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β-cell Assembly for the Quad Gas Sampling Detector

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April 2008

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99352

Summary

The β-cells used in the β-γ detector have taken time to develop and to standardize the assembly of them. In making the assembly routine it is important to have step-by-step assembly instructions as well as a list of potential problems and their solutions. This document attempts to accomplish these goals.

Contents

Figures

β-cell Assembly

The β-cell is composed of several components that are assembled to make a fully functional nuclear detector. These components consist of a gas cell that also acts as a scintillator, a photomultiplier tube (PMT), a PMT base, the plastic housing that hold the cell together, and a gas transfer tube that attaches to the gas cell. The cell itself is ordered from the manufacturer as a base disk and a bullet-shaped cone that are glued together to make the gas cell. The PMT is attached directly to the cell and then the tube base is attached to the PMT. Surrounding all of this is a black plastic shell made up of a cylinder that fits over the cell and PMT with a nipple cap and an end-cap that fit over the end of the gas cell to make a light-tight housing. Finally, there is a gas transfer tube that runs along the plastic shell into the cell through a hole in the nipple cap. Construction of the β-cell is done in stages to allow the epoxy to cure between steps.

Step 1 – β-cell Scintillator Assembly

The beta cells arrive from the manufacturer with a hole predrilled for the gas transfer tube. The hole should be 1 one-thousandths smaller than the outer diameter of the gas line (see diagram 413-05 for hole outer diameter [OD] and position). Currently a gas line with an OD of 1/16 in. and an inner diameter (ID) of 0.023 in. is used. Thus, the first step is to chamfer the gas line hole by hand to a 45-degree angle using a 45-degree countersink bit. The bevel will help maintain a reservoir for the high vacuum sealant and epoxy during the gas line attachment step. After removing any loose material from the cell, which can be done using a compressed air can (Chemtronics E-Series Ultrajet), the next step is to cement the β-cell together using optical epoxy (Saint-Gobain: Crystals & Detectors BC-600 Optical cement). The β-cell is composed of the beta cell body and the beta cell cap (Figure 1).

Figure 1. β-cell

Apply a small amount of the optical cement in a line around the lip of the disk (Figure 2). Visually inspect the cell for good coverage of the optical cement. The cell should be placed in an upright position in a cradle as shown in Figure 2 to ensure the optical cement does not run onto the cell and to protect the cell from outside disturbance (*note:* the cell should be placed on a surface that the optical cement will not bond well to). Note that although the cure time is 24 hours, the cement should harden enough in 6 hours to continue the assembly process and can be checked by testing the firmness of the leftover optical cement.

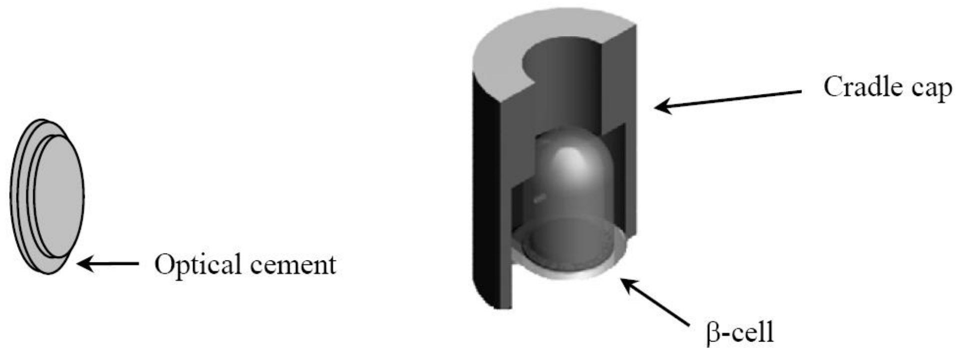


Figure 2. β-cell End-Cap (left); β-cell in cradle for the optical-cement curing process (right)

Step 2 – Photomultiplier Tube Attachment

Once the cell has been cemented together and the glue has cured, the cell must be cemented to the end of a PMT using the same optical cement used to glue the cell together. Place the PMT into the black plastic cradle with the PMT at the bottom facing up, as seen in Figure 3. To cement the cell to the PMT, place a few drops of optical cement onto the center of the PMT face. Next, place the cell onto the PMT and rotate the cell several times. Rotating the cell will help remove trapped air and spread the optical cement evenly over the cell surface. Place the cradle cap onto the cylinder. The cradle cap is used to ensure the cell stays centered on the PMT. Cure time for this stage is also 24 hours.

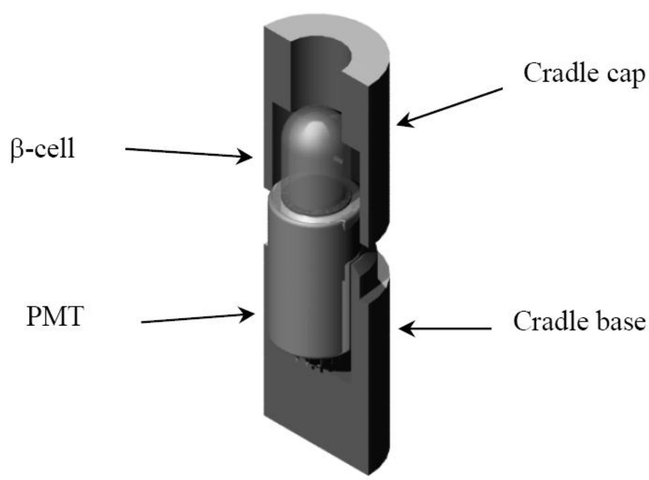


Figure 3. Black Plastic Cradle used for Cell Assembly

Step 3 – Light-Tight Shell Assembly

Once the optical cement on the PMT and cell assembly is hard, wrap a double layer of white Teflon tape around the β-cell as described below. The Teflon tape will act as a reflective coating and help to keep the cell light-tight. To apply the Teflon tape, cut a 3-inch piece of 2-inch wide Teflon tape and center it above the plastic cell, then pull straight down over the cell until the cell is completely covered with tape. Remove all wrinkles, and then apply a second layer of tape. Be sure to not stretch the Teflon tape so tight as to get inhomogeneous coverage. Excess Teflon tape should be removed using a surgical razor. A hole should be cut through the Teflon tape to allow the gas line to be inserted into the cell and to allow a surface for the epoxy in the later stage to bond to. The hole should be 3/16 inches in diameter, which will match the hole in the cell nipple.

To prepare the plastic shell for assembly, the first step is to drill a 3/16-inch hole in the shell cap as shown in the diagram 413-03. The hole is larger than the gas line size to allow easy attachment of the gas line in the later stages of assembly.

Next, place the shell cap over the cell and put a bead of Scotch-Weld DP-270 Potting Compound on the collar of the cap with another bead around the side of the PMT. Be sure that the hole in the shell cap lines up with the hole in the cell. Attach the main part of the light-tight shell to the shell cap. Twisting the two parts of the light-tight shell together will ensure the epoxy has full coverage. Be sure to align the groove in the light-tight shell with the hole in the cap. This groove is where the gas line for the β-cell will be attached. To reduce the flow of epoxy onto other surfaces on the cell, use Kapton tape at all edges. The Kapton tape will be easy to remove along with excess epoxy.

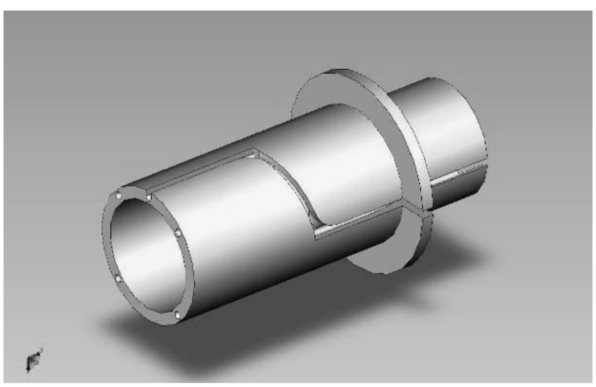


Figure 4. Light-tight Shell Made up of a Beta Tube and Nipple Cap (see 413-02 and 413-03 for dimensions)

Step 4 – Gas sample tube attachment:

Once the shell nipple and tube body are bonded, it is time to prepare the cell for gas line insertion. Any Teflon tape that is visible in the insertion hole should be carefully tucked under the cell nipple. Now the cell tubing needs to be bent to match the curves of the groove in the shell body. Bend the gas line as shown in diagram 413-07. The bends should be checked by loosely inserting the tube onto the gas cell.

Once it is determined that the tube fits well, a custom low dead volume VCR fitting should be welded to the tube. The VCR fitting should be machined as shown in diagram 413-08. Once the weld is complete, the tube is ready to be attached.

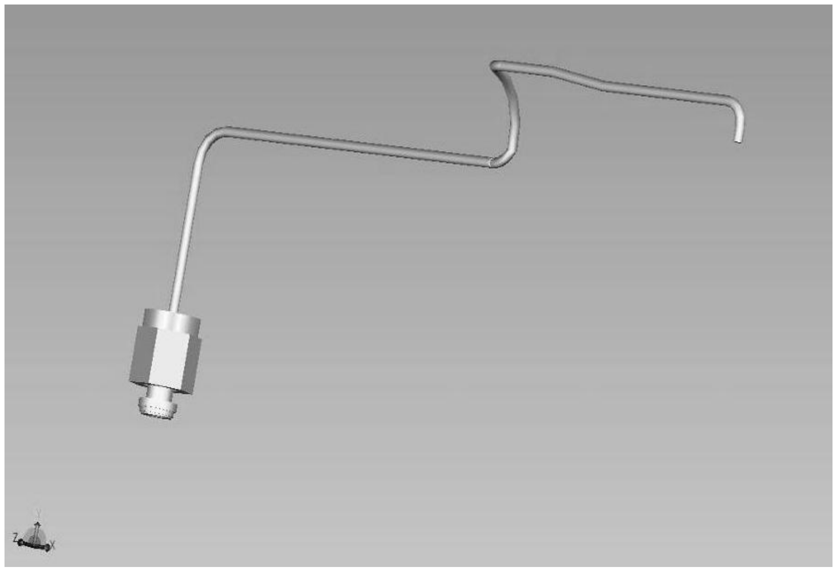


Figure 5. Stainless Steel Cell Tubing used as a Gas Line (see 413-07 for dimensions)

The gas sample tube is attached to the groove along the side of the β-cell. The hole in the cell also needs epoxy applied to it to hold the tube in place; however, the epoxy should be allowed to run into the hole to allow any air to escape from the hole. Furthermore, the amount of epoxy should be kept to a minimum at the hole. Allow the epoxy to cure before putting epoxy over the remainder of the tubing and groove.

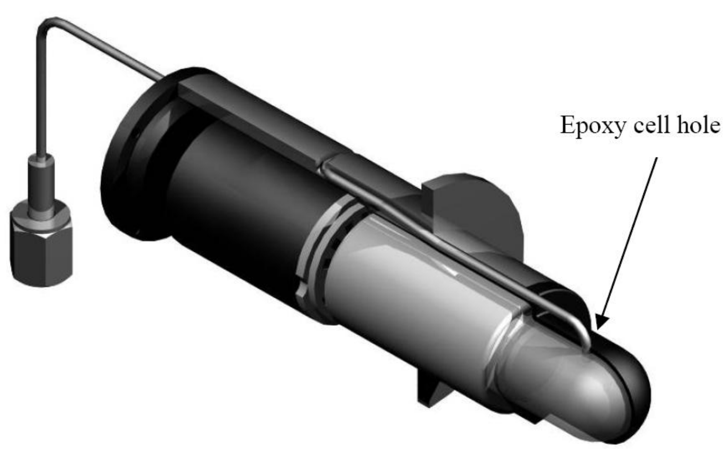


Figure 6. Gas Sample Tube Insertion

Step 5 – Gas Sample Tube Testing

Test the gas sample tube for air flow to the cell and to check for leaks. This can be done in several ways. Both tests require a vacuum-tight manifold of known volume. The manifold must contain at least one vacuum port, one pressure gauge port, one vent port, and one port for test gas cells.

The first step in testing for leaks is to apply a vacuum to the manifold and cell; because the gas sample tube is narrow, the cell may take up to 5 minutes to evacuate, depending on gas cell size and sample tube length. The extra time is due to the distance between the gas cell and the pressure gauge and the air flow through the gas line. A good rule of thumb is to allow the cell to be pumped on for 5 minutes to ensure the cell is completely evacuated. Once the cell and manifold are under vacuum and isolated from the pump, check the rate at which the pressure increases. The increase should be no greater than 50 mTorr/min. If the increase is greater than 50 mTorr/min., then there is either a leak in the manifold or gas cell. Once this test is done, isolate the cell from the manifold and allow the manifold to return to 760 Torr, but keep the cell under vacuum. Once the manifold is at 760 Torr, isolate the manifold from the atmosphere and open the valve to the gas cell. The pressure in the manifold should drop an appropriate amount with respect to the cell volume (several 100 Torr). The actual amount of pressure drop should be calculated ($P_1V_1 = P_2V_2$, ignoring temperature effects) to confirm the gas cell volume. The second test is a reverse of the previous one. Place the manifold under vacuum with the cell at 760 Torr. When the valve to the cell is opened, the pressure in the manifold should go up by an appropriate amount with respect to the cell volume (once again several 100 Torr). If these tests fail, there is something blocking the gas sample tube and you should skip to the repair section. The common volumes for gas cells are 3.22 cc and 3.83 cc, but can be increased up to 6 cc depending on the application.

Step 6 – End Cap Attachment

Once the PMT base has been attached, the end-cap (Figure 7) for the light-tight shell should be attached.

Figure 7. Light-tight Shell End Cap

The end-cap has a hole in the back for the PMT base cables to feed through. The hole needs to be blocked either by sandwiching o-rings or foam between the cap and the PMT base to ensure there will be no light leaks. The cap is attached with four screws and should be oriented so that the flat edge is against the gas sample tube. The final detector will look like that shown in Figure 8.

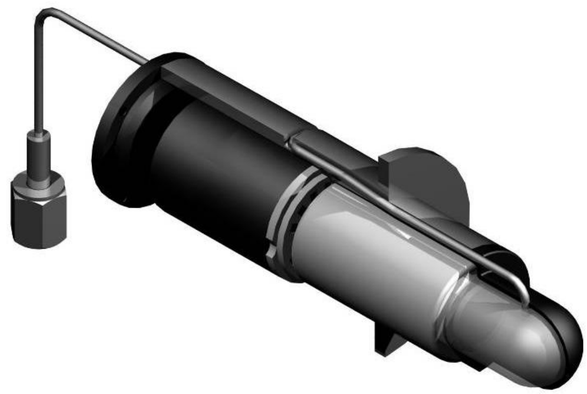


Figure 8. Fully Assembled β-cell

Step 7 – Testing

Once the β-cell has been fully assembled, it should be leak tested and then be inserted into either a NaI or CsI well detector and tested for resolution. It can be tested by using a ^{137}Cs source, insert Xe gas into the cell, or Rn gas into the cell. At this point it will be assumed that the γ detector has been properly calibrated and only the β-cell needs calibration. Check to be sure γ-β coincidence data is observable; if it is not observable, then troubleshoot it appropriately. If γ-β coincidence data is observed, the β-cell can be calibrated.

β-cell Repair

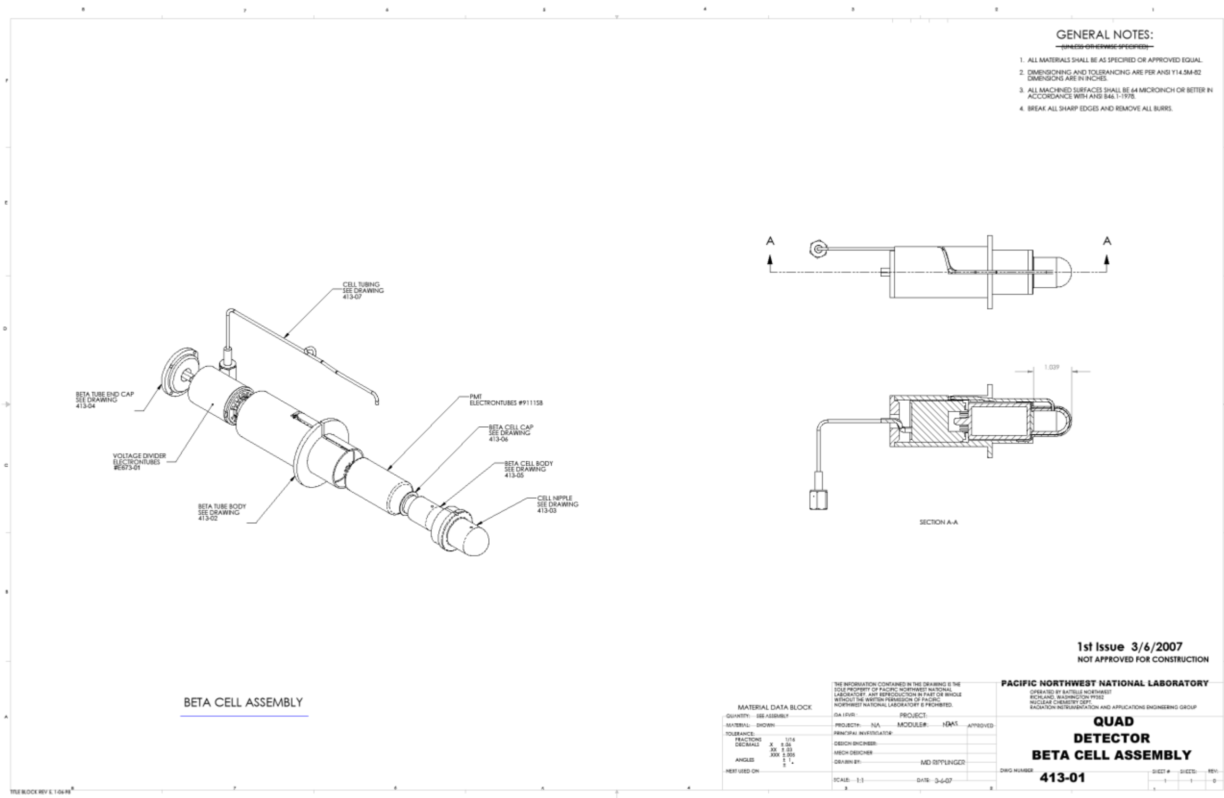
No Gas Transfer

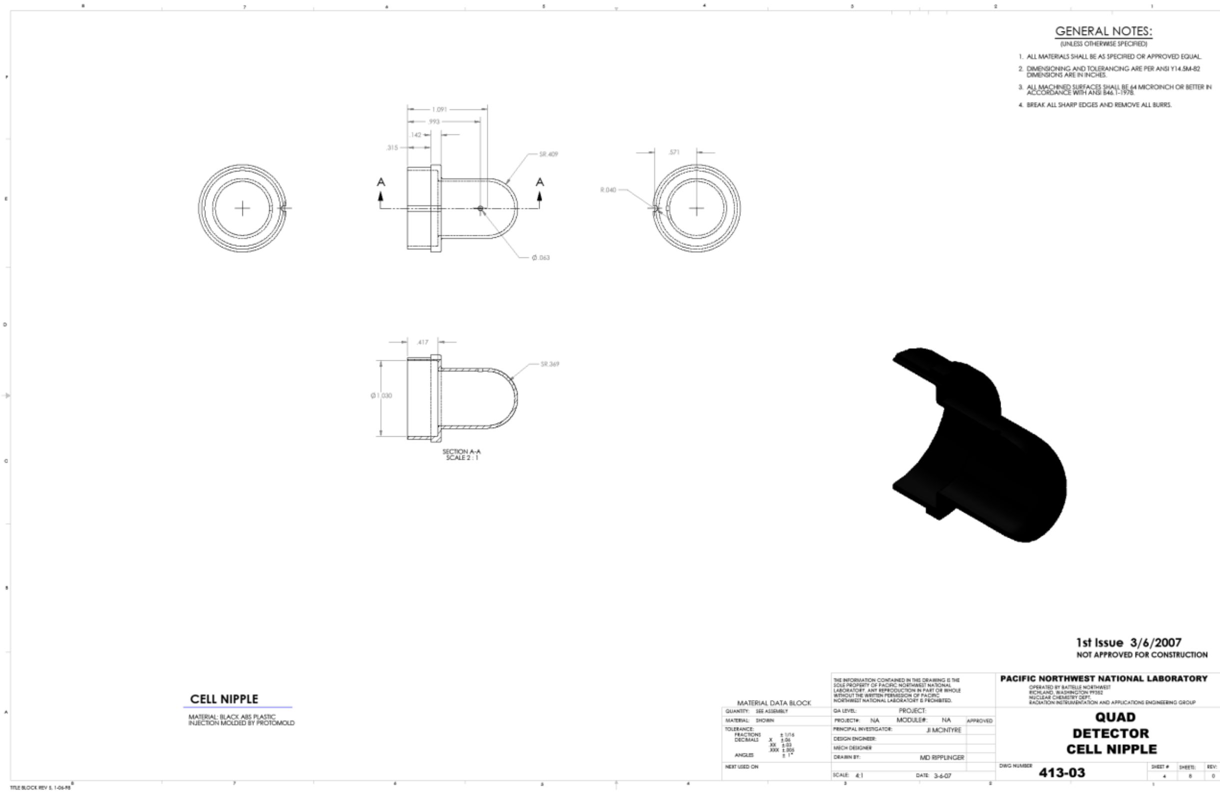
If there is little or no gas transfer through the gas sample tube, then there is likely epoxy blocking the tubing. The most likely location for epoxy to block the tube is where the tube enters the cell. To repair this, gently pull the gas sample tube out from the cell hole. The hole will need to be carefully cleaned using a razor and, if necessary, a very small hand drill. Because the tube may be blocked, it is a good idea to check for air flow through it before proceeding further. This can be done by connecting the gas tube to the manifold and pumping on it. If you are able to get a good vacuum, then the tube itself is blocked. A new tube should be bent as shown in 413-07. Once again follow the assembly instructions starting from step 5. Note that each repair will adversely affect both the energy resolution and potentially the efficiency of the beta cell, so it is advisable to build a new cell rather than make a repair.

Leak

If there appears to be a leak in the cell, check for a bad seal at the connector to the manifold and at the cell hole using a mass spectrometer leak detector. Epoxy should be used to cover the leak if it is at an accessible location. Once the epoxy has cured, repeat the cell leak testing. If there is still a leak after following these steps, the leak is probably at the β-cell itself, which means opening the light-tight shell and removing the β-cell. The cell should easily be detached from the PMT using a razor blade to gently pry along the edge. Once the β-cell has been detached, it should be visually inspected for air pockets in the optically cemented areas. Wherever air pockets are found, apply a small amount of optical cement to fill in the spot. All repairs are likely to result in worse energy resolution and potentially worse detection efficiency.

Technical Diagrams

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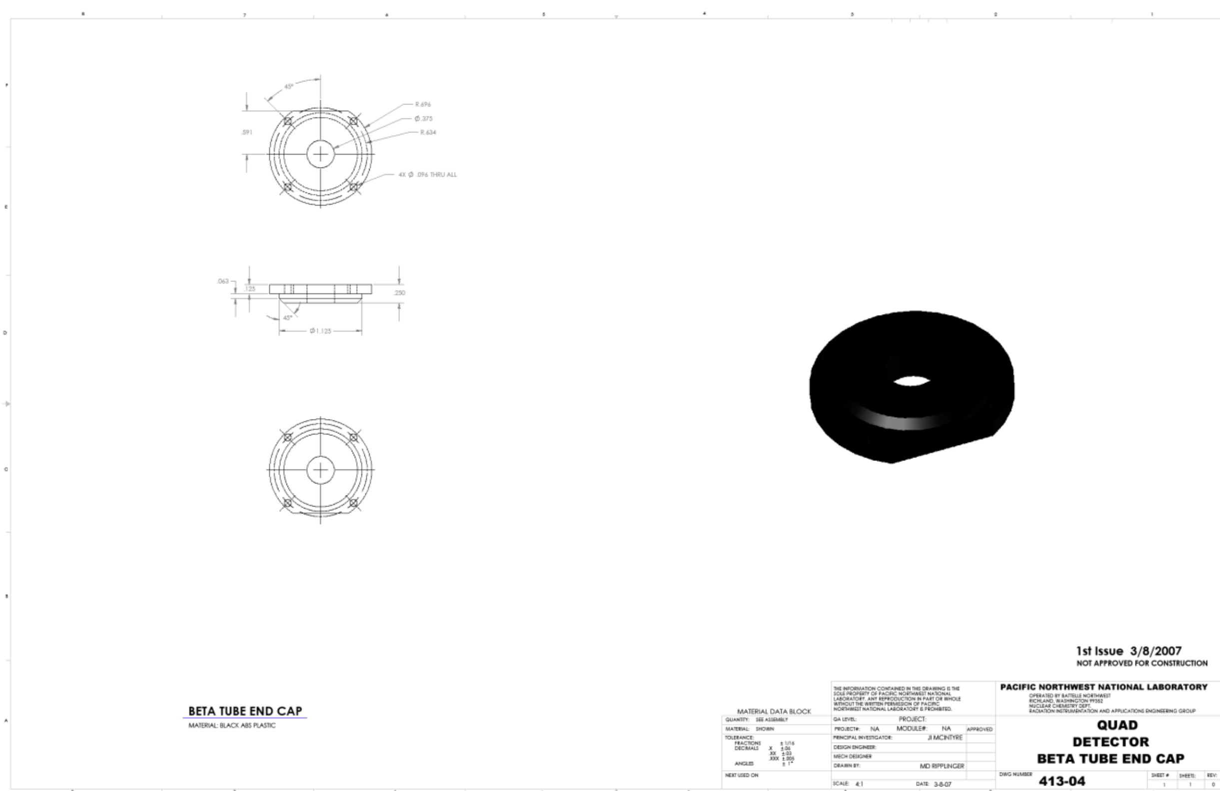
JI MCINTYRE
MD RIPPLINGER
413-03


1st Issue 3/8/2007
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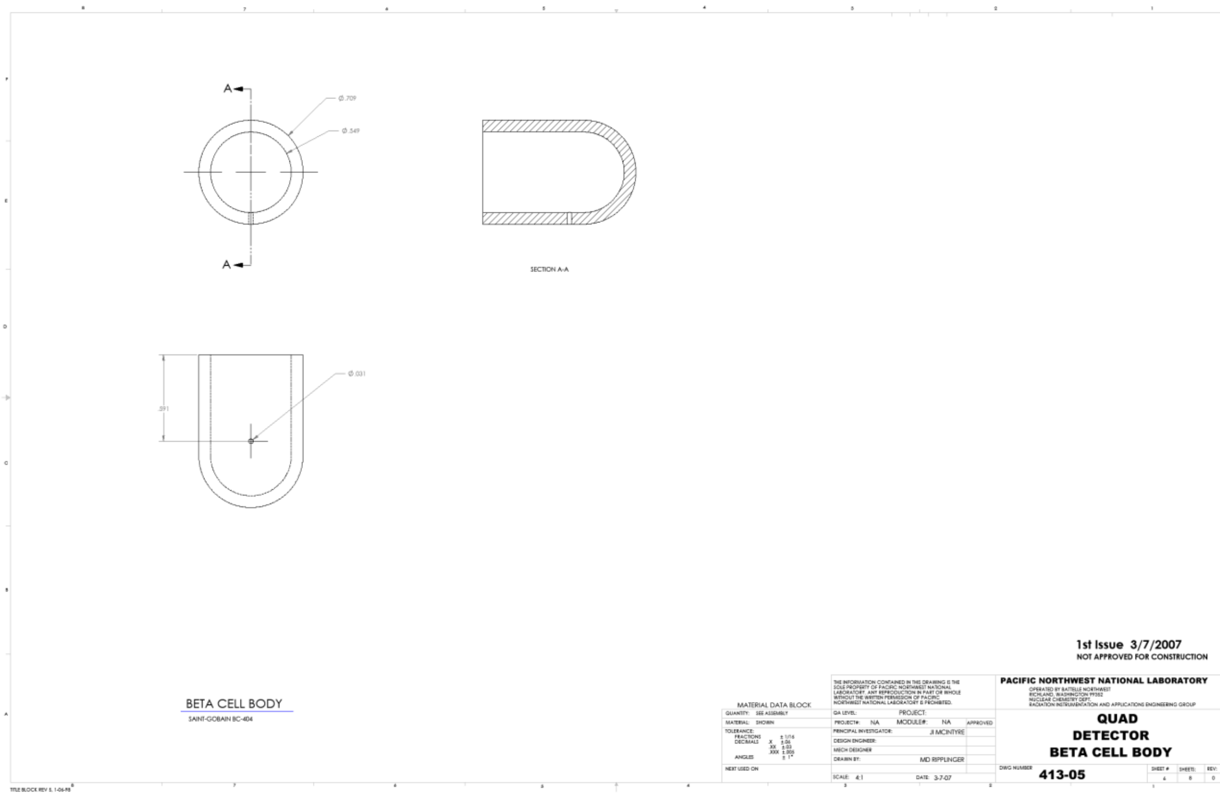
A
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Ø .709
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SECTION A-A
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BETA CELL BODY
SAINT-GOBAIN BC-404
1st Issue 3/7/2007
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MATERIAL: SHOWN
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DECIMALS .X ±.06
.XX ±.03
.XXX ±.005
ANGLES ± 1°
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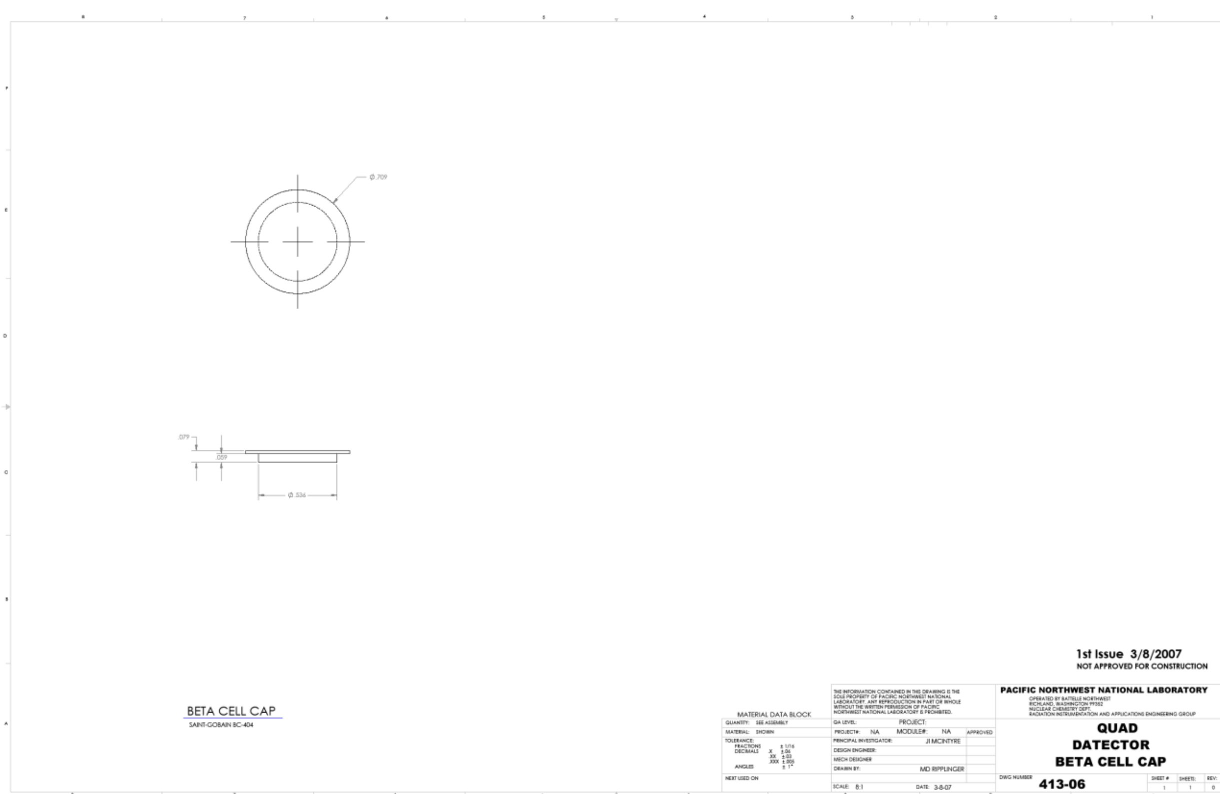
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1st Issue 3/8/2007
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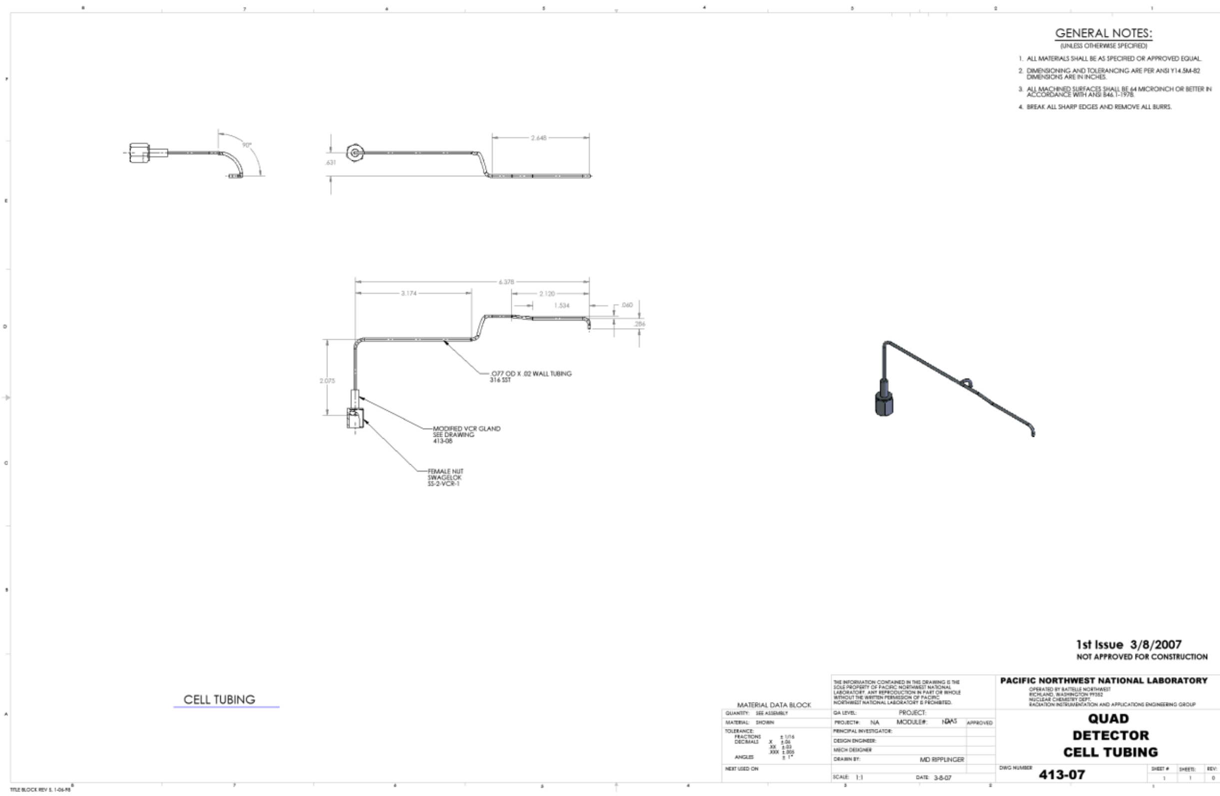
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3. ALL MACHINED SURFACES SHALL BE 64 MICROINCH OR BETTER IN ACCORDANCE WITH ANSI B46.1-1978.
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6.378
3.174
2.120
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.256
2.075
.077 OD X .02 WALL TUBING 316 SST
MODIFIED VCR GLAND SEE DRAWING 413-08
FEMALE NUT SWAGELOK SS-2-VCR-1
1st Issue 3/8/2007
NOT APPROVED FOR CONSTRUCTION
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MATERIAL DATA BLOCK
PACIFIC NORTHWEST NATIONAL LABORATORY
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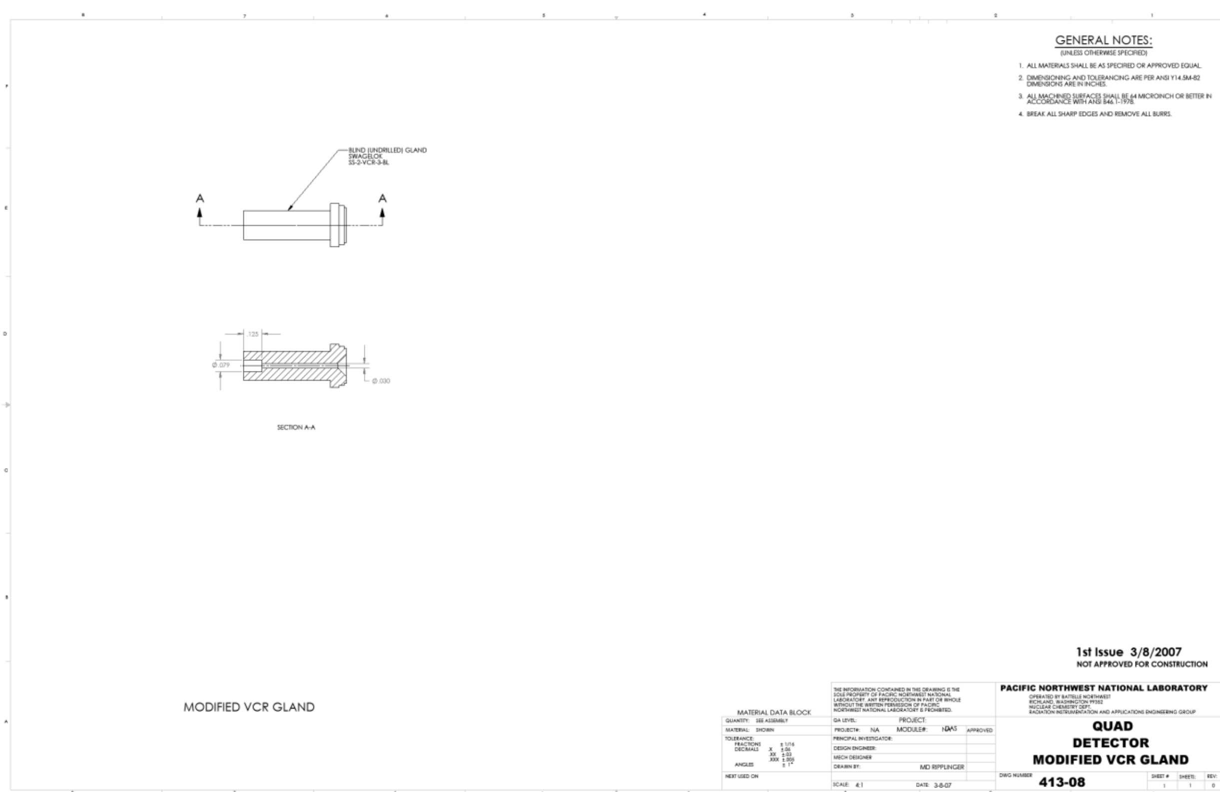
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2. DIMENSIONING AND TOLERANCING ARE PER ANSI Y14.5M-82 DIMENSIONS ARE IN INCHES.
3. ALL MACHINED SURFACES SHALL BE 64 MICROINCH OR BETTER IN ACCORDANCE WITH ANSI B46.1-1978.
4. BREAK ALL SHARP EDGES AND REMOVE ALL BURRS.
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A
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1st Issue 3/8/2007
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DETECTOR
MODIFIED VCR GLAND
MD RIPPLINGER
SCALE: 4:1
DATE: 3-8-07
413-08

Parts Listing

Description	Manufacturer	PN	QTY
Shipping Case	Hardigg Industries	AL1212-1904	1
Shipping Case	Hardigg Industries	AL1212-0404	3
Dowel Pin	McMaster Carr	97395A473	12
Lifting Strap	Power Systems	450710	14
Roll Pin	McMaster Carr	92373A181	12
Base Plate	McMaster Carr	8973K49	1
Aluminum Ring	McMaster Carr	8973K49	12
Lead Base	Vulcan Lead Inc.	1.25" × 10" × 10"	1
Small Lead Layer 1 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 4" × 5"	4
Large Lead Layer 1 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 4" × 6"	4
Small Lead Layer 2 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 5" × 6"	4
Large Lead Layer 2 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 5" × 6"	4
Small Lead Layer 3 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 5" × 6"	4
Large Lead Layer 3 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 5" × 6"	4
Lifting Lug	McMaster Carr	8973K49	2
Eye Bolt	McMaster Carr	3016T17	2
Plastic 1 (Black ABS)	Port Plastic	4" × 8" × 8"	1
Plastic 2 (Black ABS)	Port Plastic	4" × 8" × 8"	1
Plastic 3 (Black ABS)	Port Plastic	4" × 8" × 8"	1
Plastic 4 (Black ABS)	Port Plastic	4" × 8" × 8"	1
Copper 1 (OFHC Copper)	McMaster Carr	89675K37	1
Copper 2 (OFHC Copper)	McMaster Carr	89675K47	1
Copper 3 (OFHC Copper)	McMaster Carr	89675K47	2
Copper 4 & 5 (OFHC Copper)	McMaster Carr	89675K37	1
Lead 1 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 6" × 10"	2
Lead 2 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 3.5" × 10"	1
Lead 3 (6% Antimonial)	Vulcan Lead Inc.	1.25" × 3.5" × 3.5"	1
Fitting Support	McMaster Carr	9055K111	1
Fitting Cap	McMaster Carr	9055K111	1
Voltage Divider	Bicron	E673-01	4
PMT	Bicron	9111SB	4
Beta Tube Body	McMaster Carr	8587K51	1
Cell Nipple	McMaster Carr	8587K922	1
Beta Cell Body	Saint-Gobain	BC-404	4
Beta Cell Cap	Saint-gobain	BC-404	4
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Modified VCR Gland	Swagelok	SS-2-VCR-3-BL	4
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Male Connector	Swagelok	SS-200-1-4	1