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Electric Spray Aerosol Generator

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2004/2005 OURE

ABSTRACT

The 2004-2005 OURE research project was to devise and execute a test matrix specifically designed to evaluate the performance of the Electric Spray Aerosol Generator (ELSPRY). The first phase, for the 2003-2004 year, was to research the Electric Spray Aerosol Generator, and then to build it. This year there were two parts as well, the assembly and the testing, each of which had to be carefully monitored. The assembly of the parts also includes the testing of the individual pieces to ensure that all were working properly. This was key to determine if the ELSPRY was functioning properly.

INTRODUCTION

For the 2003-2004 OURE Project, the Electric Spray Aerosol Generator (ELSPRY) was to be built for the reason of replacing the nebulizer with something that would produce smaller particles. The nebulizer is only capable of producing particles greater than twenty nanometers in size, although smaller particles are often needed. In order to get particles less than twenty nanometers, a furnace has to be used. The furnace is not a reliable source of getting the small particles for two reasons. First, the furnace takes about four hours to heat to a suitable temperature, leaving no time to actually do what is needed. Second, the furnace can only produce aerosols from compounds that will sublimate at high temperatures yet not be decomposed at these temperatures. Cloud and Aerosol Science (CASL) would like to use a wider variety of compounds for challenge aerosols.

The ELSPRY is designed to work by first taking liquid solution, for example distilled water with NaCl, and putting it into a vial that sits in the pressure chamber. This chamber can hold large pressures; the vial chamber has been tested up to 55 psi. The capillary tube is grounded to the high voltage power supply, which allows the particles to become charged. The pressure pushes the liquid solution up through the capillary tube. At the end of the capillary tube, very small solution droplets are pulled from the capillary tube by an equal, opposite charge on an aluminum plate setting in front of the tube. The solution droplets are dried by an annular flow of dry, particle free air. The dried particles are then pulled through this aluminum plate and taken to the bipolar charger, which neutralizes the particles. This is where the particles exit the ELSPRY, and go on through the other parts of the system, where the particles will be counted and sized.

The first part of the project was to put the system together. The system needed to include, a high voltage power supply, a source of CO2, particle free house compressed air, filters, a Condensation Nucleus Counter, pumps, a ballast tank, a differential mobility analyzer (DMA), bipolar chargers, mass flow meters, and the ELSPRY. The DMA had to be re assembled for concentration vs. particle diameter testing. After all pieces of the system were pulled together, there was an amount of testing the parts to make sure that they were all working. We did this testing by generating commercially available standardized particles of known diameter (90 nm) of polystyrene latex (PSL) with the nebulizer and performing a size sweep to make sure everything was working well. The measured diameter was 103 nm, which is comparable to what we usually measure with other DMAs and the 90 nm PSL.

The next thing to be tested was the spray of the capillary tube, making sure the pressure chamber up through the capillary tube was working well. This proved to show that there was a leak in the pressure from the chamber, which was fixed with a sealant on the nylon ferrule. After doing this, the capillary tube flow was measured in respect to the pressure in the vial holder. The pressure was increased to find larger flows, showing the optimum pressure to be 5psig, giving a flow of 600 μL/min. The graph and some data are provided in appendix 1. This number needs to be lowered to be more similar to that shown in the journal article describing the commercially available ELSPRY, but that has not been achieved as of yet. Also, at the same time, there seemed to be a problem with the end of the capillary tube; the end was too flat to release the droplets off of the end, so they dripped off of the bottom of the tube, which incited another modification. The capillary tube was then shaped into a cone. This helped the droplets come off of the end of the capillary. Next, the 3rd piece of the ELSPRY was put together with the preceeding parts; this is the high voltage plate and its holder. Once this was placed on, it stopped the particles from going through, so this too had to be modified. It was originally 1/8 inch diameter, modified to ¼ inch diameter. While this piece was being modified, it was realized that the high voltage connection was not very well attached to the aluminum plate. So, while it was out, there were 2 new holes drilled to allow the high voltage wire to attach to the plate. This ensures that the high voltage wire will not fall out in the middle of an experiment, or in a move.

After all of the modifications and initial testing were accomplished, the system was ready to be tested for actual data. First, the pressure was changed; the ELSPRY works better, when all assembled, at around 45 psig. Next, the high voltage was increased

up to 6000 V. At 6000 V, however, there seemed to be a corona discharge, which caused an instability in the output concentration. The voltage was arcing from the tip of the capillary to the plate. Decreasing the voltage to 5000 V proved to not help the arcing problem. This needs to be looked at more in depth in the future; it has not been fixed. The DMA was then used to make size sweeps. Everything except DMA voltage was held constant. The voltage (AV) for the DMA ran from 12V to 6000V initially, showing that there is nothing trailing above 1000 V, and there seemed to be a peak at around 200 V. These size sweeps were continued back and forth through the DMA voltages. Also, there were backgrounds done to make sure that the particles that were being seen were not part of the background. The background proved to be insignificantly small, and not part of what was seen during the size sweeps. The data taken was then transferred to Gaussian curve fit in PEAKFIT.MCD, a MathCad application written by Dr Otmar Schmid, to compute the diameter selected by a DMA. This proved that there was a peak at around 25 nm. This is significantly smaller than the particles produced by a nebulizer, which are around 100 nm.

There still seams to be much to do with this instrument; all of the problems are not worked out yet. Also, there are some projects that are planned for shortly in the future. These include: using HNO_3 and sugar concentrations in the aerosol generator, varying the distance between the capillary and the high voltage plate, working on the pulsing of the high voltage (which may be fixed by the use of the HNO_3 in the solution in the vial), working on the overall stability of the concentration versus time, and finding the optimum of the flows of CO_2 and particle free house air, and the optimum high voltage.

ACKNOWLEDGMENTS

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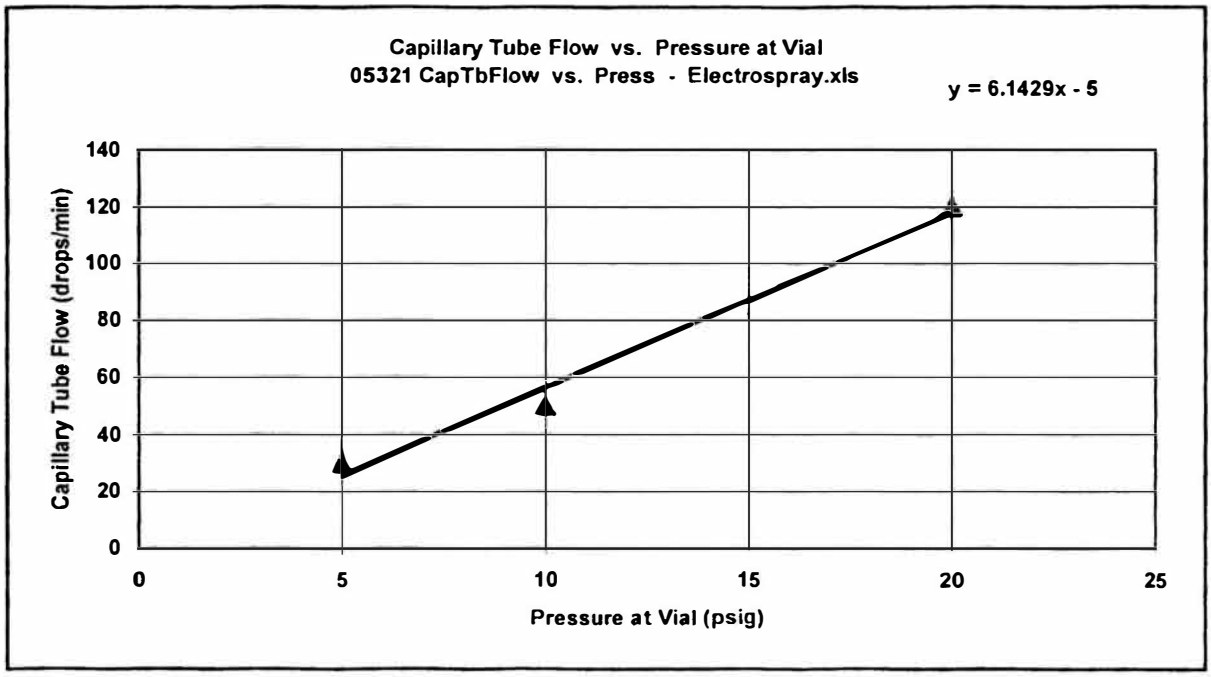
REFERENCES

Chen, Da-Ren, Pui, David Y. H. (1995). "Electrospraying of Conducting Liquids for Monodisperse Aerosol Generation in the 4nm to 1.8μm Diameter Range." J. Aerosol Sci., 26, 963-977.

05321 CapTbFlow vs. Press - Electrospray.xls

Date	Time	dt (sec)	Drops	Press (psig)	Flow (drops/min)	Q-cc (cc/min)	Q-L (L/m)	Q-micrL (microL/m)
05321	1515	30	15	5	30	0.6	0.0006	600
		30	25	10	50	1	0.0010	1000
		15	30	20	120	2.4	0.0024	2400



Gaussian curve fit: differential conc vs size

Data fr 05331 215p

The location of the maximum is: $Max_{gauss} = 25.3$ nm

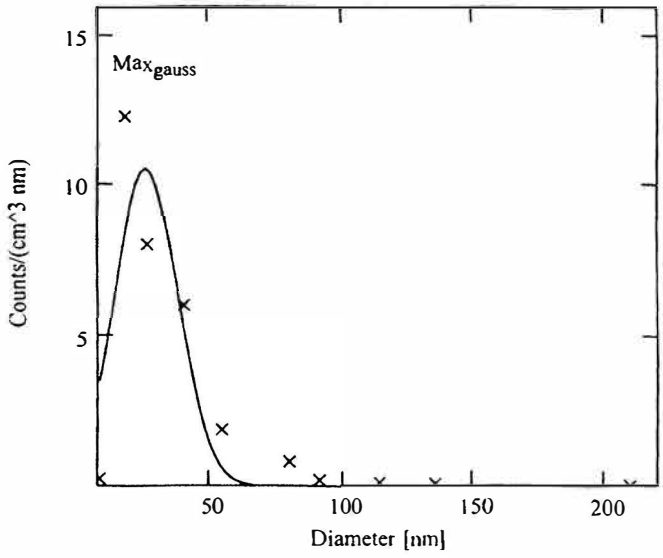
Correlation coeff. r^2 $Rsqr_G = 0.797$

Root mean square deviation (normalized to maximum of diff. conc) $SD_G = 0.227$

$\sigma_{diffconc} = 12.12$ nm

$T = 293.2\,K$

$p = 972.2\,hPa$



$\frac{\sigma_{diffconc}}{Max_{gauss}} = 0.478$

$Q_s = 24.522 \frac{liter}{min}$

$\beta = 0.056$

Gaussian curve fit: differential conc vs size

Data fr 05331 230p

The location of the maximum is: $Max_{gauss} = 29.6$ nm

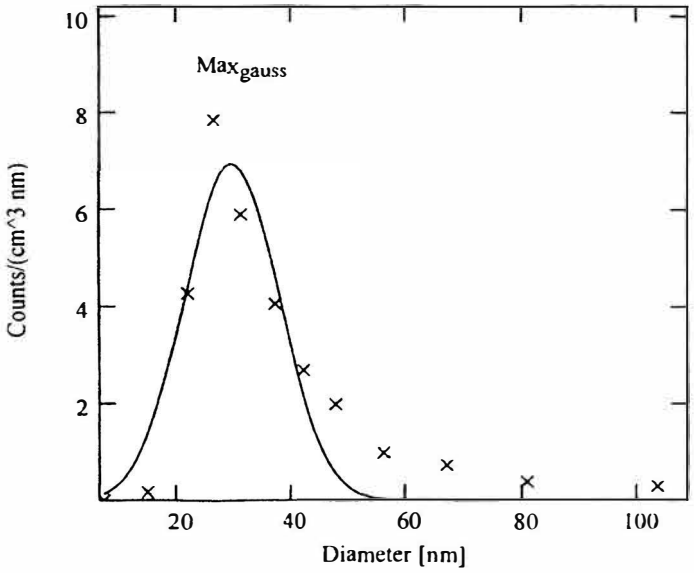
Correlation coeff. r^2 $Rsqr_G = 0.896$

Root mean square deviation (normalized to maximum of diff. conc) $SD_G = 0.153$

$\sigma_{diffconc} = 8.10$ nm

$T = 293.2\,K$

$p = 972.2\,hPa$



$\frac{\sigma_{diffconc}}{Max_{gauss}} = 0.274$

$Q_s = 24.522 \frac{liter}{min}$

$\beta = 0.056$

Gaussian curve fit: differential conc vs size

Data fr 05331 234p

The location of the maximum is: $Max_{gauss} = 24.4$ nm

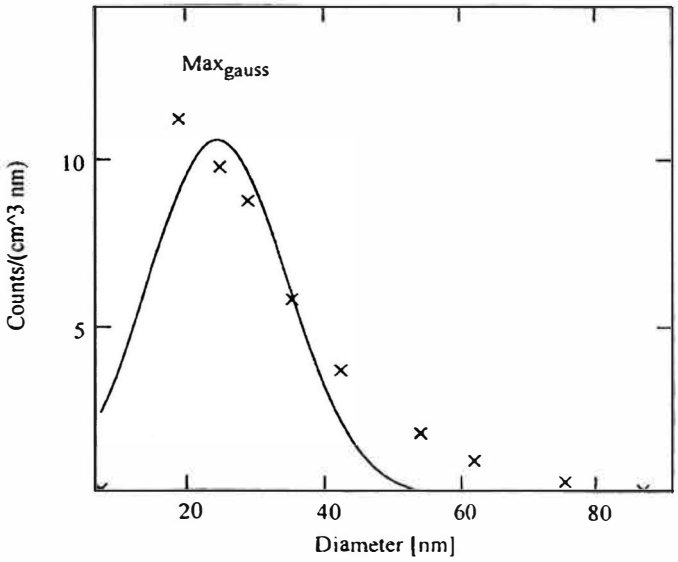
$\sigma_{diffconc} = 10.08$ nm

Correlation coeff. r^2 $Rsqr_G = 0.903$

$T = 293.2\,K$

Root mean square deviation (normalized to maximum of diff. conc) $SD_G = 0.163$

$p = 972.2\,hPa$



$\frac{\sigma_{diffconc}}{Max_{gauss}} = 0.413$

$Q_s = 24.522 \frac{liter}{min}$

$\beta = 0.056$

Gaussian curve fit: differential conc vs size

Data fr 05331 253p

The location of the maximum is: $Max_{gauss} = 196.9$ nm

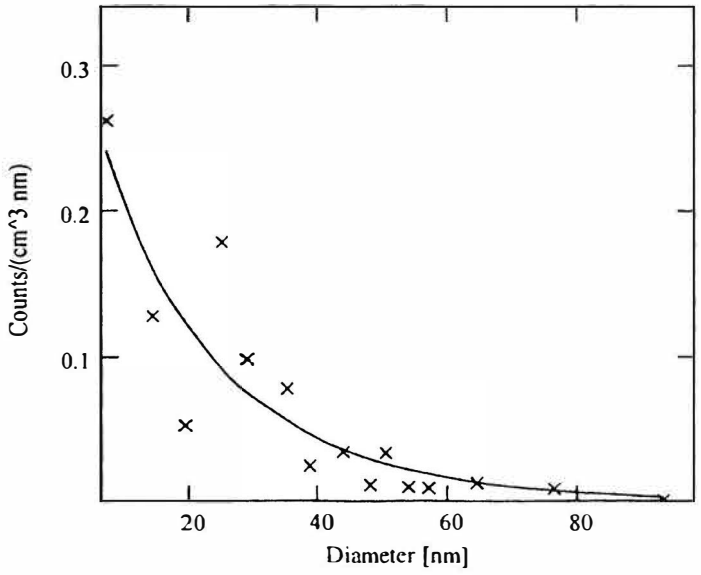
Correlation coeff. r^2 $Rsqr_G = 0.795$

Root mean square deviation (normalized to maximum of diff. conc) $SD_G = 0.158$

$\sigma_{diffconc} = 58.05i$ nm

$T = 293.2\,K$

$p = 972.2\,hPa$

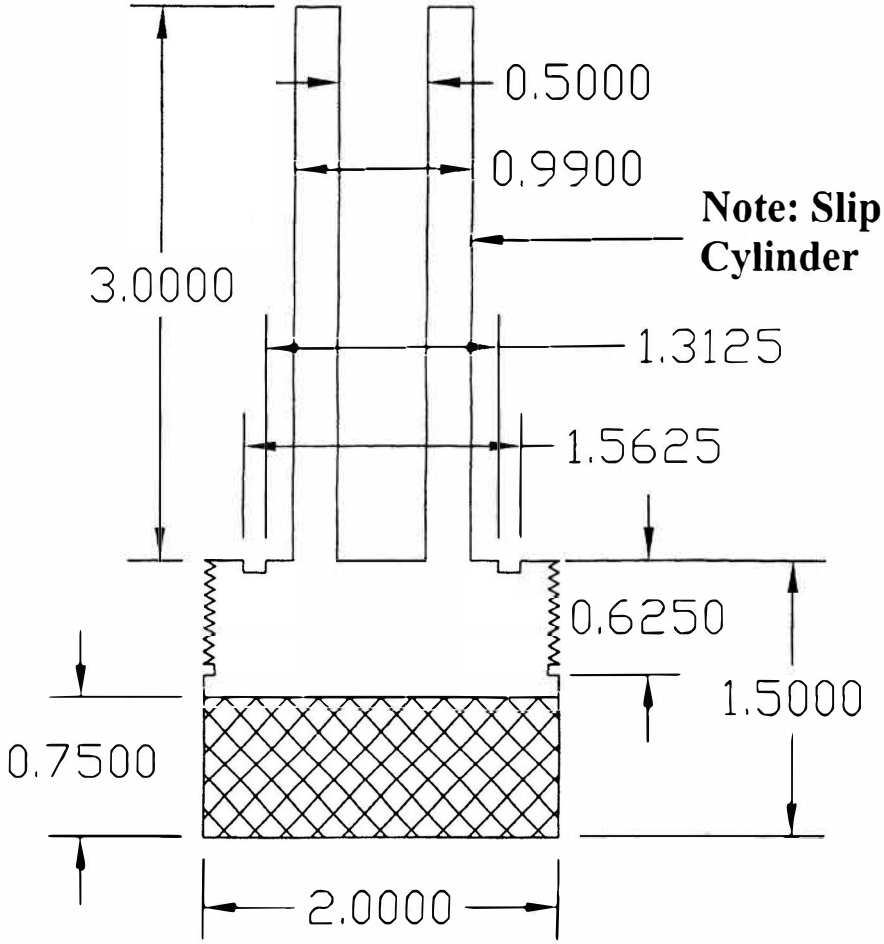


$\frac{\sigma_{diffconc}}{Max_{gauss}} = 0.295i$

$Q_s = 24.522 \frac{liter}{min}$

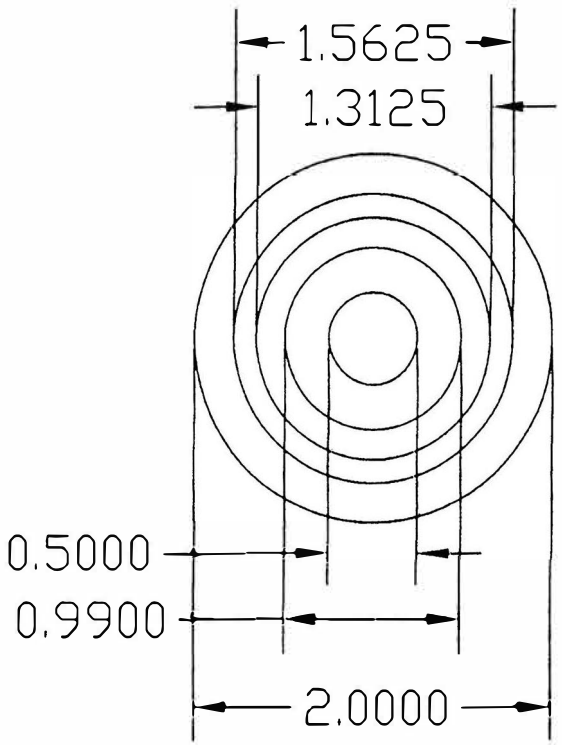
$\beta = 0.056$

INNER CYLINDER



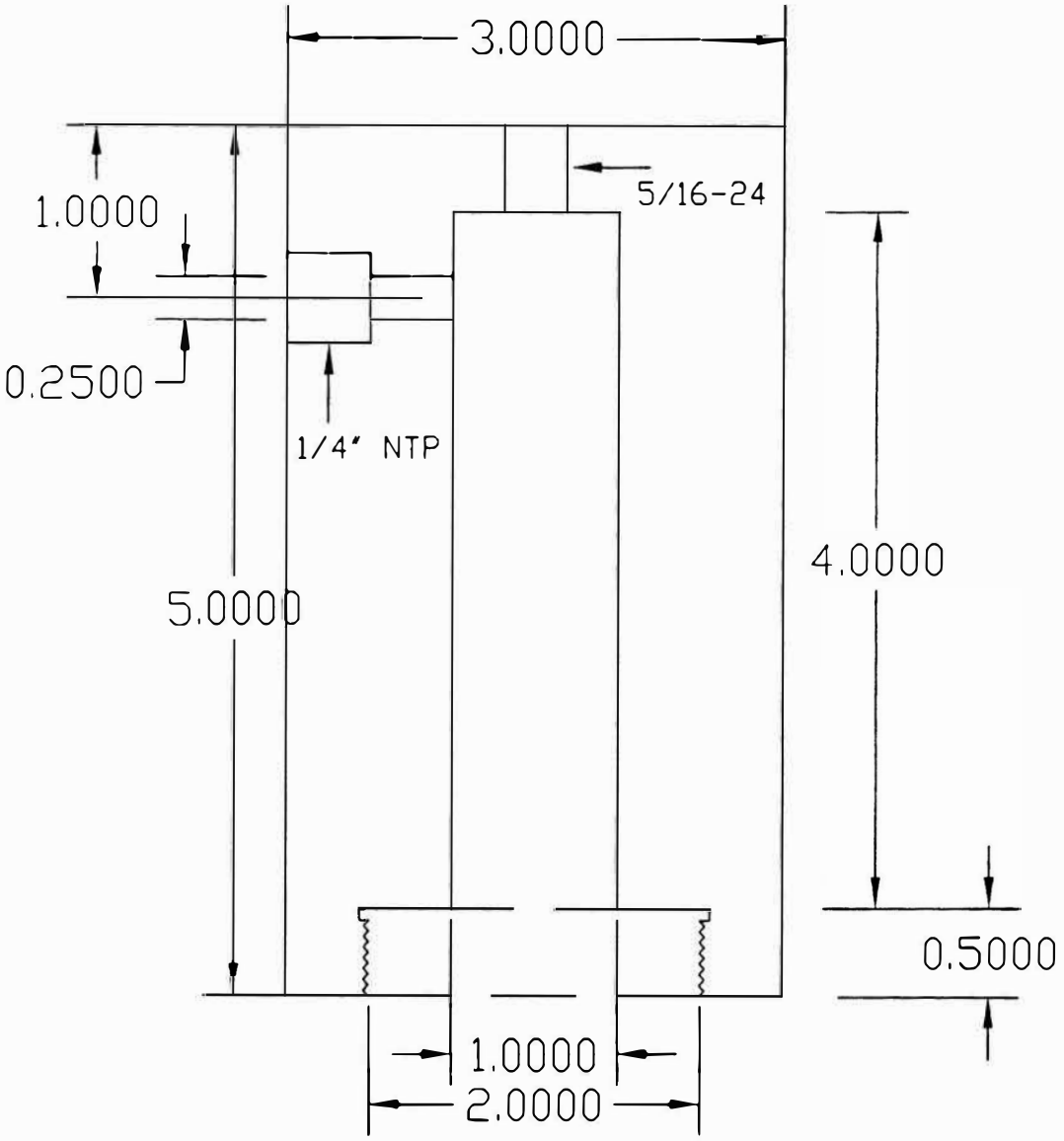
Note: Slip Fit into Outer Cylinder

Top View

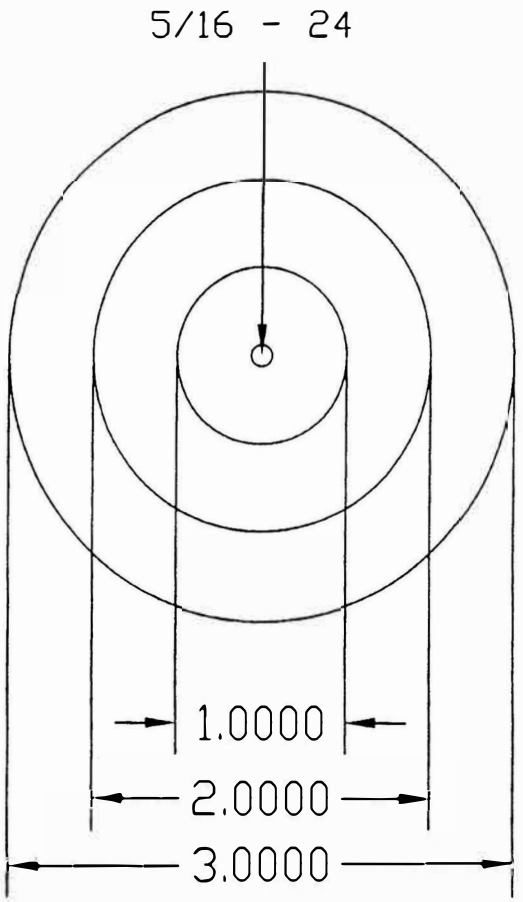


03731 DURE Vial Holder
Made by: Jeanne & Shane

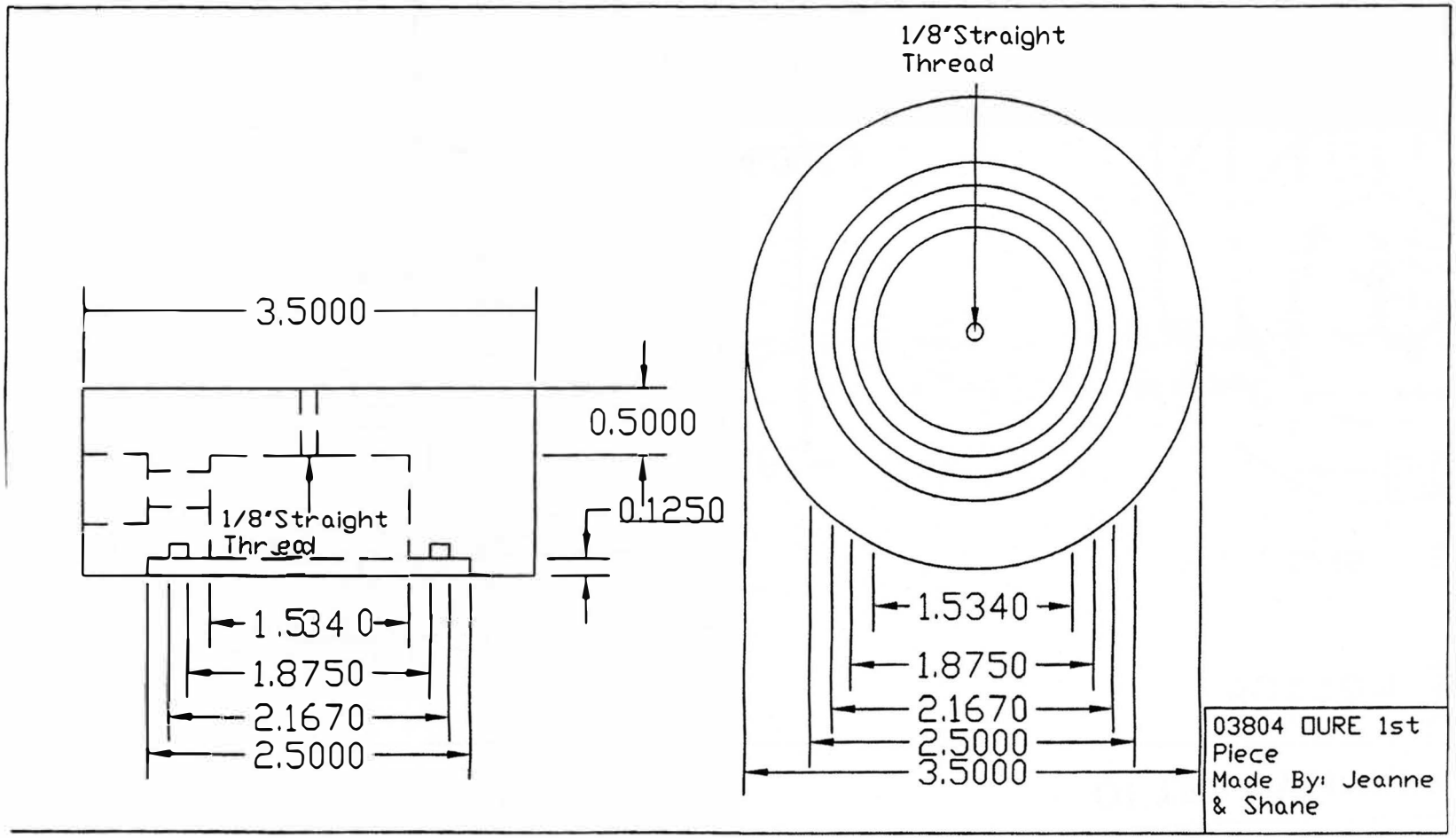
OUTER CYLINDER

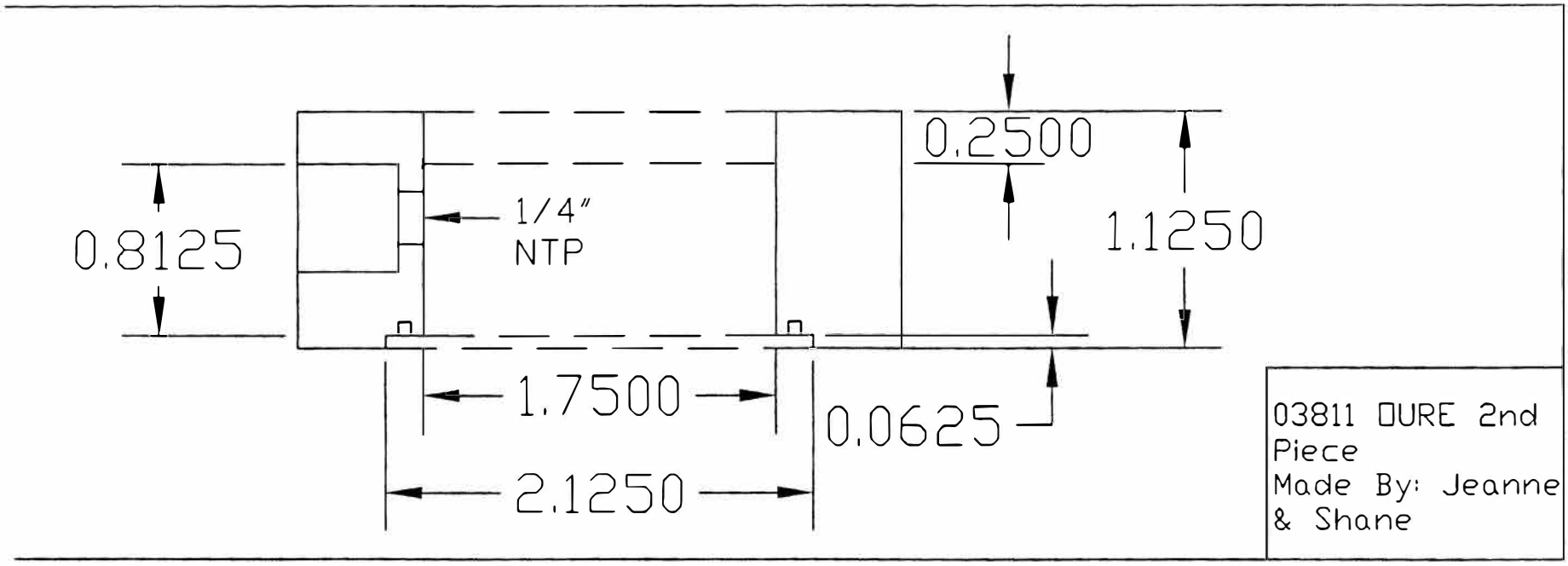


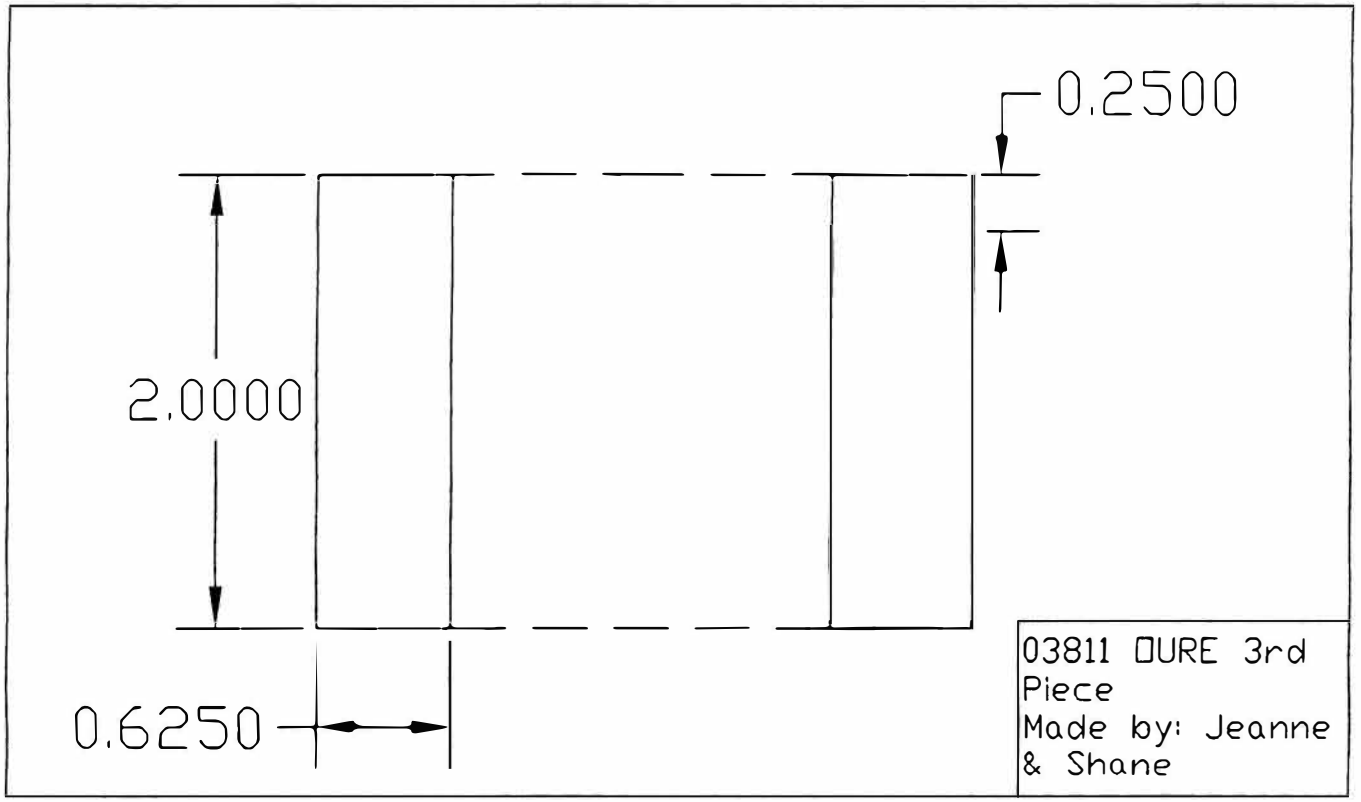
Bottom View



03801 OURE Outside of Holder
Made by: Jeanne & Shane


1/8"Straight
Thread
3.5000
0.5000
0.1250
1/8"Straight
Thread
1.5340
1.8750
2.1670
2.5000
1.5340
1.8750
2.1670
2.5000
3.5000
03804 □URE 1st
Piece
Made By: Jeanne
& Shane


0.2500
1.1250
0.8125
1/4"
NTP
1.7500
0.0625
2.1250
03811 DURE 2nd
Piece
Made By: Jeanne
& Shane


0.2500
2.0000
0.6250
03811 DURE 3rd Piece
Made by: Jeanne & Shane