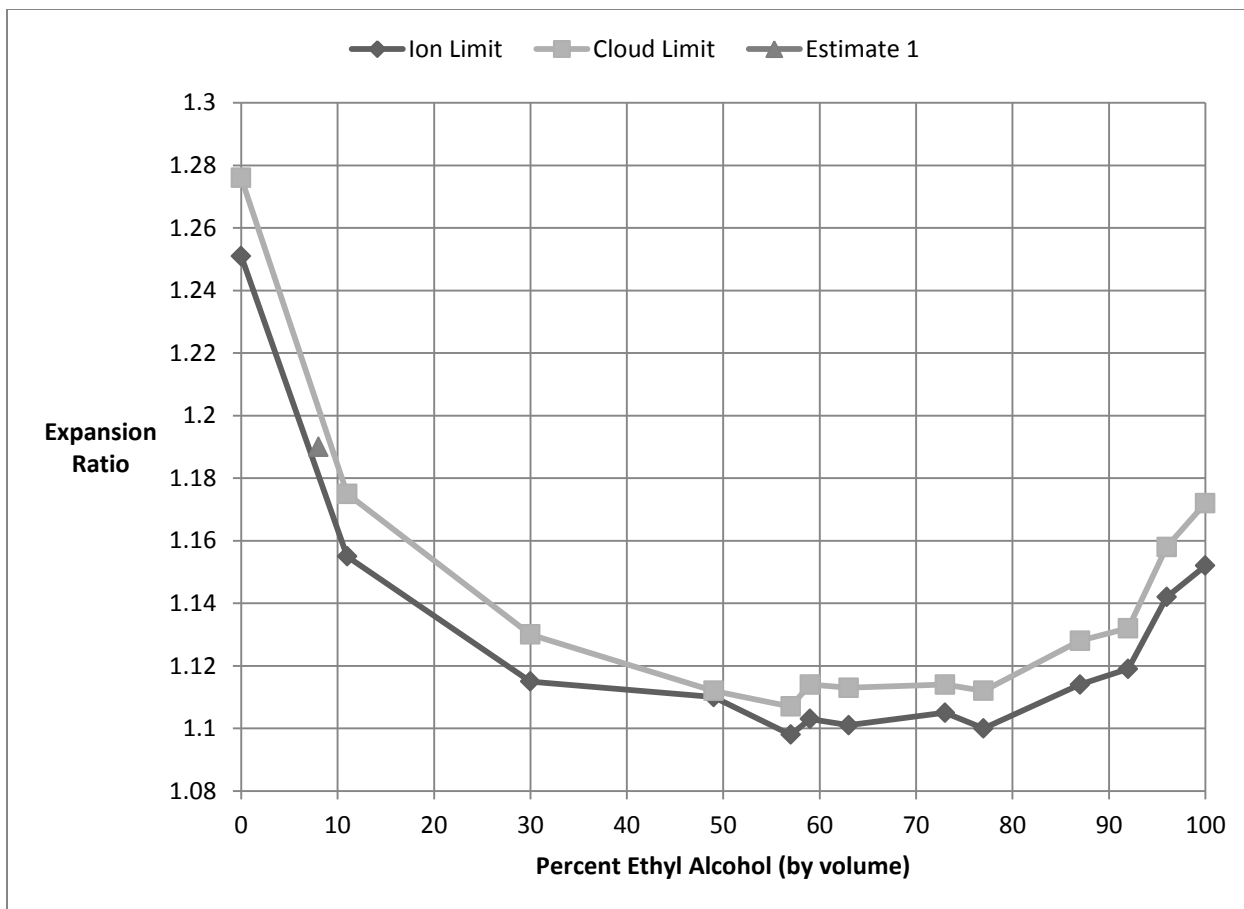


Figure 17. Ion and Cloud limits with the first alcohol percent estimate for cloud chamber.

When this level of dilution failed, a different method was attempted for matching the proper dilution to the expansion ratio of the chamber. An electronic spreadsheet program was used to calculate and plot a best fit curve to up to a 6th order polynomial for each of the upper and lower limits, as can be seen in Chart 2. According to the best fit curves, a dilution of 5.88% ethyl alcohol would produce an ion limit expansion ratio of 1.19, and a cloud limit of 1.21. This dilution also failed to yield results.

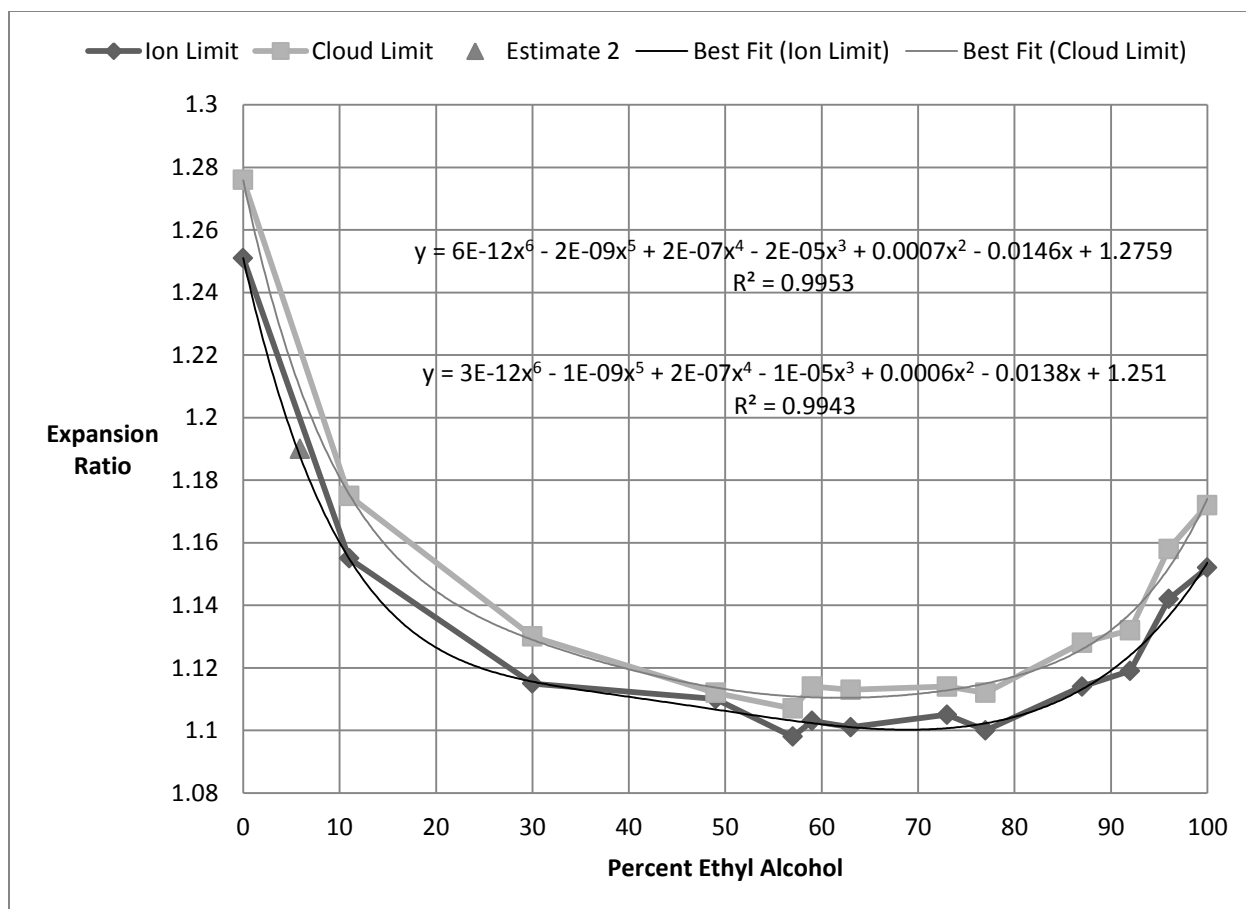


Figure 18. Ion and Cloud limits with best fit lines and equations, along with the second alcohol percent estimate for cloud chamber.

During this testing of the chamber, the pneumatic pistons were likely too slow to produce a rapid enough full expansion for the supersaturation of such a low alcohol content. The division of the upper and lower limits on Charts 1 and 2 provided a very narrow window of expansion to produce ion trails without producing a general fog. During the process of drawing back the pistons, the chamber passes through every expansion ratio between 1 (no expansion) and 1.19 (full expansion). From this realization, instead of trying to match the alcohol dilution to the expansion ratio of the chamber, or even testing random dilution levels, dilutions of alcohol matching the largest windows between upper and lower cloud limits, and thus had the best chance of yielding results, were chosen. These values were 11, 30, 60, 63, 78, 87, and 100%[†].

[†] This last value is likely closer to 99%, as there was still moisture inside the chamber from previous testing.

Early Results

Of these dilutions no ion trails were seen with 11% ethyl alcohol; faint ion trails were observed at 30 and 60%; faint trails were observed at 77, 87, and 100% ethyl alcohol as well, but could not be duplicated with regularity. The best ion trails were repeatedly observed with an ethyl alcohol content of 63% (12 parts ethanol, 7 parts water).

During these experiments, multiple expansions of the chamber were made with each dilution of alcohol. The pistons were pulled back, dropping the pressure and temperature, causing the supersaturation of the alcohol solution. During this part of the process, the cloud trails would become visible, if they were going to appear. Then the pistons were moved forward again, and the pressure of the chamber was allowed to return to normal. This “rest” period of the chamber took about 2 minutes, the amount of time required to refill the air compressor. Below are some actual images recorded during these tests. Figure 19 shows the chamber without any ion trails. The source is in the center of the plate just to the left of center. Figure 20 shows the same chamber moments later, during the expansion, in which cloud trails are visible.



Figure 19. The interior of the cloud chamber, just before the expansion of the pistons. Note the Am-241 source in the center of the holder, visible just below the wing nut.



Figure 20. The interior of the cloud chamber, just after the expansion of the pistons. Ion trails from alpha radiation are visible within the red circle.

Chapter 4. Conclusion & Discussion

Conclusion

The cloud chamber operating procedure developed during the course of this experiment can be found in Appendix A on page 30. The schematics and operation of the source holder are found in Appendix B.

The cloud chamber was able to obtain recordable ion trails. After testing the chamber with an alpha source, the best supersaturated vapor to use is 63% ethyl alcohol made from 12 parts pure ethanol to 7 parts water. Even though this dilution resulted in the best and most observable ion trails, they were still observed in only half of that dilution's trial runs. As can be noted in the previous figure, the cloud trails have also drifted because of air currents within the chamber. Due to these factors, some recommendations have been made for continuing work on the project.

Future Project Recommendations

The first recommendation would be to use a diffusion cloud chamber instead of a pulsed one. Diffusion cloud chambers operate via a temperature differential and can be "always on". Cheaper demonstrative units use dry ice to achieve this temperature differential, while others use a cooling system on the bottom and can be turned on when needed. The continuous process of creating ion trails in these diffusion chambers can create an obstructed view, so some chambers are created with an "ion trail clearing circuit", which usually consists of a wire inside the chamber that an electrical current can run through. This creates an electric field which pulls the ions towards the wire, clearing the chamber. Some of these units can be purchased entirely prefabricated at a relatively low cost around \$1300. One benefit of diffusion cloud chambers is that it is in a continuous process of creating ion trails, without the need for "resetting" the chamber pressure to its original state. Moreover, diffusion chambers create less air currents, as the process does not rely on air expansions to achieve supersaturation. Lastly, no extra or reduced pressures are required; diffusion chambers are capable of operating at normal atmospheric pressures.

If a pulsed cloud chamber is required for experimentation, an adjustment could be to use mechanical instead of pneumatic pistons. There are two reasons for this, one of which being the relatively slow speed of the pneumatic pistons. Mechanical pistons would not require air pressure to build up in the cylinders before overcoming the friction required to move the pistons, and would thus be faster. The second reason is that mechanical pistons could have different stopping positions, allowing for adjustment to the expansion ratio of the chamber.

Another change that could be made while still using a pulsed cloud chamber would be the material of the main chamber itself. If still using polycarbonate, the use of a more appropriate and longer lasting adhesive would be advisable, as the current adhesive is prone to leaks. An alternative would be to make the main chamber out of a lightweight metal, such as aluminum, with the seams professionally welded, virtually guaranteeing no chamber leaks. This style would require a viewing window, as well as moisture proof lighting for the interior. However, further studies would have to be

performed so see if a hodoscope fabricated from aluminum would be transparent enough to high energy neutrons to be able to serve in TREAT experiments.

One last pulsed cloud chamber modification could be to use a chamber similar to Wilson's original cloud chamber. It consisted of a much smaller main chamber connected to an evacuated chamber. A piston dividing these two would be rapidly drawn back, causing the required rapid expansion. A smaller main chamber would mean that it would be easier to reach the needed expansion ratio. The piston in Wilson's original chamber is also not fighting against the pull of the vacuum, and would move more rapidly than the current pistons. Finally, different expansion ratios could still be achieved by varying the vacuum pressure in the evacuated chamber.

An additional needed modification for the project would be the use of upgraded cameras and recording software. The current recording software available on the computer has limited capabilities. The cameras likewise are unable to have higher framerates necessary to capture the cloud trails, while having a large resolution. Due to advances in camera technology, high-resolution, high-framerate cameras can be procured at a relatively inexpensive cost, some cameras being around \$500-600. These new cameras would likely require the use of wide-angle, low-distortion lenses, in order to fully view the chamber.

To conclude, one of the future directions the cloud chamber project can advance in is neutron research, e.g. finding the location of a neutron source. For this, a different type of gas would be required in the chamber in addition to, or in place of, air. Since neutrons are uncharged, they do not directly produce ions in a cloud chamber for the ion cloud trails. Instead they need to collide with nuclei of similar size so that the recoil protons may be tracked in the chamber. Some researchers have used hydrogen gas to analyze neutrons in a cloud chamber, however it is flammable. Helium gas could be used for neutron detection. This would be more benign than hydrogen, as it is inert and will not interact with any of the chemicals present in any of the lubricants or adhesives in the chamber and pistons. Researchers have successfully used helium in neutron research.³

As indicated earlier, neutron research involving a cloud chamber could potentially be a replacement for a neutron hodoscope. In addition to helium or hydrogen producing recoil protons to be tracked, it is possible to seed the chamber with boron. Due to its large (n,α) reaction cross section, boron captures neutrons and eject alpha particles, which in turn can be tracked in a cloud chamber. A diffusion cloud chamber would likely be better suited for research such as this, as cloud trails would be easier to achieve. Additionally, diffusion chambers are readily available for purchase, even fully assembled. A diffusion chamber operating on dry ice and ethanol with an active area of 50 x 50 cm can be purchased for around \$1300. With a diffusion chamber of this size, using modern camera techniques still shows promise as a replacement for a neutron hodoscope.

An experiment for a neutron hodoscope replacement could potentially be to seed the atmosphere of a cloud chamber with boron or helium gas as discussed above. A strong fast neutron source, such as an Am-Be source, would then be moved outside of the chamber, simulating fissioning fuel movement. As the neutrons enter the chamber they would interact with the seeded gas to produce

ions. In turn, the ions would react with the ethyl alcohol and water vapor to form ion trails. Digital cameras would then record these images and send them to a computer where the chamber reaction could be observed and the source movement could be back-projected.

References

- ¹ “Future Transient Testing of Advanced Fuels”, INL/EXT-09-16392, September, 2009.
- ² Gupta, N. N., and S. K. Ghosh. *A Report on the Wilson Cloud Chamber and Its Applications in Physics*. Review of Modern Physics, 1946. 2nd ed. Vol. 18. 225-290.
- ³ Shaw, D. F. *Scattering of 14.3 MeV Neutrons by 4He Nuclei*. Proceedings of the Physical Society. Section A. 1955: 43-45.
- ⁴ Wilson, J. G. *The Principles of Cloud-Chamber Technique*. Cambridge University Press, 1951.

APPENDICES

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Appendix A:

Cloud Chamber Operation and Checklist

Before turning on the cloud chamber table power sources:

- ☐ Ensure cameras are positioned correctly and connected to computer securely
- ☐ Ensure all valves are closed
- ☐ Ensure the compressors were previously turned off properly

Then:

- ☐ Turn both power sources on (if UPS is not already on)
- ☐ Turn compressors on
- ☐ Close compressor cabinet doors securely
- ☐ If needed, add 50 to 200mL of ethyl alcohol/water mixture through the liquid fill valve

Operation

1. Turn on computer (if not already powered on)
2. If proper procedure was previously followed, the pistons should be in the “in” position
3. Start camera/data recording
4. Open **Air Relief Valve #2** on the right hand side manifold
5. Open the **Pull** valve on the left hand side manifold
6. Pistons should move to the “out” position
7. Close the **Pull** valve

When the total chamber volume reaches the correct level, cloud trails should form.

When data has been gathered and cloud trails have dissipated, begin next steps.

8. Stop data recording (if not set to automatically stop recording)
9. Open **Air Relief Valve #1** on the left hand side manifold
10. Allow the vacuum of the chamber to pull the pistons most of the way back
11. Close **Air Relief Valve #2**
12. **Slightly** open the **Push** valve on the right hand side manifold
13. Pistons should **slowly** move to the “in” position
14. Once pistons are in the “in” position, close the **Push** valve and **Air Relief Valve #1**
15. Repeat steps 3-14 for as many data collecting runs as desired, allowing the compressors to refill, as needed.

Lacking all else, please note: when using the *PUSH* or *PULL* valves, the *Air Relief Valve* on the OPPOSITE manifold must be opened.

When finished collecting data:

- ☐ Ensure the pistons are in the “in” position
- ☐ Close all valves
- ☐ Carefully open compressor cabinet doors
- ☐ Turn compressors off
- ☐ Turn power off
- ☐ Close compressor cabinet doors securely
- ☐ Open chamber air and drain valves, if runs are not planned in the near future
- ☐ Empty drain container as needed
- ☐ Empty Compressors

To empty the compressors:

1. Repeat Operation steps 4-6
2. Open **Air Relief Valve #1** until the pressure has subsided
3. Close all valves
4. Repeat Operation steps 9 & 12
5. Fully open the **PUSH** valve
6. Open **Air Relief Valve #2** until the pressure has subsided
7. Close all valves

Weekly Checklist

- ☐ Check the power cables for any frays or other damage
- ☐ Check the compressor and fan power cables any frays or other damage and are plugged tightly into the power supply
- ☐ Check the computer and monitor power cables any frays or other damage and are plugged tightly into the power supply
- ☐ Check to ensure all hose fittings are tight
- ☐ Empty condensation out of compressors*
 - Leave between 1-3 pounds of pressure in each compressor when during the emptying procedure
 - Locate drain valve on bottom of compressor
 - Place paper towels under drain valve, hold securely
 - Open drain valve, the remaining pressure will force water out of the drain
 - Tip compressor toward drain to ensure all condensation has been drained
 - Repeat for other compressor

*This may need to be done more than once a week, if the compressors have been running frequently.

Appendix B: Source Holder Operation

Figure B-1 shows the source holder main support bar, labeled “1”. The main support bar has ¼-20 screw holes spaced 1 inch apart through the entire length. The attachment bars shown in Figures B-3 & B-4 can be attached to the main support bar with a screw system that can then be rotated to any position needed afterwards (see Figure B-2). To attach one of the attachment bars, simply remove the wing-nut and nylon washer (pictured in the top of the image) and slide the top hole of the attachment bar over the screw, then replace the washer and wing-nut, hand-tightening securely. To re-position the attachment screw system on the main bar, use wrenches to loosen the connecting nut from the locking nut, and fully remove the connecting nut, the rubber washer (1), and the locking nut from the turning knob screw. Then use the knob to remove the screw and reinsert into desired location on the main support bar. Tighten until the rubber washers (2) are squished down slightly. These allow the source holding attachment plates to be easily rotated to any position. Replace the locking nut while leaving a few millimeters of room for movement of rotating the threaded screw; as well as replacing the rubber washer (1), and the connecting nut. Be sure to tighten the connecting nut and the locking nut together.

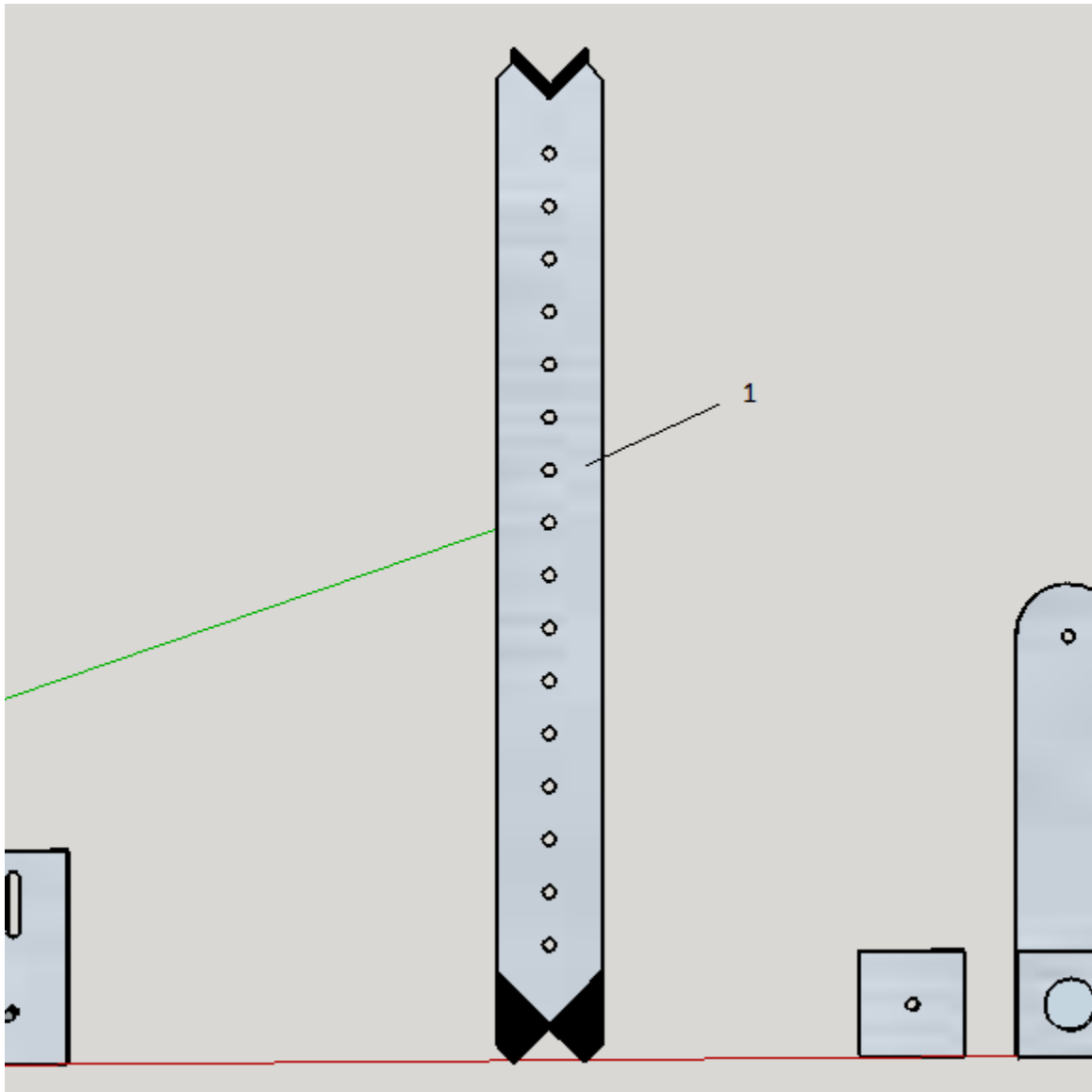


Figure B-1. Source holder main support bar.

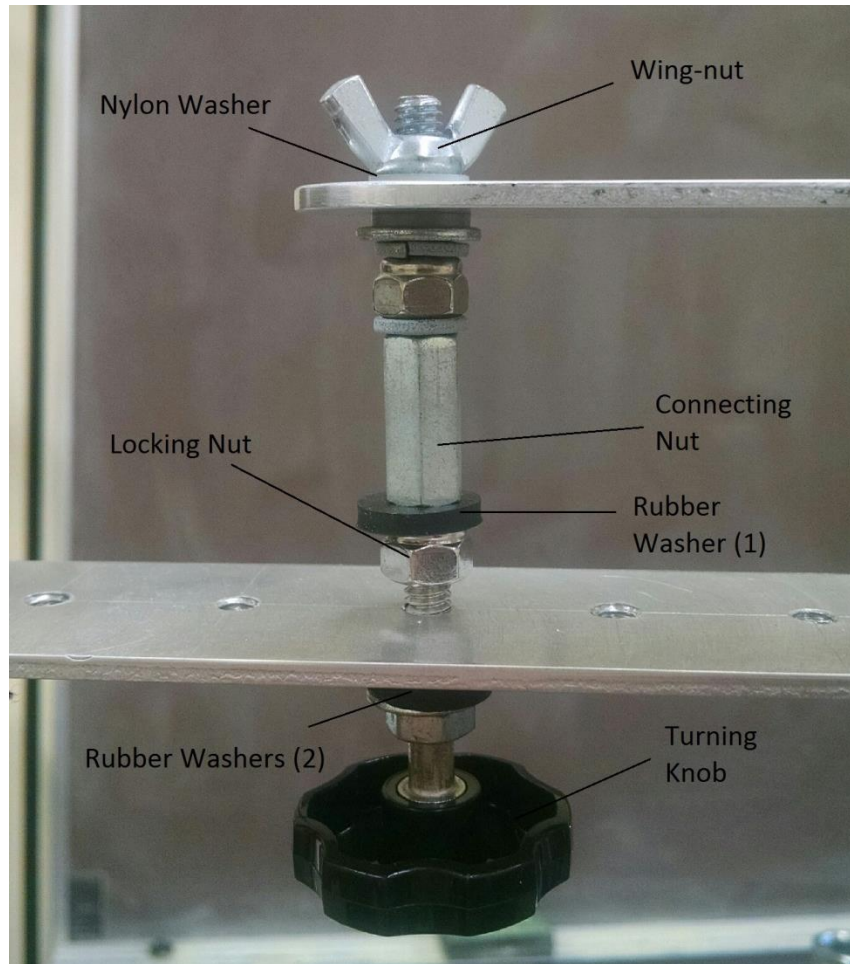


Figure B-2. Main support bar attachment screw system, with turning knob.

Figure B-3 shows the long source holder attachment bars, labeled “2” and “3”. Attachment bar 2 is used to hold disk sources. Piece 2.2 is for the placement of the source, and is attached to bar 2 with sunken flat-top screws. 2.1 is the cover plate for the disk source with a whole to allow radiation to travel through. It is attached with wing-nuts tightened onto screws threaded through all 3 plates. Attachment bar 3 is used to hold needle sources, and 3.1 is a rubber stopper pushed through the bar in the place the needle source is placed.

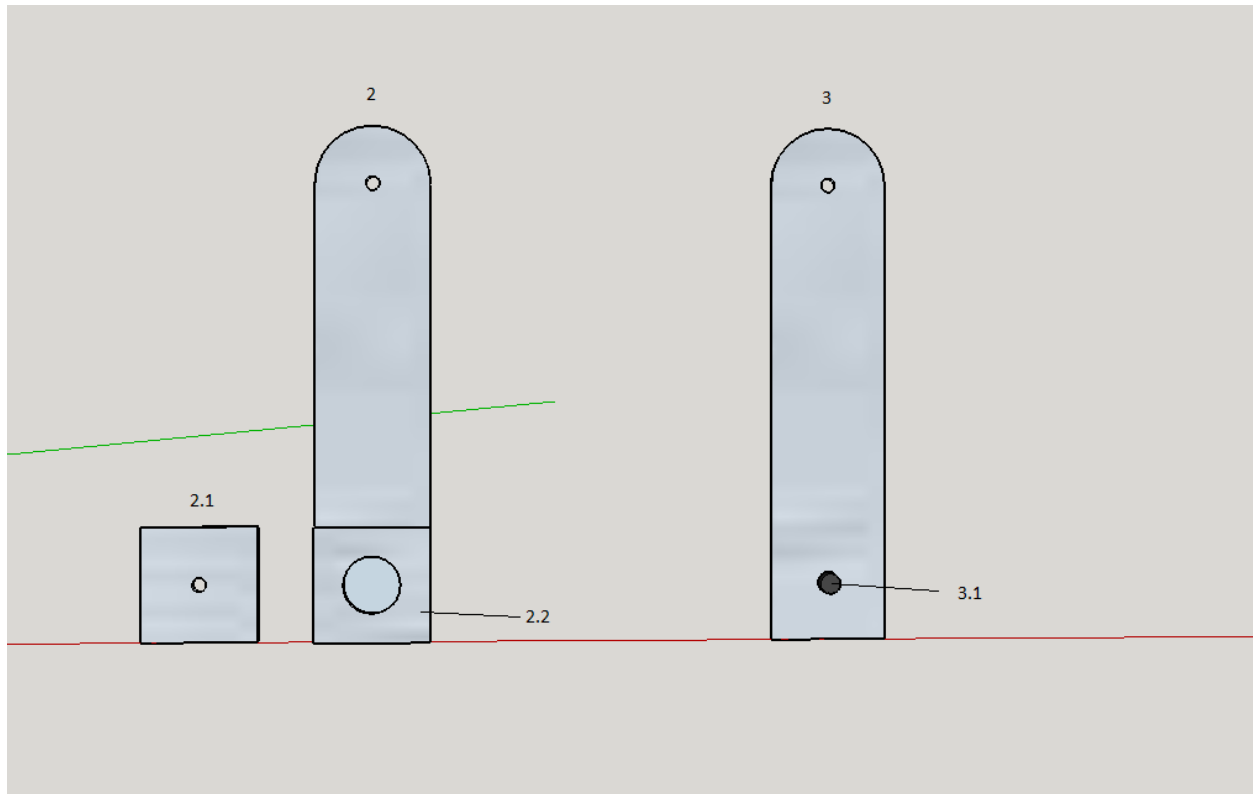


Figure B-3. Long attachment bars.

Figure B-4 shows the short attachment bar with the interchangeable holders. These allow sources to be positioned in even more locations throughout the chamber. Each of the pieces, 4a, 4b, and 4c can attach to the screw at 4.1. Similar to the attachment screw system pictured above, it has a wing nut and a nylon washer that need to be removed to interchange the short pieces. The piece, 4, can then be attached to the main support bar using the attachment screw system. 4a is a disk source holder similar to 2 in Figure B-3 above, and 4b is a needle source holder similar to 3, pictured above. Item 4c is a threaded source holder, with a 10-32 threaded screw used for threading sources onto it. Threaded sources are sometimes called an “add-a-source”.

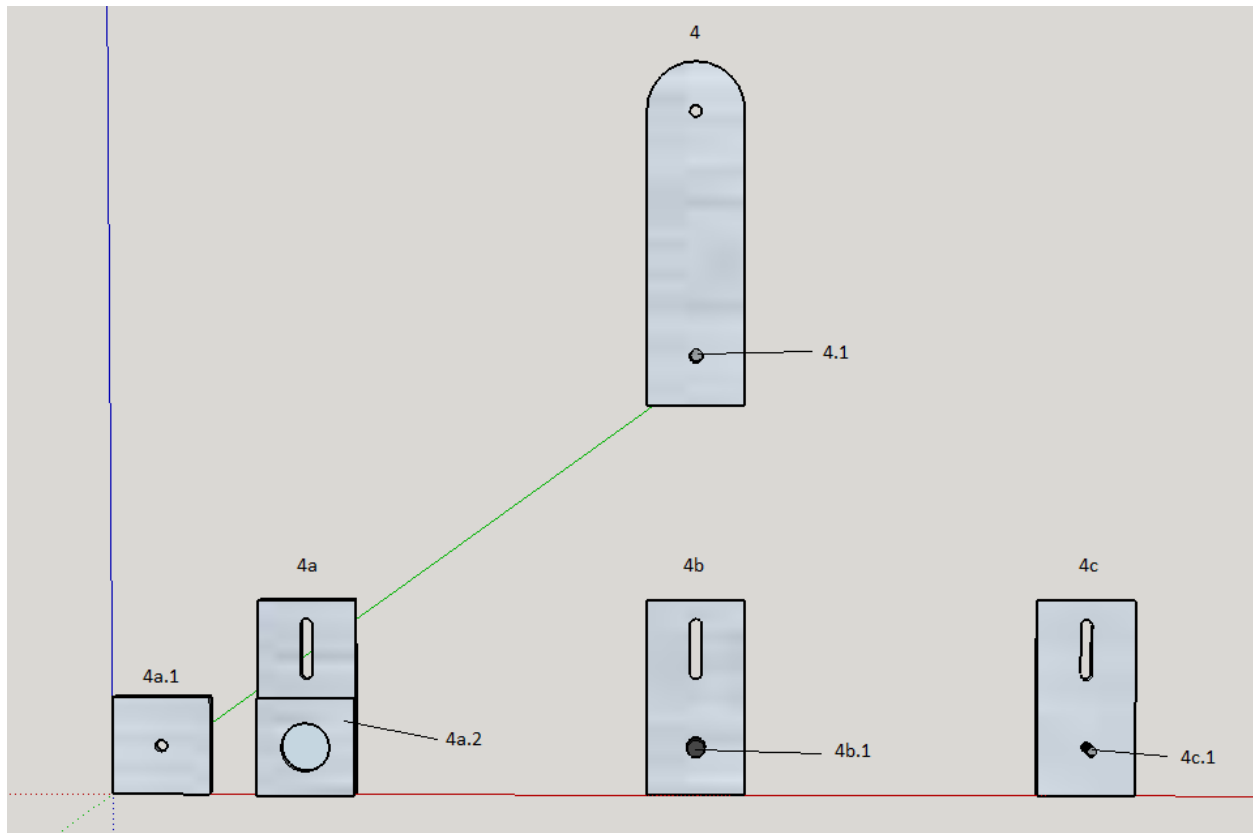


Figure B-4. Short attachment bar with interchangeable holders.

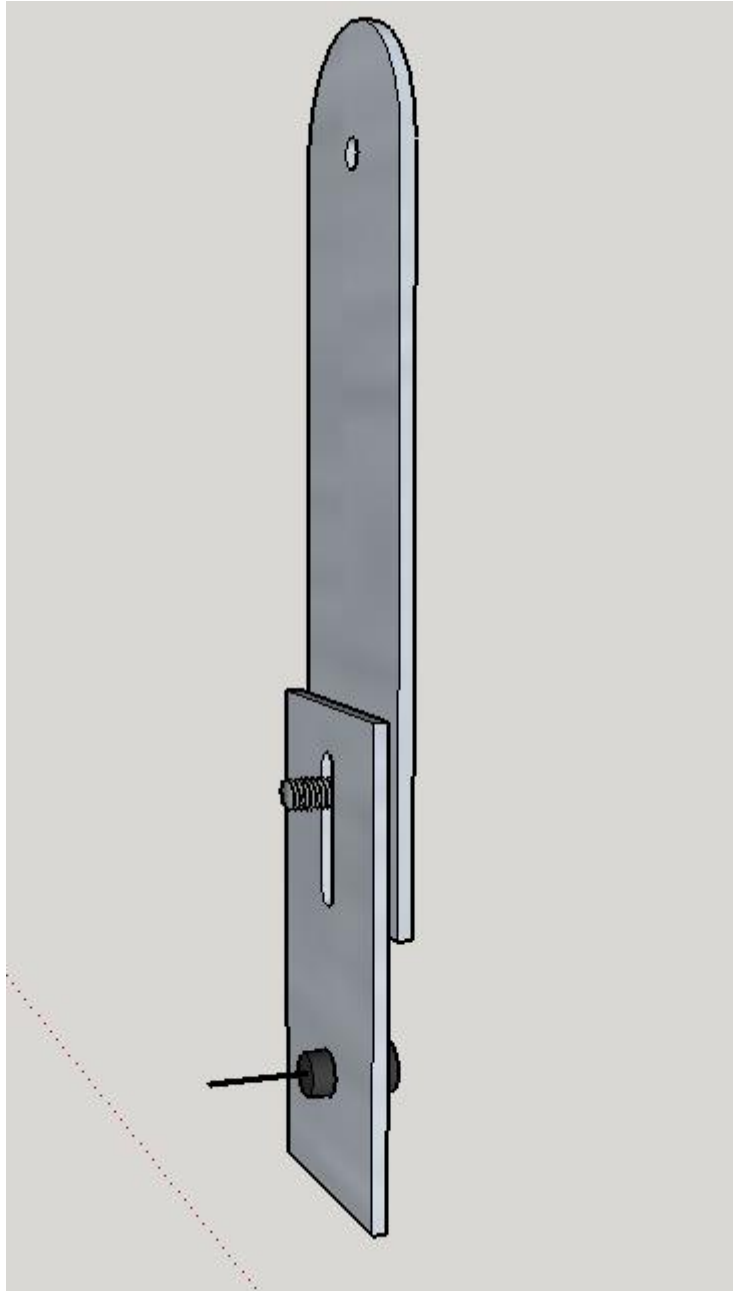


Figure B-5. Short attachment bar with needle source holder, 4b, attached.

Appendix C: Pictures and Diagrams of Alternate Ideas

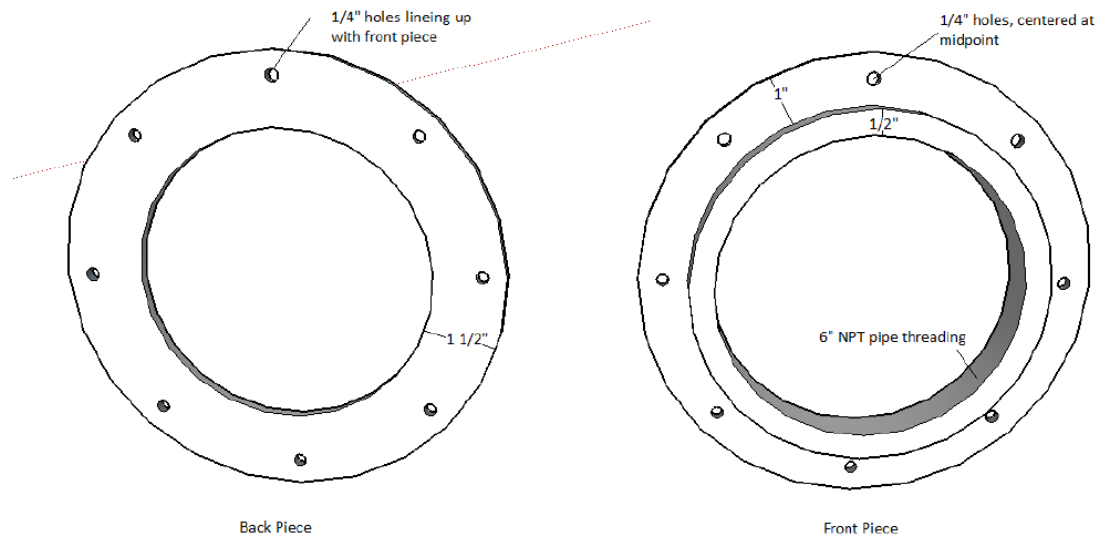


Figure C-1. Alternate flange idea. If used, it would likely have been made from either aluminum or been a PVC flange.

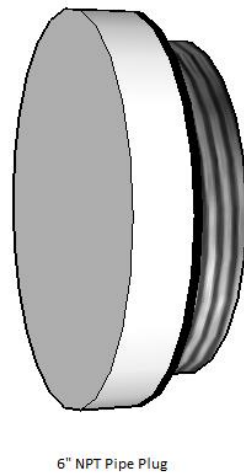


Figure C-2. Pipe plug for the flange in previous figure.

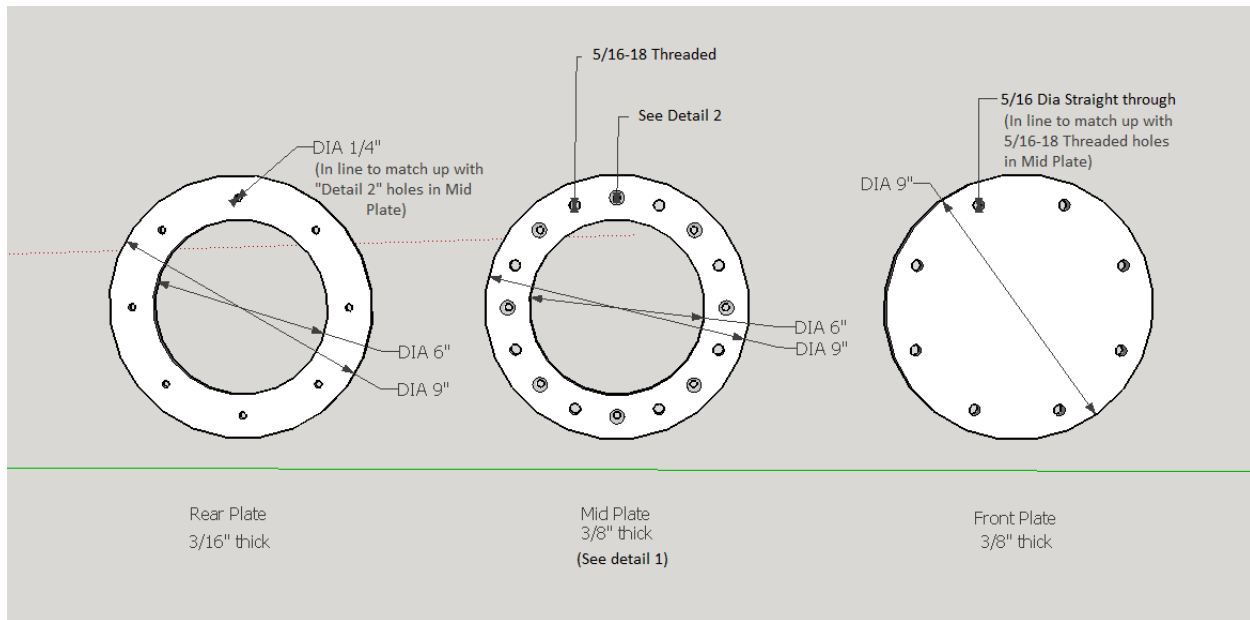


Figure C-3. Another alternate idea for the chamber access port. The rear plate would have gone on the inside of the chamber, and the mid plate on the outside, connected with sunken flat-top screws. Then the front plate could attach to the mid plate, sealing the chamber. It would have been required to remove eight screws each time the cover is removed.

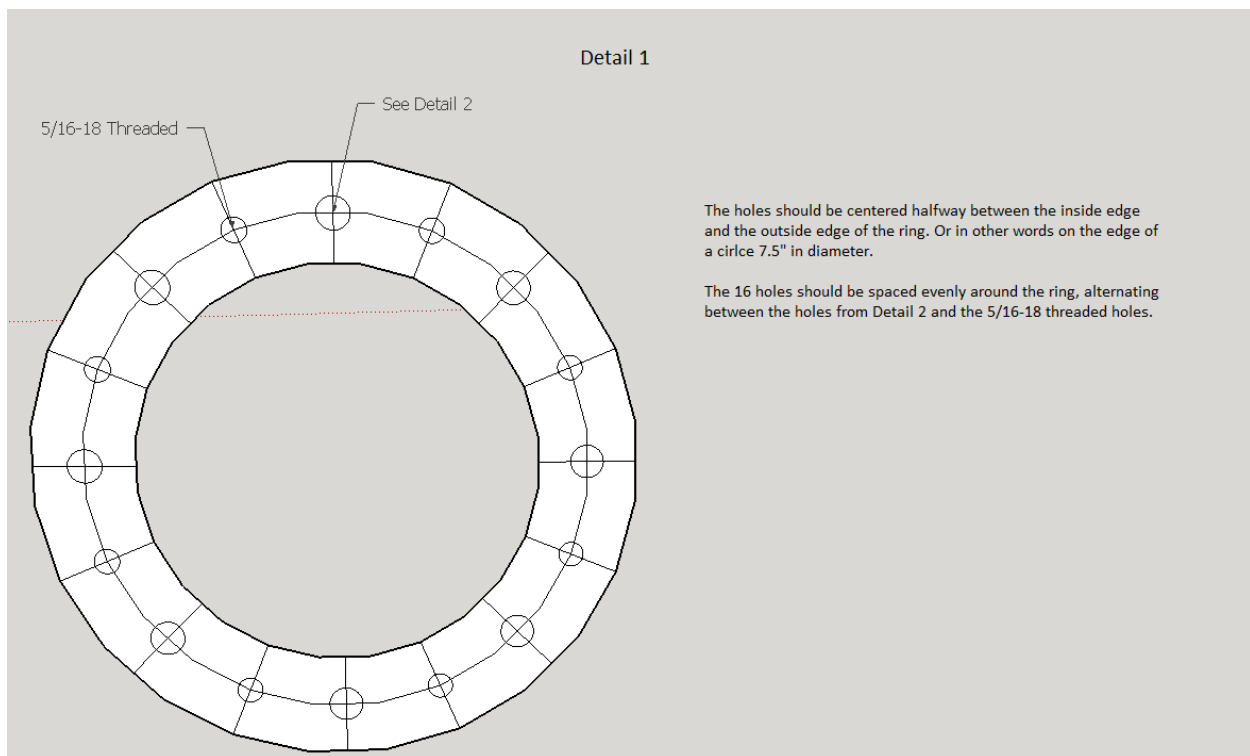


Figure C-4. Close up of the middle plate in previous figure.

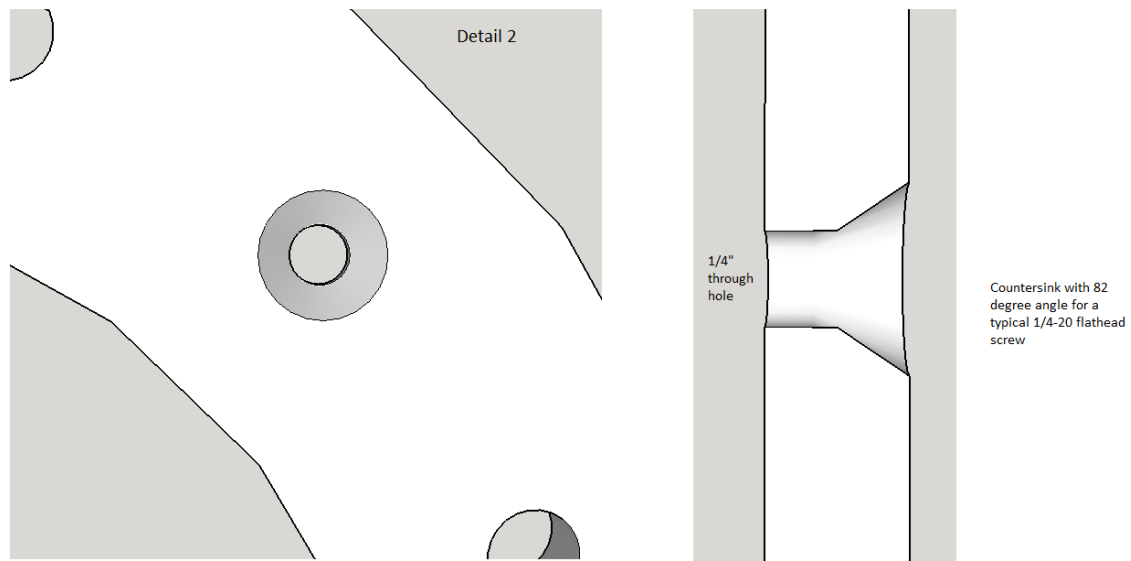


Figure C-5. Close-up of the countersunk hole in middle plate.

Alternate interior source holder

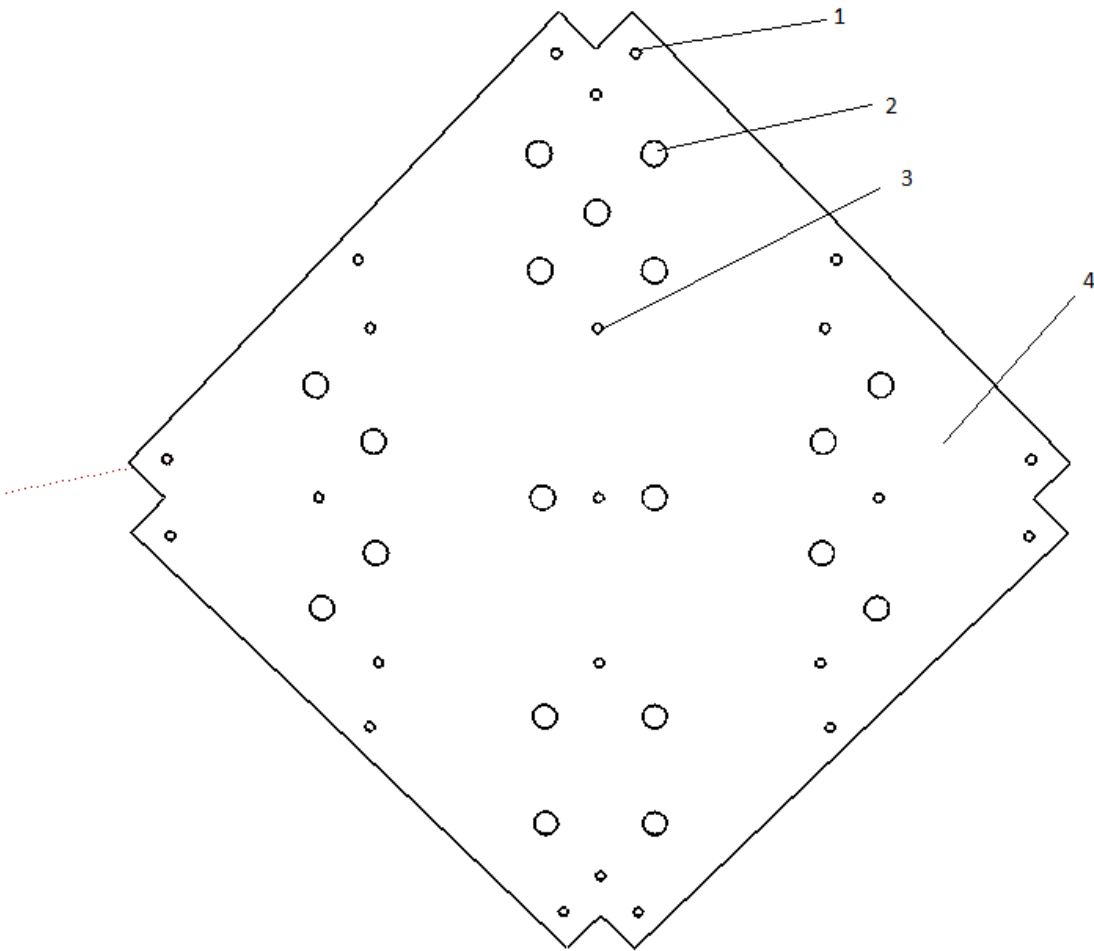


Figure C-6. This figure shows the first of three plates involved in possible interior source holder. This first plate is the cover plate that is closest to the exterior of the chamber. Hole number 1 is a screw hole meant for connecting all three plates. Number 2 is a hole running through all 3 plates, meant for the rubber or cork stoppers of needle sources. Number 3 is for an “add-a-source”. Lastly, position 4 is covering the hole in the middle plate where a disk source would be placed.

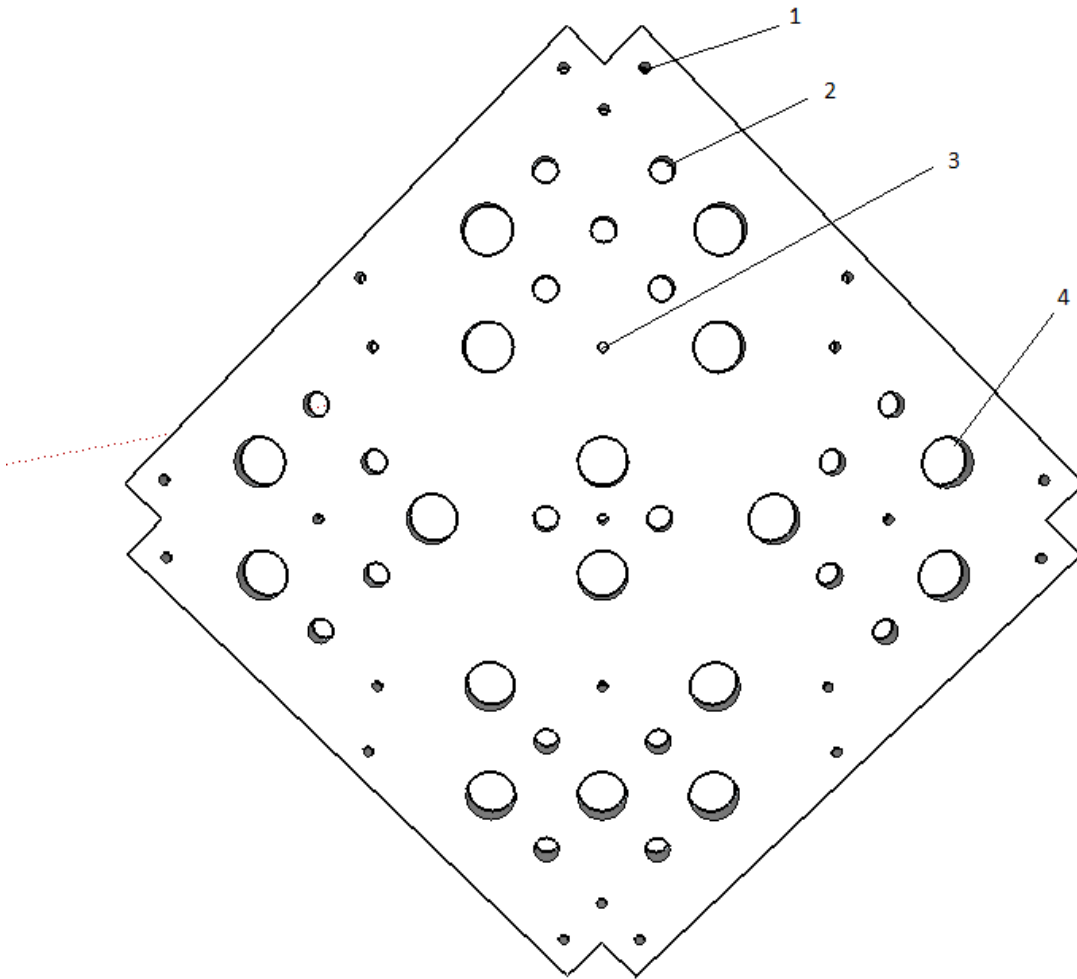


Figure C-7. This is the middle plate of the alternate source holder. Again, hole number 1 is the screw hole connecting all three plates; number 2 is a hole running through all 3 plates, for the use of needle sources; 3 is for an “add-a-source”. Lastly, position 4 here is the actual hole in the middle plate where the disk source would be placed. The source would be placed towards the back plate.

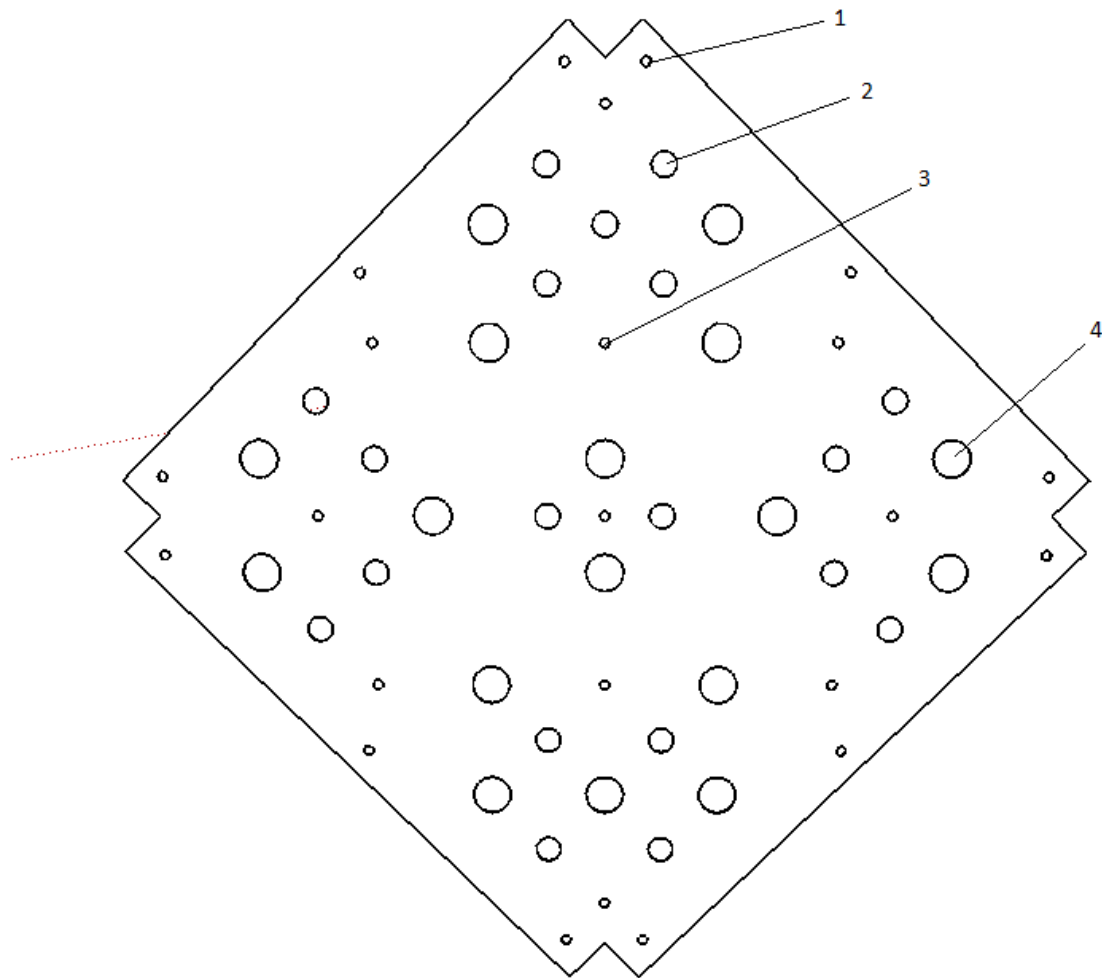


Figure C-8. The back plate of the alternate source holder. The holes 1, 2, & 3 are the exact same as the other 2 plates. The only difference with this plate would be that number 4 is slightly smaller than in the previous plate. This is to provide an edge to keep the disk source from falling out the front of the unit, while still allowing the radiation to travel through.

Appendix D:

Buna-N O-Ring Information (for piston O-rings)

McMaster-Carr; Part # 5018T43

NITRILE OR BUNA N (NBR) Typical Trade Names:

- Chemigum Goodyear Tire & Rubber Co.
- Paracril Uniroyal
- Hyvcar Goodrich Chemical Co.
- Krynac Polysar, Ltd.
- Ny Syn Copolymer Rubber & Chem. Corp.

Buna N or Nitrile is a copolymer of butadiene and acrylonitrile. Acrylonitrile content is varied in commercial products from 18% to 48%. As the nitrile content increases, resistance to petroleum base oils and hydrocarbon fuels increases, but low temperature flexibility decreases. Due to its excellent resistance to petroleum products, and its ability to be compounded for service over a temperature range of -65 to + 275 degrees F (- 54 to +135 degrees C), Nitrile is the most widely used elastomer in the seal industry today. Most military rubber specifications for fuel and oil resistant MS and AN O-rings require nitrile base compounds. It should be mentioned, however, that to obtain good resistance to low temperature with nitrile compounding, it is almost always necessary to sacrifice some high temperature fuel and oil resistance. Nitrile compounds are superior to most elastomers with regard to compression set or cold flow, tear and abrasion resistance. Inherently, they do possess good resistance to ozone, sunlight or weather but this can be substantially improved through compounding. However, since ozone and weather resistance are not always built in, seals from nitrile bases should not be stored near electric motors or other equipment which may generate ozone, or in direct sunlight.

Nitrile Is Recommended for:

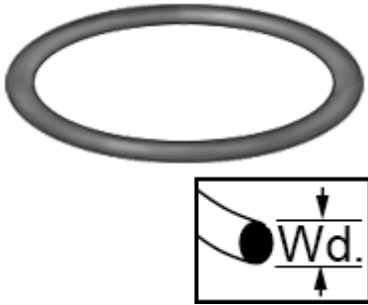
- General purpose sealing.
- Petroleum oils and fluids.
- Cold Water.
- Silicone greases and oils
- Di-ester base lubricants (MIL-L-7808).
- Ethylene glycol base fluids (Hydrolubes)

Nitrile is not recommended for:

- Halogenated hydrocarbons (carbon tetrachloride, trichloroethylene)
- Nitro hydrocarbons (nitrobenzene, aniline)
- Phosphate ester hydraulic fluids (Skydrol, Fyrquel, Pydraul).
- Ketones (MEK, acetone)
- Strong Acids Ozone
- Automotive brake fluid.

AS3578 Buna-N O-Ring

- AS568A Dash Number 433



- 5018T43

AS568A Dash No.	433
-----------------	-----

Fractional Size

ID	5 1/2"
----	--------

OD	6"
----	----

Actual Inch Size

ID	5.475"
----	--------

OD	6.025"
----	--------

Additional Specifications Buna-N-AS3578

Width: 1/4" Fractional (0.275"Actual)

- Buna-N that meets AS3578 has a temperature range of -20° to +212° F. Durometer hardness is A65.

Possible recommended lubricants:

- Dow 111 O-Ring Lubricant (Part number# 21912-02)
- Parker Super O Lube
- Super Lube Silicone base O-ring lubricant

Chemical (Fluid, Gas) Compatibility: Buna-n (Nitrile Rubber)

Commercial Buna-N (Nitrile) rubber compounds are generally resistant to the following list of over 300 chemicals, normally exhibiting little or no effect on the physical properties of the rubber and, therefore, are normally suitable for both dynamic and static seals and gaskets in environments containing them.

51-F-23; Acetamide; Acetylene; Adipic Acid; Aluminum Chloride (aq); Aluminum Fluoride (aq); Aluminum Nitrate (aq); Aluminum Phosphate (aq); Aluminum Sulfate (aq); Alum-NH₃-Cr-K (aq); Ammonia Gas (cold); Ammonium Chloride (aq); Ammonium Nitrate (aq); Ammonium Nitrite (aq); Ammonium Phosphate (aq); Ammonium Sulfate (aq); Amyl Borate; Animal Fats; Aroclor, 1260; Arsenic Acid; Arsenic Trichloride (aq); ASTM #1 Method D-471; ASTM #2 Method D-471; ASTM #3 Method D-471; Barium Chloride (aq); Barium Hydroxide (aq); Barium Sulfate (aq); Barium Sulfide (aq); Beer; Beet Sugar Liquors; Benzene (Ligroin) (Nitrobenzene) (Pet Ether); Boric Acid; Brine; Bunker Oil; Butane; Butter (Animal Fat); Butyl Alcohol; Calcium Chloride (aq); Calcium Hydroxide (aq); Calcium Nitrate (aq); Calcium Sulfide (aq); Cane Sugar Liquors; Carbon Dioxide; Carbon Monoxide; Castor Oil; China Wood Oil (Tung Oil); Citric Acid; Coal Tar (Creosote); Cobalt Chloride (aq); Coconut Oil; Cod Liver Oil; Copper Chloride (aq); Copper Cyanide (aq); Copper Sulfate (aq); Corn Oil; Cottonseed Oil; Creosote (Coal Tar); Cyclohexane; Decane; Denatured Alcohol; Detergent Solutions; Developing Fluids; Diesel Oil; Diethylene Glycol; Dimethyl Ether (Methyl Ether) (Monomethyl Ether); Ethane; Ethyl Alcohol; Ethyl Chloride; Ethyl Silicate; Ethylene; Ethylene Diamine; Ethylene Glycol; Ferric Chloride (aq); Ferric Nitrate (aq); Ferric Sulfate (aq); Fish Oil; Fluoroboric Acid; Fluorocarbon Oils; Fluorolube; Fluorosilicic Acid (Hydrofluosilicic Acid); Freon 113; Freon 114; Freon 115; Freon 12; Freon 13; Freon 13B1; Freon 142b; Freon 152a; Freon 218; Freon 32; Freon C316; Freon C318; Freon MF; Freon TA; Freon TC; Freon TF; Freon T-P35; Fuel Oil; Fumaric Acid; Gelatin; Glucose; Glue ; Glycerin; Glycols; Hexane; Hexyl Alcohol; Hydraulic Oil (Petroleum); Hydrofluosilicic Acid (Fluosilicic Acid); Hydrogen Gas; Isooctane; Kerosene; Lactic Acid (Cold); Lard; Lead Nitrate (aq); Ligroin (Benzene) (Nitrobenzene) (Pet Ether); Lime Bleach; Linseed Oil; Liquefied Petroleum Gas; Lubricating Oils (Petroleum); Magnesium Chloride (aq); Magnesium Sulfate (aq); Malic Acid; Mercury; Mercury Chloride (aq); Methane; Methyl Alcohol; Methyl Ether (Dimethyl Ether) (Monomethyl Ether); MIL-1-8660 B; MIL-A-8243 B; MIL-C-4339 C; MIL-C-8188 C; MIL-F-16929 A ; MIL-F-16958 A; MIL-F-17111; MIL-F-19605; MIL-F-25172; MIL-F-25524 A; MIL-F-25558 B (RJ-1); MIL-F-25576 C (RP-1); MIL-F-25656 B; MIL-F-5566; MIL-F-5602; MIL-F-7024 A; MIL-G-10924 B; MIL-G-15793; MIL-G-18709 A; MIL-G-2108; MIL-G-23827 A; MIL-G-25013 D; MIL-G-25537 A; MIL-G-25760 A; MIL-G-27343; MIL-G-7118 A; MIL-G-7187; MIL-G-7421 A; MIL-G-7711 A; MIL-H-13862; MIL-H-13866 A; MIL-H-13919 A; MIL-H-22072; MIL-H-25598; MIL-H-46001 A; MIL-H-46004; MIL-H-5559 A; MIL-H-5606 B (Red Oil); MIL-H-6083 C; MIL-H-7083 A; MIL-H-81019 B; MIL-I-27686 D; MIL-J-5161 F; MIL-J-5624 G JP-3, JP-4, JP-5; Milk; MIL-L-10295 A; MIL-L-10324 A; MIL-L-11734 B; MIL-L-15017; MIL-L-15018 B; MIL-L-15019 C; MIL-L-17331 D; MIL-L-17353 A; MIL-L-17672 B; MIL-L-18486 A; MIL-L-19701; MIL-L-2104 B; MIL-L-2105 B; MIL-L-21260; MIL-L-21568 A; MIL-L-22396; MIL-L-23699 A; MIL-L-25336 B; MIL-L-25681 C; MIL-L-25968; MIL-L-26087 A; MIL-L-27694 A; MIL-L-3150 A; MIL-L-3503; MIL-L-46000 A; MIL-L-46002; MIL-L-5020 A; MIL-L-6082 C; MIL-L-6085 A; MIL-L-6086 B; MIL-L-6387 A; MIL-L-644 B; MIL-L-7808 F; MIL-L-7870 A; MIL-L-8383 B; MIL-L-9000 F; MIL-L-9236 B; MIL-O-11773; MIL-O-6081 C; MIL-S-3136 B Type I; MIL-S-3136 B Type II; MIL-S-3136 B Type III; MIL-S-3136 B Type IV; MIL-S-3136 B Type V; MIL-S-3136 B Type VI; MIL-S-3136 B Type VII; MIL-S-81087; Mineral Oil; Monomethyl Ether (Methyl Ether) (Dimethyl Ether); Monovinyl Acetylene; Natural Gas; Neats Foot Oil; Nickel Chloride (aq); Nickel Sulfate (aq); Niter Cake; Nitrobenzene (Petroleum Ether); Nitrogen; O-A-548 b; Octadecane; Olive Oil; Palmitic Acid; P-D-680; Peanut Oil; Petroleum-Below 250°F; Plating Solution-Others; Potassium Chloride (aq); Potassium Cupro Cyanide (aq); Potassium Cyanide (aq); Potassium Nitrate (aq); Potassium Sulfate (aq); Potassium Dichromate (aq); Producer Gas; Propane; Propyl Alcohol; P-S-661 b; Pyranol, Transformer Oil; Red Oil (MIL-H-5606); RJ-1 (MIL-F-25558 B); RP-1 (MIL-F-25576 C); Sal Ammoniac; Salt Water; Sewage ; Silicone Greases; Silicone Oils; Soap Solutions; Soda Ash; Sodium Bicarbonate (aq) (Baking Soda); Sodium Bisulfite (aq); Sodium Borate (aq); Sodium Chloride (aq); Sodium Cyanide (aq); Sodium Metaphosphate (aq); Sodium Phosphate (aq); Sodium Silicate (aq); Sodium Sulfate (aq); Soybean Oil; Stannic Chloride (aq); Stannous Chloride (aq); Stoddard Solvent; Sucrose Solution; Tannic Acid; Tartaric Acid; Transformer Oil; Transmission Fluid Type A; TT-I-735 b; TT-N-95 a; TT-N-97 B; TT-S-735 Type I; TT-S-735 Type II; TT-S-735 Type III; TT-S-735 Type IV; TT-S-735 Type V; TT-S-735 Type VI; TT-S-735 Type VII; Tung Oil (China Wood Oil); Turpentine; Vegetable Oils; Versilube F-50; VV-G-632; VV-G-671c; VV-I-530a; VV-K-211d; VV-K-220a; VV-L-800; VV-L-820b; VV-L-825a Type I; VV-L-825a Type II; VV-O-526; VV-P-216a; Water; Whiskey, Wines; White Oil; Wood Oil; Zeolites; Zinc Chloride (aq); Zinc Sulfate (aq)

Appendix E:

Material Safety Data Sheets

Ethyl Alcohol.....	50
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MATERIAL SAFETY DATA SHEET

ETHYL ALCOHOL

RICHARD-ALLAN SCIENTIFIC
4481 Campus Drive
Kalamazoo Michigan 49008
800-522-7270 U.S.A. 8:00 a.m. - 5:00 p.m. EST

CHEMTREC (800) 424-9300
24 hours Everyday

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1. SUBSTANCE IDENTIFICATION

SUBSTANCE: **Ethyl Alcohol**

CATALOG NUMBER: 9200-1, 9200-5, 9200-55

TRADE NAMES/SYNONYMS: Denatured alcohol; Denatured Ethanol, SDA-1 Alcohol fully denatured, Denatured spirits, Proprietary solvent general-use, Denatured Proprietary Ethanol

CHEMICAL FAMILY: Hydroxyl, aliphatic

2. COMPOSITION AND INGREDIENTS INFORMATION

Ethyl alcohol	CAS# 64-17-5	<92%
Methyl alcohol	CAS# 67-56-1	<4%
Ethyl Acetate	CAS# 141-78-6	<4%
Methyl isobutyl ketone	CAS# 108-10-1	<1%
Heptane	CAS# 142-82-5	<1%

3. HAZARDS IDENTIFICATION

NFPA RATINGS (SCALE 0-4):	Health=1	Fire=3	Reactivity=0
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Danger: Poisonous
 Vapor Harmful
 May be fatal or cause blindness if swallowed
 Cannot be made nonpoisonous
 Flammable liquid

Ethanol is a clear liquid with a characteristic sweet alcohol odor. It is a flammable liquid with an irritating vapor. It is poisonous by ingestion due to the denaturant. Vapor is harmful and may be fatal or cause blindness if swallowed. It cannot be made non-poisonous. Affects central nervous system. Causes irritation to eyes, skin and respiratory tract. Ethanol is a probable human carcinogen (IARC) with experimental tumorigenic and teratogenic data.

Primary Routes of Exposure: Inhalation, ingestion, skin and eye contact.

Acute Effects: Irritation of mucus membranes, eyes, nose, throat and membranes of the upper respiratory tract. Central nervous system depression resembling intoxication by ethyl alcohol. Excitation is followed by impaired motor coordination, slurred speech, sensory disturbances such as blurred and double vision, drowsiness, loss of appetite, and an inability to concentrate. Irritation to skin results in cracking and flaking due to defatting action of the alcohol. Splashes may cause temporary pain and blurred vision. High exposure can cause gastritis, blindness and death.

Chronic Effects: Irritation of the eyes, nose, throat and mucus membranes of the upper respiratory tract. Central nervous system effects such as dizziness and sleepiness can occur, as can dryness, irritation and inflammation of the skin. The denaturants in this formulation may cause chronic kidney, liver, nervous system and blood cell damage. Continued ingestion of small amounts may result in blindness. Chronic exposure may cause cancer or a change in female fertility index.

Potential Health Effects:

- Inhalation may cause irritation of mucous membranes and respiratory tract.
- Eye contact may cause eye irritation.
- Skin contact may cause irritation, rashes or burning sensation.
- Ingestion may cause gastritis, intoxication, blindness and in acute cases, death.

4. FIRST-AID PROCEDURES

Inhalation: Remove from exposure area to fresh air immediately. If breathing has stopped, give artificial respiration. If breathing is difficult give oxygen. Get medical attention immediately.

Eye Contact: Flush eyes immediately with large amounts of water, occasionally lifting upper and lower lids for at least 25-20 minutes. If irritation persists, seek medical attention.

Skin Contact: Remove contaminated clothing and shoes immediately. Wash effected area with soap or mild detergent and large amounts of water. If irritation persists, seek medical attention.

Ingestion: ANTIDOTE: (Ingestion) Unless unconscious or convulsing, give large amounts of water or milk to induce vomiting. NOTE TO PHYSICIAN: When plasma methanol concentrations exceed 20 mg/dl and when there is evidence of acidosis or visual abnormalities, a 10% solution of ethanol in 5% dextrose administered intravenously is a safe, effective antidote.

5. FIRE FIGHTING PROCEDURES

FIRE AND EXPLOSION HAZARD:

DANGEROUS FIRE HAZARD WHEN EXPOSED TO HEAT OR FLAME.

VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL A CONSIDERABLE DISTANCE TO A SOURCE OF IGNITION AND FLASH BACK.

VAPOR-AIR MIXTURES ARE EXPLOSIVE ABOVE FLASHPOINT.

FLASH POINT: 55 F (13 C) (CC)
LOWER EXPLOSIVE LIMIT: 3.3%
FLAMMABILITY CLASS (OSHA): IB

UPPER EXPLOSIVE LIMIT: 19%
AUTOIGNITION TEMP.: 793 F

FIRE FIGHTING MEDIA: DRY CHEMICAL, CARBON DIOXIDE, WATER SPRAY OR ALCOHOL-RESISTANT FOAM (1993 Emergency Response Guidebook, Dot P 5800.5).

FOR LARGER FIRES, USE WATER SPRAY, FOG OR ALCOHOL-RESISTANT FOAM (1993 Emergency Response Guidebook, Dot P 5800.5).

FIRE RESPONSE PROCEDURES: Move container from fire area if you can do it without risk. Apply cooling water to sides of containers that are exposed to flames until well after fire is out. Extinguish only if flow can be stopped. Use flooding amounts of water as fog: solid streams may be ineffective. Cool containers with flooding amounts of water from as far a distance as possible. Avoid breathing vapors; keep upwind. Fire fighters should wear full protective clothing and NIOSH approved self-contained breathing apparatus with full-face piece operated in the pressure demand or other positive pressure mode. Water spray can be used to extinguish fires and cool fire-exposed containers. Water may be used to flush spills away from exposures and to dilute spills to non-flammable mixtures.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Dangerous fire hazard when exposed to heat. Flashback along vapor trail may occur. Vapor may explode if ignited in an enclosed area. **POISONOUS GASES ARE PRODUCED IN THE FIRE. CONTAINERS MAY EXPLODE IN FIRE.**

6. ACCIDENTAL RELEASE MEASURES

SMALL SPILL: Shut off ignition sources. Do not touch spilled material. Stop leak if you can do it without risk. Ventilate the area of spill or leak. Use water spray to reduce vapors. For small spills, take up with sand or other absorbent material and place into sealed containers for disposal.

LARGE SPILLS: Shut off ignition sources. Dike far ahead of spill for disposal. Use water spray to reduce vapors. No smoking, flames, or flares in spill area! Keep unnecessary people away. Ventilate area. Wear appropriate protective equipment, isolate hazard area and deny entry. Take up spill with vermiculite, dry sand, earth or a similar material and deposit into sealed containers. For very large spills, call fire department immediately.

REPORTABLE QUANTITY (RQ): 5000 POUNDS

The Superfund Amendments and Reauthorization Act (SARA) Section 304 requires that a release equal to or greater than the reportable quantity for this substance be immediately reported to the local emergency planning committee and the state emergency response commission (40 CFR 355.40). If the release of this substance is reportable under CERCLA Section 103, the national response center must be notified immediately at (800) 424-8882 or (202) 426-2675 in the metropolitan Washington, D. C. area (40 CFR 302.6).

7. HANDLING AND STORAGE

General Handling: Keep away from heat, sparks and flame. Keep container tightly closed and upright to prevent leakage. Use only with adequate ventilation. Prevent buildup of vapors. Extinguish all pilot lights and turn off heater, non explosion-proof electrical equipment and other sources of ignition during use and until all vapors are gone. Avoid contact with eyes. Avoid prolonged or repeated breathing of vapor. Avoid prolonged or repeated contact with skin. Wash thoroughly after handling.

OBSERVE ALL FEDERAL, STATE AND LOCAL REGULATIONS WHEN STORING OR DISPOSING OF THIS SUBSTANCE. FOR ASSISTANCE, CONTACT THE DISTRICT DIRECTOR OF THE ENVIRONMENTAL PROTECTION AGENCY. STORE IN ACCORDANCE WITH 29 CFR 1910.126.

Ethanol is a class IB flammable liquid (NFPA). Follow maximum allowed pile heights specified in the BOCA codes or the NFPA manual. Local fire authorities should be notified for storage of this material in any quantity. Local permits are required for storage in warehouse quantities.

Store in a well-ventilated place, away from sources of ignition and direct sunlight. Store at 15 C to 30 C (59 F to 86 F). In laboratory quantities, store away from oxidizing material, mineral acids, and chloroform. In warehouse quantities, follow NFPA and BOCA guidelines for storage of flammable liquids. Store Ethanol in areas equipped with automatic sprinklers or fire extinguishing system. Containers of this material may be hazardous when empty. Since emptied containers retain product residues, assume emptied containers to have the same hazard qualities as full containers.

8. EXPOSURE CONTROL (PERSONAL PROTECTION)

VENTILATION: Provide local exhaust ventilation and/or general dilution ventilation to meet published exposure limits.

RESPIRATION: Where the potential exists for exposures over 1000 ppm, use a NIOSH approved respirator with and organic vapor cartridge/canister. More protection is provided by a full facepiece respirator than by a half-mask respirator, and even greater protection is provided by a powered-air purifying respirator.

FOR FIRE FIGHTING AND OTHER IMMEDIATELY DANGEROUS TO LIFE OR HEALTH CONDITIONS:

Any self-contained breathing apparatus that has a full face piece and is operated in a pressure-demand or other positive-pressure mode. Any supplied-air respirator that has a full face piece and is operated in a

pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive-pressure mode.

CLOTHING: Employee must wear appropriate protective (impervious) clothing and equipment to prevent repeated or prolonged skin contact with this substance.

GLOVES: Employee must wear appropriate protective gloves to prevent contact with this substance. ACGIH recommends NITRILE rubber or VITON as good to excellent protective materials.

EYE PROTECTION: Employee must wear splash-proof or dust-resistant goggles to prevent eye contact with this substance.

EMERGENCY EYE WASH: Where there is any possibility that an employee's eyes may be exposed to this substance, the employer should provide an eye wash fountain within the immediate work area for emergency use.

EXPOSURE LIMITS:

100% Ethyl Alcohol (Ethanol):

1000 ppm (1900 mg/m³) OSHA TWA
1000 ppm (1880 mg/m³) ACGIH TWA
1000 ppm (1900 mg/m³) NIOSH RECOMMENDED TWA
1000 ppm (1900 mg/m³) DFG MAK TWA;
2000 ppm (3760 mg/m³) DFG MAK 60 MINUTE PEAK, MOMENTARY VALUE, 3 TIMES/SHIFT

100% Methyl Alcohol (Methanol):

200 ppm (260 mg/m³) OSHA TWA (SKIN); 250 ppm (325 mg/m³) OSHA STEL
200 ppm (262 mg/m³) ACGIH TWA (SKIN); 250 ppm (325 mg/m³) ACGIH STEL
200 ppm (260 mg/m³) NIOSH RECOMMENDED TWA (SKIN);
250 ppm (325 mg/m³) NIOSH RECOMMENDED STEL
200 ppm (260 mg/m³) DFG MAK TWA (SKIN);
400 ppm (520 mg/m³) DFG MAK 30 MINUTE PEAK, AVERAGE VALUE, 4 TIMES/SHIFT

100% Ethyl Acetate:

400 ppm (1400 mg/m³) OSHA TWA
400 ppm (1400 mg/m³) ACGIH TWA
400 ppm (1400 mg/m³) NIOSH RECOMMENDED TWA
400 ppm (1400 mg/m³) DFG MAK TWA;
800 ppm (2800 mg/m³) DFG MAK 5 MINUTE PEAK, MOMENTARY VALUE, 8 TIMES/SHIFT

MEASUREMENT METHOD: CHARCOAL TUBE; CARBON DISULFIDE; GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION.

9. PHYSICAL DATA

DESCRIPTION: Clear, colorless liquid

MELTING POINT: -172 F (-114 C)

VAPOR PRESSURE: 40 mmHg @ 20 C

FLASH POINT: 13 C(55 F)

VAPOR DENSITY: 1.6

SOLVENT SOLUBILITY: Ether, Chloroform, Water, Alcohol

BOILING POINT: 172 F (78 C)

SPECIFIC GRAVITY: 0.8

SOLUBILITY IN WATER: soluble

DENSITY (20C) = 0.7893g/mL

MOLECULAR WEIGHT = 46.07

10. STABILITY AND REACTIVITY INFORMATION

REACTIVITY: Stable under normal temperatures and pressures (Ethyl alcohol, methyl alcohol, and isopropyl alcohol)

INCOMPATIBILITIES: ETHYL ALCOHOL (ETHANOL):

ACETIC ANHYDRIDE AND SODIUM HYDROGEN SULFATE: Possible explosion.

ACETYL CHLORIDE: Violent reaction.

ACETYL BROMIDE: Violent reaction.

ALKALI METALS: Liberates flammable hydrogen gas.

ALUMINUM HYDROXIDE AND SILVER (I) OXIDE: Formation of explosive silver nitride.

BARIUM PERCHLORATE: Formation of explosive compound.

BROMINE PENTAFLUORIDE: Ignition and explosions are possible.
 CALCIUM HYPOCHLORITE: Possible explosion.
 CHLORINE TRIOXIDE: Violent reaction.
 CHLORYL PERCHLORATE: Possible ignition.
 CHRONIC ANHYDRIDE: Ignition.
 CHROMIUM TRIOXIDE: Possible ignition.
 CHROMYL CHLORIDE: Ignition.
 DIOXYGEN DIFLUORIDE: Possible explosion.
 DISULFURIC ACID AND NITRIC ACID: Possible ignition.
 DISULFURYL DIFLUORIDE: Violent reaction.
 FLUORINE NITRATE: Explosion.
 HYDROGEN PEROXIDE: Formation of highly explosive shock-sensitive compound.
 HYDROGEN PEROXIDE-SULFURIC ACID MIXTURE: Explosion.
 IODINE HEPTAFLUORIDE: Ignition.
 IODINE-MERCURIC OXIDE-METHYL ALCOHOL MIXTURE: Possible explosion.
 IODINE AND PHOSPHORUS: Formation of explosive ethane iodide.
 MANGANESE PERCHLORATE AND 2,2-DIMETHOXY PROPANE: Possible explosion.
 MERCURIC NITRATE: Formation of explosive compound.
 NITRIC ACID: Violent reaction.
 NITROSYL PERCHLORATE: Possible explosion.
 OXIDIZERS (STRONG): Fire and explosion hazard.
 PERCHLORATES: May form explosive compound when mixed.
 PERCHLORIC ACID: Explosion.
 PERMANGANIC ACID: Ignition or explosion.
 PERMANGANATES AND SULFURIC ACID: Explosion.
 PEROXYDISULFURIC ACID: Possible explosion.
 PHOSPHORUS(III) OXIDE: Ignition.
 PLATINUM: Ignition.
 POTASSIUM: Violent reaction.
 POTASSIUM DIOXIDE: Violent reaction, possible explosion.
 POTASSIUM PERCHLORATE: Possible explosion.
 POTASSIUM PERMANGANATE: Possible explosion.
 POTASSIUM TERT-BUTOXIDE: Ignition.
 RUTHENIUM(VIII) OXIDE: Formation of explosive compound.
 SILVER AND NITRIC ACID: Formation of explosive compound.
 SILVER NITRATE: Formation of explosive compound.
 SILVER PERCHLORATE: May form explosive compound when mixed.
 SODIUM-AIR: Possible explosion.
 SODIUM HYDRAZIDE: May cause violent explosion on contact.
 SODIUM PEROXIDE: Violent reaction.
 SULFURIC ACID AND SODIUM DICHROMATE: Possible explosion.
 TETRACHLOROSILANE: Violent reaction.
 URANIUM HEXAFLUORIDE: Violent reaction.
 URANYL PERCHLORATE: May form explosive compound when mixed.
 See also alcohols.

METHYL ALCOHOL (METHANOL):

ACETYL BROMIDE: Violent reaction with formation of hydrogen bromide.
 ALKYLALUMINUM SOLUTIONS: Violent reaction.
 ALUMINUM: Corrodes.
 BARIUM PERCHLORATE: Distillation yields highly explosive alkyl perchlorate.
 BERYLLIUM HYDROXIDE: Violent reaction, even at -196 C.
 BROMINE: Vigorously exothermic reaction.
 CALCIUM CARBIDE: Violent reaction.
 CHLORINE: Possible ignition and explosion hazard.
 CHLOROFORM AND SODIUM HYDROXIDE: Explosive reaction.
 CHROMIUM TRIOXIDE (CHRONIC ANHYDRIDE): Possible ignition.
 CYANURIC CHLORIDE: Violent reaction.
 DICHLOROMETHANE: Possible ignition and explosion.

DIETHYL ZINC: Possible ignition and explosion.
 HYDROGEN PEROXIDE + WATER: Explosion hazard.
 IODINE + ETHANOL + MERCURIC OXIDE: Explosion hazard.
 LEAD: Corrodes.
 LEAD PERCHLORATE: Explosion hazard.
 MAGNESIUM: Violent reaction.
 MAGNESIUM (POWDERED): Mixtures are capable of detonation.
 METALS: Incompatible.
 NICKEL: Possible ignition in the presence of nickel catalyst.
 NITRIC ACID (CONCENTRATED): Mixtures of greater than 25% acid may decompose violently.
 OXIDIZERS (STRONG): Fire and explosion hazard.
 PERCHLORIC ACID: Explosion hazard.
 PHOSPHOROUS TRIOXIDE: Possible violent reaction and ignition.
 PLASTICS, RUBBER, COATINGS: May be attacked.
 POTASSIUM: Possible dangerous reaction.
 POTASSIUM HYDROXIDE + CHLOROFORM: Exothermic reaction.
 POTASSIUM TERT-BUTOXIDE: Fire and explosion hazard.
 SODIUM + CHLOROFORM: Possible explosion.
 SODIUM HYPOCHLORITE: Explosion hazard.
 Hazardous polymerization has not been found to occur under normal temperatures and pressures. SODIUM METHOXIDE + CHLOROFORM: Violent reaction.
 SULFURIC ACID: Fire and explosion hazard.
 ZINC: Explosion hazard.

DECOMPOSITION: Thermal decomposition products may include toxic and hazardous fumes by formaldehyde and oxides of carbon.

POLYMERIZATION: Hazardous polymerization has not been found to occur under normal temperatures and pressures.

11. TOXICOLOGICAL INFORMATION

100% ETHYL ALCOHOL (ETHANOL): skn-rbt 400mg open MLD
 skn-rbt 500mg/24H SEV
 eye-rbt 100mg/24H MOD
 orl-rat LD50:7060mg/kg
 inh-rat LC50:20000ppm/10H
 orl-hmnLDLo:1400mg/kg
 Mutagenic data (RTECS); reproductive effects data (RTECS); tumorigenic data (RTECS).

100% METHYL ALCOHOL (METHANOL): skn-rbt 500mg/24H MOD
 eye-rbt 40mg MOD
 orl-rat LD50:5627mg/kg
 inh-rat LC50:64000ppm/4H
 orl-man TDLo:3429mg/kg: EYE
 orl-hmn LDLo:428mg/kg: EYE,PUL
 orl-hmn LDLo:4g/kg: EYE, PUL, GIT
 inh-hmn TCLo:300ppm: EYE, CNS, PUL
 Mutagenic data (RTECS); reproductive effects data (RTECS).

100% ETHYL ACETATE: eye-hmn 400ppm
 ihl-hmn TCLo: 400 ppm: NOSE, EYE, PUL
 orl-rat LD50: 5620 mg/kg
 ihl-rat LC50: 1066 ppm/8H
 orl-rbt LD50: 4935 mg/kg

12. ECOLOGICAL INFORMATION

Acute toxic effects of Ethanol may include death of animals, birds, or fish and death or low growth rate in plants. Acute effects are seen two to four days after animals or plants come into contact with a toxic chemical substance. Chronic effects may include shortened lifespan, reproductive problems, lower fertility, and changes in appearance or behavior. Chronic effects can be seen long after first exposure(s) to a toxic chemical. Ethanol has slightly acute and chronic toxic effects to aquatic life. It has caused germination and size decrease and other injury to agricultural and ornamental crops

13. DISPOSAL GUIDELINES

Ethanol is a toxic mixture of ethyl & methyl alcohol, with ethyl acetate and very small amounts of methyl isobutyl ketone, and heptane.

RCRA: The unused product is a RCRA hazardous waste if discarded. The RCRA ID number is: D001 or the appropriate spent solvent code.

DISPOSAL MUST BE IN ACCORDANCE WITH STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE, 40 CFR 262

OTHER DISPOSAL CONSIDERATIONS: The waste material should be treated and/or disposed of at site authorized to handle hazardous chemical waste. Appropriate Federal, State and Local Regulatory Authorities should be contacted before discharge, treatment or disposal of waste material.

The information offered here is for the product as shipped. Use and/or alterations to the product such as mixing with other materials may significantly change the characteristics of the material and alter the RCRA classification and the proper disposal method.

14. TRANSPORT INFORMATION

Proper shipping name: Ethyl alcohol solutions

Hazard class or Division: 3

Identification Numbers: UN1170

Packing Group: II

Label(s) required (if not excepted): Flammable Liquid

Special Provisions: T1 refers to transportation of IM portable tanks

Packaging authorizations: Exceptions:None

Non-bulk packaging: 173.202: for liquid hazardous material in packing group II

Bulk-packaging: 173.242: for liquid hazardous material

Quantity Limitations: Passenger aircraft or railcar: 5L

Cargo aircraft only: 60 L

15. REGULATORY INFORMATION

SARA TITLE III (Superfund Amendment and Reauthorization Act)

SECTION 302 AND 304: Extremely Hazardous Substance List (40 CFR 355)- Not Listed

SECTION 311: Hazard Categorization (40 CFR 370)- Acute, Chronic, and Fire

SECTION 313: Toxic Chemicals Listing (40 CFR 372.65)- Listed as a toxic chemical

CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act)

SECTION 102(A) Hazardous Substances (40 CFR 302.4)- Listed

Reportable Quantity - 5,000 pounds.

SECTION 101(14) Reportable Quantity: 5,000 lbs

RCRA (Resource Conservation and Recovery Act.)

40 CFR 261.21 Hazardous Waste Number: D001 or appropriate Spent Solvent Number.

NJ-RTK (New Jersey- State Right To Know)

Environmental Hazardous Substance List: Listed, Substance # 0844

ATF (Alcohol Tobacco and Firearms)

General Use Formula

TSCA (Toxic Substance Control Act)

This is a listed substance; CAS # 64-17-5

16. OTHER INFORMATION:

Ethyl Alcohol as manufactured by Richard-Allan Scientific, is intended for legal use in laboratories and manufacturing environments.



Material Safety Data Sheet

Issue Date: March 25, 2010

Revised Date: August 26, 2014

Reason: Removed item no's

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product name: Super Lube® Silicone Lubricating Grease

Product use: Lubricant Compound

Company address:

Synco Chemical Corporation
24 DaVinci Dr., P.O. Box 405
Bohemia, NY 11716

Contact Information:

Telephone: 631-567-5300
Emergency telephone: 800-424-9300
Internet: www.super-lube.com
E-Mail: info@super-lube.com

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Physical state: Semi-solid

Color: Translucent

Odor: Mild

WHMIS hazard class: Not Hazardous

HMIS codes: Health - 1

Fire - 1

Physical - 0

WARNING:

MAY CAUSE SKIN OR EYE IRRITATION

Relevant routes of exposure:

Skin, Eyes

Potential Health Effects

Inhalation:

Not expected to cause respiratory tract irritation during normal conditions of use.

Skin contact:

Repeated or prolonged contact may be irritating to skin.

Eye contact:

Contact with eyes may cause irritation.

Ingestion:

Not expected under normal conditions of use.

Existing conditions aggravated by exposure:

None generally recognized.

See Section 11 for additional toxicological information.

3. COMPOSITION/INFORMATION ON INGREDIENTS

<u>Components</u>	<u>%</u>	<u>ACGIH TLV</u>	<u>OSHA PEL</u>	<u>OTHER</u>
Polydimethylsiloxane 63148-62-9	<90	None	None	None
Silane, dichlorodimethyl- reaction products with silica 68611-44-9	<9	10mg/m ³ TWA	6mg/m ³ TWA	None
Polytetrafluoroethylene 9002-84-0	<7	None	None	
Polyglycol 025322-69-4	<1	None	None	AIHA WEEL is 50 ppm Total 10mg/m ³ aerosol only

4. FIRST AID MEASURES

Inhalation:	Inhalation not likely.
Skin contact:	After contact with skin, wash immediately with plenty of water (using soap, if available). Get medical attention if symptoms develop and persist.
Eye contact:	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get medical attention.
Ingestion:	Do not induce vomiting. Get medical attention.

5. FIRE-FIGHTING MEASURES

Flash point:	>572° F (300° C) TCC
Auto ignition temperature:	Not Determined
Flammable/Explosive limits-lower %:	No Data
Flammable/Explosive limits-upper %:	No Data
Extinguishing media:	Carbon dioxide (CO2). Dry chemical. Foam.
Special fire fighting procedures:	None
Unusual fire or explosion hazards:	None
Hazardous combustion products:	Oxides of carbon, silica, formaldehyde.
Sensitivity to mechanical impact:	Not Determined

Sensitivity to static discharge: Not Determined

6. ACCIDENTAL RELEASE MEASURES

Environmental precautions: Spilled material may make surface slippery. Do not flush to drain.

Clean-up methods: Scrape up and dispose of in accordance with local and national regulations.

7. HANDLING AND STORAGE

Handling: Good manufacturing procedures should be followed in handling and storage.

Storage: Keep in cool, dry area.

Incompatible products: Oxidizing agents.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering controls: Local exhaust ventilation is recommended when general ventilation is not sufficient to control airborne contamination.

Respiratory protection: If personal exposure cannot be controlled below applicable limits by ventilation, wear a properly fitted organic vapor/particulate respirator approved by NIOSH.

Skin protection: Chemical resistant, impermeable gloves.

Eye/face protection: Safety glasses with side-shields.

See Section 3 for exposure limits.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	Semi-solid
Color:	Translucent
Odor:	Mild
Odor Threshold:	Not available
Vapor pressure:	Not determined
pH:	Not applicable
Boiling point/range:	Not available
Melting point/range:	Not available
Specific gravity:	.96
Vapor density:	Not available
Evaporation rate:	Not available
Solubility in water:	Not soluble
Partition coefficient (n-octano/water):	Not determined
VOC content:	Essentially zero

10. STABILITY AND REACTIVITY

Stability:	Stable
Hazardous polymerization:	Will not occur.
Hazardous decomposition products:	Thermal: Dimethylcyclsiloxanes, Hydrogen fluoride. Oxidative/Thermal: Formaldehyde
Incompatibility:	Oxidizing agents.
Conditions to avoid:	None known

11. TOXICOLOGICAL INFORMATION

Product toxicity data:	Not available
Toxicologically synergistic products:	Not available

Refer to the following for irritancy of Product, Sensitization to Product, Carcinogenicity, Reproductive Toxicity, Teratogenicity, and Mutagenicity.

Ingredient Toxicity Data & Carcinogen Status

Components	LD50s & LC50s	Other LD50s and LC50s	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen	ACGIH-Carcinogen
Polydimethyl-siloxane 63148-62-9	Oral LD50 (Rat) >5000 mg/kg	Dermal LD50 (Rat) >2000 mg/kg	No	No	No	No
Silane, dichlorodimethyl reaction products with silica 68611-44-9	Oral LD50 (Rat) >5000 mg/kg	Inhalation LC50 (Rat) >0.477 mg/l/4h	No	No	No	No
Polytetrafluoroethylene 9002-84-0	Not Determined	None	No	No	No	No
Polyglycol 025322-69-4	Oral LD50 (Rats) >2,000 mg/kg	None	No	No	No	No

Literature Referenced Target Organ & Other Health Effects

Components	Health Effects/Target Organs
Polydimethyl-siloxane 63148-62-9	No target organs
Silane, dichlorodimethyl reaction products with silica 68611-44-9	No target organs
Polytetrafluoroethylene 9002-84-0	Irritant
Polyglycol 025322-69-4	No target organs

12. ECOLOGICAL INFORMATION

Ecological information:

General Notes: Water hazard class 1 (self assessment): slightly hazardous for water. Do not allow undiluted product or large quantities of it to reach ground or sewage systems.

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

Recommended method of disposal: Dispose of in accordance with federal and local regulations.

14. TRANSPORT INFORMATION

Transportation of Dangerous Goods – Ground:

Proper shipping name:	Not regulated
Hazardous class or division:	None
Identification number:	None
Packing group:	None

International Air Transportation (ICAO/IATA):

Proper shipping name:	Not regulated
Hazardous class or division:	None
Identification number:	None
Packing group:	None

Water Transportation (IMO/IMDG):

Proper shipping name:	Not regulated
Hazardous class or division:	None
Identification number:	None
Packing group:	None
Marine pollutant:	None

15. REGULATORY INFORMATION

Canada Regulatory Information

CEPA DSL/NDL Status: All components are listed on or are exempt from listing on the Domestic Substances List.

United States Regulatory Information

TSCA 8 (b) Inventory Status: All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.

SECTION 16: OTHER INFORMATION

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Product Regulations.

Data prepared by Environment protection department.

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