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Abstract

This document presents the assembly procedure for the GLAST Beam Test Calorimeter as established during trial assemblies performed at HYTEC from March to May 1999. This work, including fabrication of the mechanical components for two calorimeter units, was funded by subcontract 19958-PXI-003 from Praxis, Inc., under contract N00173-99-C-6003 with the Naval Research Laboratory.

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1. Beam Test Hodoscopic CsI Calorimeter

The Beam Test 99 calorimeter assembly is shown in Figure 1. The mechanical structures closely represent the concept proposed for the flight units. However, all components are made of aluminum in this prototype; a flight version would likely be made of carbon composites.

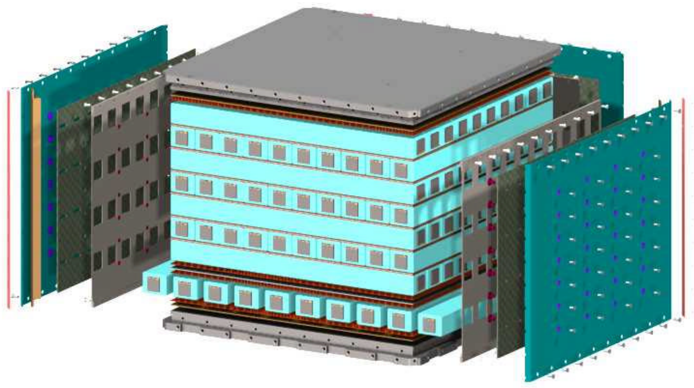

Figure 1: exploded view of the GLAST Beam Test 99 Calorimeter.

The concept has been described in detail in [1]. It consists of a uni-directional compression cell, holding the Cesium Iodide (CsI) logs in position by compressing the stack in the vertical direction only between stiff top and bottom panels. The stack includes several layers of compliant silicon rubber to help control the amount of compression, accommodate tolerances in CsI log dimensions, absorb thermal expansion of the CsI, and provide high friction on the outer surfaces of the logs.

The stack is held in compression by 4 containment panels, bolted to the top and bottom panels. Those panels have large rectangular cutouts for clearance to the PIN diodes that instrument the logs, and a number of posts that serve as supports for the PC boards and for mechanical connection with the outer shear panels. The containment/shear panel assemblies, tied together with those posts form structural sandwich structures that contain and protects the PC boards, and serve as a backup lateral restraints for the CsI logs.

2. Important Shipping & Handling Precautions

Most mechanical components used in this assembly have been aggressively optimized for minimum mass. This makes them somewhat delicate and susceptible to damage from improper handling. In particular, the containment panels, shear panels, and top compression panel include numerous bonded interfaces; care must be taken to avoid accidental overloading of those interfaces and/or long term exposure of the adhesive to water, harsh chemicals, or oils.

Because of tight tolerances and the fact that the uni-axial compression cell concept relies on friction for structural integrity, all components should be kept clean at all times (wipe with rubbing alcohol when necessary).

Once assembled, the stack is very heavy (around 200 lb). The side walls are not designed for handling of the assembly. Severe damage will occur if the assembly is handled by its sides in any way. The only acceptable handling of the assembled stack is via the four full-swivel lifting hooks (provided) attached in the ¼"-20 tapped lifting holes in the top panel (do not use regular lifting hooks), or through the four 3/8" tapped holes at the bottom of the bottom panel (using the beam test support bracket for example).

The stack should not be tilted into a cantilevered horizontal position without the shear panels and corners posts and strips attached (in particular, the outer shear panels and corner posts should be in place during beam test operations).

Because of the very large coefficient of thermal expansion of the CsI, the assembled stack should not be exposed to ambient temperatures exceeding 50ºC.

The assembly involves a large number of bolted interfaces, using small diameter screws in aluminum, without steel inserts. Care must be taken to avoid damaging the threads by improperly engaging the screws or over-torquing them. Do not use L-shaped Allen wrenches as they will very easily produce over-torquing. The miniature screwdrivers (provided) should be used to engage all screws and the torque-limiting screwdriver should be used for all final tightening. Refer to Appendix D for recommended torques.

3. Required Tools, Equipment, and Facilities

Special tools will be provided with the hardware package (torque limiting screwdriver and inserts, miniature Allen and Torx screwdrivers).

In addition to a standard set of shop tools, a 2'x2' or larger granite table is required for proper assembly of the calorimeter. Either an inspection quality height gage or a large caliper is needed to properly adjust the preload in the stack (18" min. capacity). Precision steel ruler(s), squares, and gage blocks are also useful. Other required tools and supplies include a 21oz. plastic hammer, grease (Teflon loaded is best, but any thick mechanical grease is acceptable), leather gloves, spray contact adhesive, sharp bladed knife, and shop caliper or micrometer.

The assembly should be performed in an air-conditioned room with a temperature stabilized in the range of 18 to 25ºC.

Cleaning supplies (rubbing alcohol and paper towels) should be kept at hand for systematic cleaning of parts before assembly.

4. Assembly Procedure

The following provides detailed descriptions of the steps involved in assembling the calorimeter. The general assembly sequence goes as follows:

- Assembling the fixtures

- Stacking and compressing the logs, rubber sheets, and shims a first time to evaluate the required adjustments to the shims
- Disassembling the stack and adjusting the shims as required
- Reassembling and compressing the stack
- Installing the containment panels, and PC boards
- Measuring the compressive load in the stack
- Installing the outer walls (shear panels, corner posts, and corner clamp strips)

The following sections provide detailed step-by-step instructions.

4.1 Prepare Assembly Press and Alignment Plates (Assy Dwg 2001)

- Assemble the two grooved *alignment plates* (2006 & 2007). Use a marble and a straight edge to insure perfect alignment of all edges. Plates are bolted together with ¼"-20 x 1.25" Allen head cap Screws.

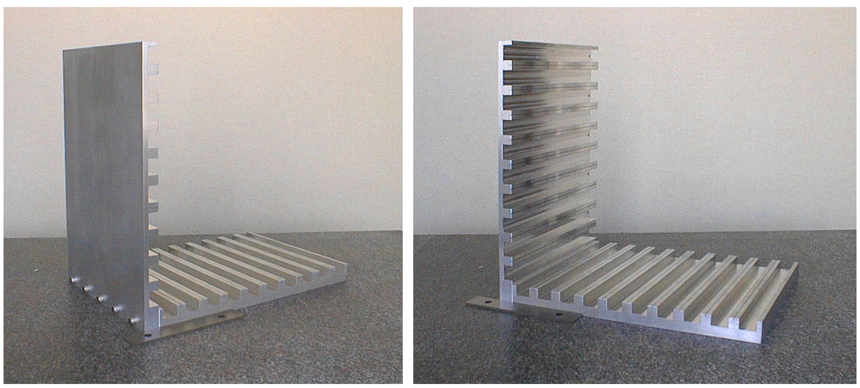

Figure 2: assembling stack alignment plates.

- Assemble the press *base plate* (2005) and *guide rods* (2003). Guide rods are bolted to bottom plate with ½"-13 x 1.5" Allen head cap screws.

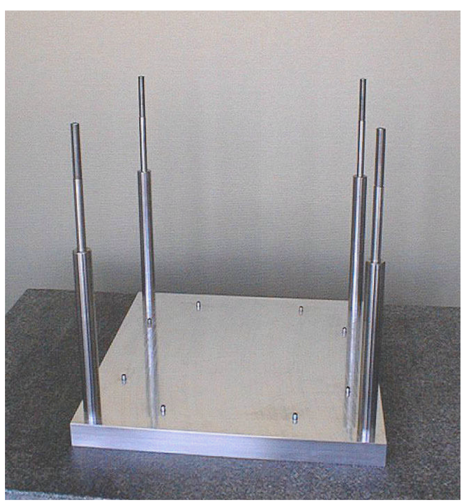

Figure 3: preparing press base plate and guide rods.

- Set *bottom compression panel* (1006) in place between the centering pins on the press base plate. Shim (0.008-0.010" brass shim stock) between pins and bottom panel to eliminate play. Make sure shimming is symmetric so the centering of the bottom panel is not affected.

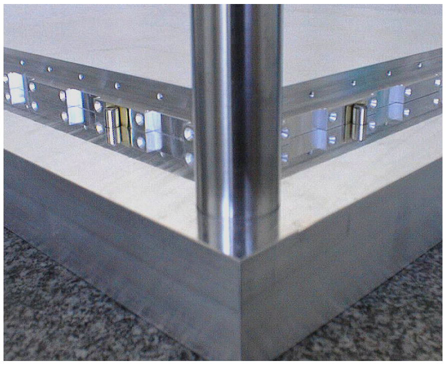

Figure 4: shimming bottom compression panel between centering pins on press base plate.

- Set the alignment plate assembly against the upper lip of the *bottom compression panel*. Attach the alignment plate assembly to the bottom panel with #4-40 Allen head cap screws (1" long through the thinnest plate, 1.25" long through the thicker one) and flat washers. Carefully tighten the screws to pull the alignment plate assembly tight against the lip of the bottom panel. Also make sure to achieve intimate contact between the bottom edge of the alignment plates and the lower lip of the panel (gently tap the plates in position with a plastic hammer as the screws are being tightened).

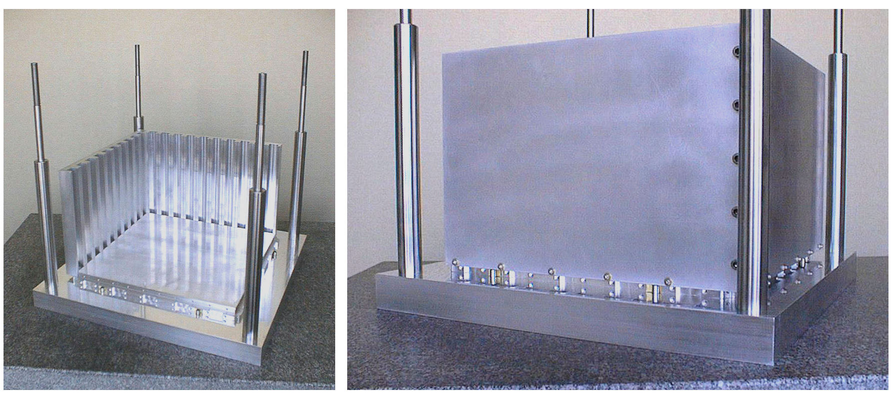

Figure 5: guide plates attached to bottom compression panel.

4.2 Stack, Align, and Adjust CsI Logs and Shims (Assy Drawing 1000)

Stacking is performed in two steps to allow for precise adjustment of the compressive preload. The stack is first assembled with full thickness aluminum shims and compressed to the design load[1]. The height of the compressed stack is accurately measured and the

[1] The silicone rubber sheets used in the stack are designed to have very high friction. Because of this, they tend to stick to clean surfaces after they have been compressed against them. To avoid difficulty in disassembling the stack and reduce the risk of damage to the wrapped CsI logs, the *initial* build of the stack could include sheets of very thin silk paper between every rubber sheet and the CsI logs. The thickness of

required shim thicknesses for the final assembly are calculated. The stack is then disassembled, the shims are adjusted to the proper thickness, and the stack is rebuilt.

4.2.1 Initial Build

- Spray a very light mist of contact glue on one face of each 0.048" *outer shim* (1014). Let the glue dry for 5 minutes then bond one shim to the *bottom compression panel* (1006), lining it against the alignment plates, and the other to the *top compression panel* (1007), lining it to the outer edges of the inner lip. Note that the goal is only to prevent slippage of the shims on the top and bottom panels; use just enough adhesive to achieve this goal.
- Place a *perforated rubber sheet* (1016) on top of the *outer shim*.
- Place 10 logs on that sheet, tight against each other and the alignment plates.
- Measure the lateral extent of the 10-log layer and calculate the shimming required between logs.

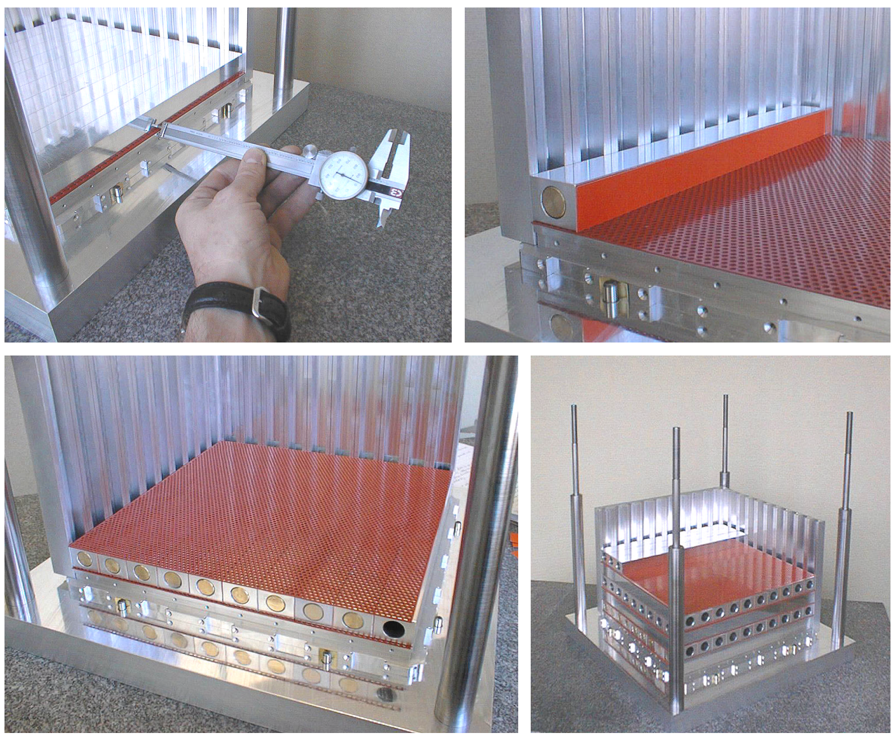

Figure 6: building the stack: measuring lateral extent of first layer to evaluate required shims (top left), rebuilding first layer with appropriate shims (top right), first layer complete (bottom left), building the fifth layer (bottom right).

- Prepare 9 rectangular shims of the proper thickness (cardboard works fine), remove the logs and rebuild the layer with the shims. If all logs are expected to be reasonably alike, a complete set of 72 shims can be prepared at this point; otherwise, the shim thickness must be reevaluated for each layer.

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these sheets must be accounted for in calculating the required shim thicknesses since they would not be used in the final assembly (after adjusting the shims).

- Position a *perforated rubber sheet* on top of the logs, then an 0.062" *inner shim* (1015), and another rubber sheet.
- Repeat until a complete stack of 8x10 logs is built.
- Finish with a rubber sheet on top of the last layer of logs.
- Place the *top compression panel* between the pins on the press *Compression Plate* (2004); shim between the pins and the top panel to eliminate play (being careful to shim symmetrically to keep the panel centered), and hold the panel in place with the two hold-down screws (finger tight).

Figure 7: shimming the top panel between pins on the press compression plate; one of the 2 hold-down screws is visible in the left view.

- Apply grease to the top of the *guide rods* and the inside of the holes in the compression plate, engage the top plate on the rods until the top panel presses down on the stack.
- Install the *spring retainers* (2002), the "<u>small</u>" springs, the nylon washers, and the speed handles; turn the handles to just touch down on the springs.
- Remove the alignment plates (separately, they will not come off as an assembled set).
- Four (4) turns at a time and following a star pattern, compress the springs by 20 turns with the speed handles (the lengths of the springs can also be measured to evaluate the load). After each step of 4 turns, tap the guide rods and the compression plate with a plastic hammer to release friction in the system. The load applied on the stack by the springs is about 5555N or about a third of the current design load for a flight unit. The load was reduced to 30% of its design value to decrease the risk of damage to the logs. The reduced load is sufficient for static 1g operation of the calorimeter. Note that a separate assembly will be built to full load for mechanical evaluation purposes.
- Leave the stack under pressure for at least an hour or two, then measure the height of the stack (using whatever controlled features on the top and bottom panels or the press plates). This measurement should be accurate within +/-0.1 mm. Note that the measured thickness of the top panel (GLS-BTC5-1007/SN01) IS 0.804" (20.42 mm).

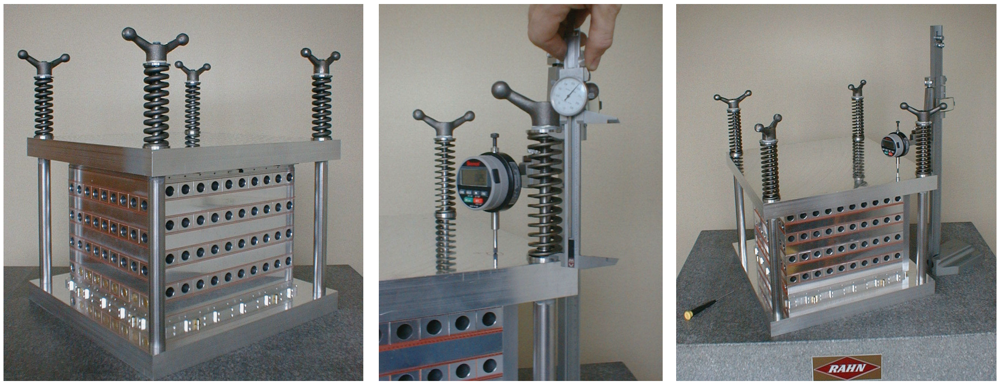

Figure 8: compressing the stack, checking the load by measuring the length of a spring, and measuring the stack height.

4.2.2 Disassemble the Stack and Adjust the Shims

- Disassemble the stack to gain access to the laminated aluminum shims: remove springs, top plate/top panel assembly, all logs, rubber sheets, and inner shims (leave the outer shims bonded to the top and bottom panels). <u>Keep track of the location of each log in the stack as they should be reinstalled in the same locations during the final assembly</u>.
- Compare the measured height with the desired number and calculate the desired finished thickness for the shims. There are 7 inner shims and 2 outer shims in the assembly; either distribute the adjustment uniformly across all shims, or tailor it to correct for vertical positions of individual layers if needed.
- Adjust the shims by peeling the proper number of layers off. The layers are about 0.0033" thick. Separate the layers at a corner with a blade, then peel them off (3 or 4 at a time works best) while holding the shim flat on a flat table with the other hand.

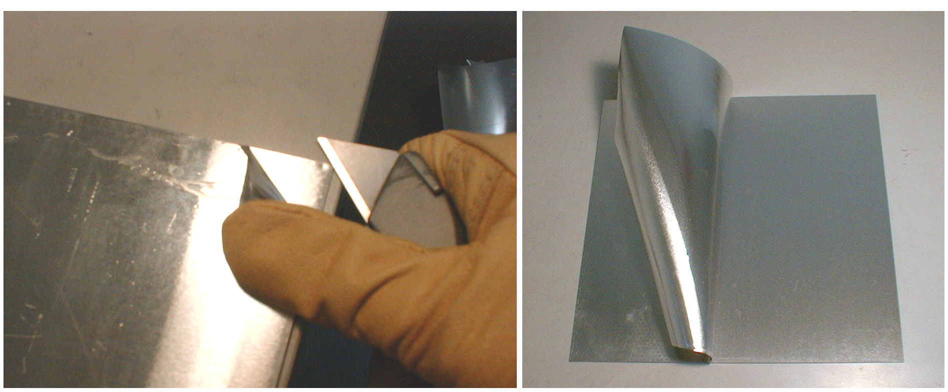

Figure 9: adjusting shim thicknesses by removing layers.

4.2.3 Reassemble Stack

- Reassemble and reinstall the alignment plates.
- Repeat all stacking operations as described in section 4.2.1, this time with the corrected shim thicknesses.

- Remove the *top compression panel* from the top press plate (remove shims and hold-down screws).
- Set the top panel on the stack, lining it against the alignment plates.
- Engage the top press plate on the guide rods (reapply grease if necessary) and drop it on the stack.
- Remove the alignment plates.
- Reinstall the springs and compress them to 20 turns on the speed handles (4 turns at a time, tap plate and posts every 4 turns to release friction).
- Let the stack settle for a couple of hours.

4.2.4 Install Containment Panels

- Assuming the shims were properly adjusted and the stack was rebuilt identically to the first time, the *containment panels* (1001) should fit nicely on the inner lips of the top and bottom panels. If it is not the case, recheck your shim adjustment calculations and remeasure the shim thicknesses.

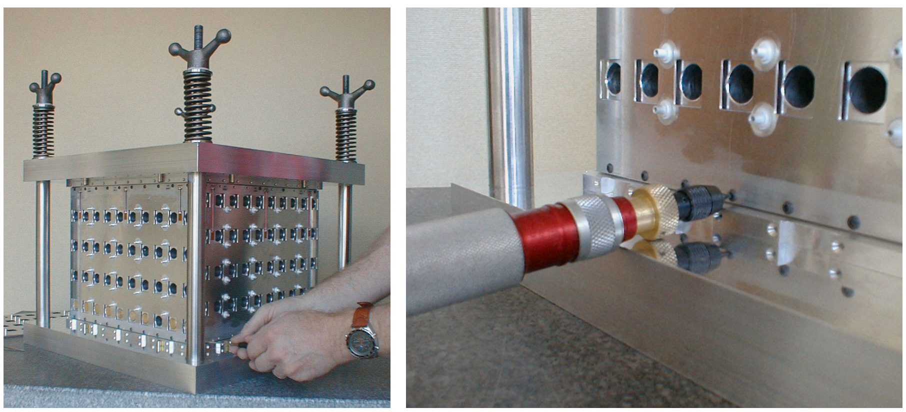

Figure 10: installing containment panels.

- With the stack held compressed by the springs, attach one *containment panel* at a time. Insert all 4-40 UNC button head retaining screws. Make sure the ledges on the containment panels and the top an bottom panels are nicely seated. Get all the screws in light contact (finger-tight).
- Once all 4 containment panels are in place and properly seated, partially release the spring compression by unscrewing the speed handles by 8 turns (leaving the springs compressed by 12 turns).
- Gently tap the top and bottom edges of the containment panels, to release any friction. The goal is to have the panels slip into tight, intimate contact with the top and bottom panel ledges.
- Tighten all button head screws using the torque limiting screwdriver.
- Now completely release the compression of the springs.

4.3 Remove Assembly from Press and Install Support Bracket

The X-shaped support bracket to be used in the beam test setup is also a good choice as a handling fixture during electronic assembly as it provides sturdy, easily accessible strong points.

- Prepare the Beam Test Calorimeter Support Bracket (provided by SLAC) and the required bolts.
- Remove the speed handles and springs.
- Remove the top press plate.
- Remove the 4 guide rods.
- Install the 4 full-swivel lifting hooks by screwing them into the 4 ¼" tapped holes at the edges of the top panel. Tighten the screws.
- Remove the centering shims from between the pins and the bottom panel.
- Use an equalized 4 leg chain or sling and an engine hoist or crane to lift the calorimeter assembly off the base plate and lower it on the support bracket.

Figure 11: lifting assembly off the base plate with a 4-legged sling..

- Attach the calorimeter to the support bracket with the 3/8" UNC bolts.

4.4 Install PC Boards and Wiring (Assy Dwg 1003 & 1000)

- Prepare the *PC Boards* (1009 & 1010) by inserting 6 rubber grommets into the ¼" holes in the locations shown on assembly drawing 1003. Note that additional/alternate locations for the grommets can also be used if necessary.

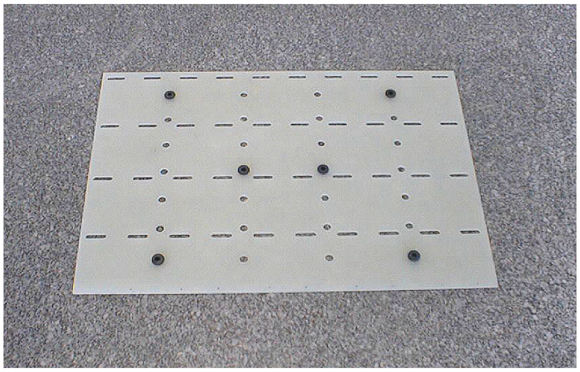

Figure 12: mockup PC board with 6 rubber grommets inserted.

- Line up PC boards against the containment walls, make sure rubber grommets engage properly on posts and carefully push PCB in place until grommets are fully engaged on posts.

- Flat head screws and flat washers can be used to hold PCB's in place until the shear panels are installed.

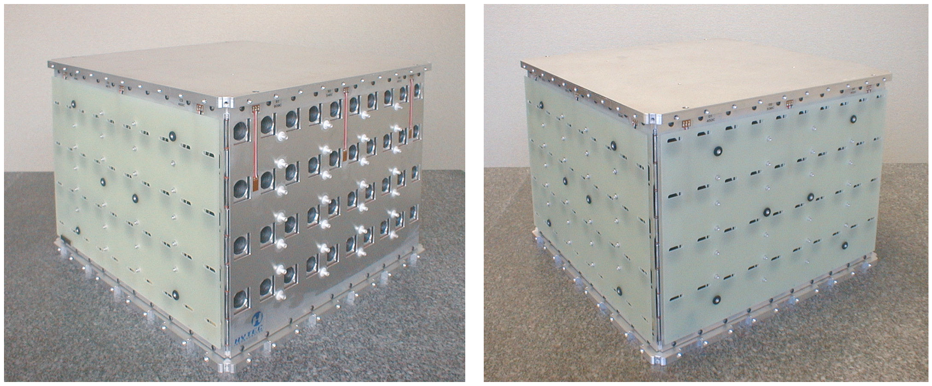

Figure 13: installing PC boards on calorimeter assembly.

- Line up the Nanonics connectors one at a time. With an Allen wrench reaching through the .060" holes in the outer lip of the bottom compression panels, engage the jack screws and use them to mate the connector pairs.

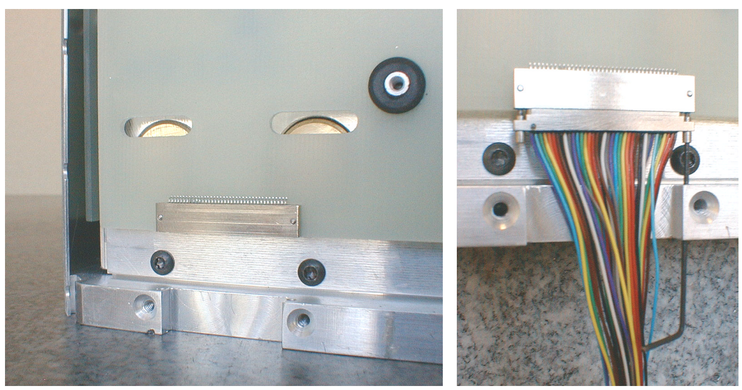

Figure 14: mating Nanonics connector pairs.

4.5 Install Bottom TEM electronics and EMI Shield

A special stand will probably be required to support the calorimeter off the 4 tie-in points that are part of the support bracket, while providing clearance for and access to the TEM electronics. Wire the side PCBs to the TEM boards and install the EMI shields.

4.6 Check Stack Preload with Strain Gage Sensors

The strain gages that are permanently installed on the containment panels are intended for long term monitoring of the compressive preload in the stack (early detection of cold flow problems). The preload can be checked at any time by measuring strains in the 4 containment panels, with the shear panels, corner posts, and corner strips removed. The procedure is as follows:

- If already installed, remove all shear panels, corner posts, and corner strips.
- Connect the P3500 bridge unit to the SB10 switch unit as described in the user's manuals (1/4 bridge operation).

- Using the provided 3 conductor leads, wire strain gages number 1, 2, and 3 of one containment panel (the 4 containment walls are identified as A, B, C, and D) to channels 1, 2, and 3 of the SB10 switch unit. Do not use other connection wires as this would invalidate the calibration. On the strain gage side, match colors for the 3 wires; on the SB10 side, the red, white, and black wires go to the red, white, and yellow quick connect contacts, respectively, as shown in Fig. 15.

Figure 15: SB10 switch and balance unit with strain gage wires connected to channels 1 to 3.

- Prepare the P3500 bridge unit:
    - Turn power on and allow to warm up for 10 minutes.
    - Check that the two RHS switches are set for ×1 Multiplier and ¼ bridge operation.
    - Check amplifier balance and correct if necessary.
    - Check gage factor (should be 2.090) and adjust if necessary.
    - Check that the balance potentiometer and switches are centered (selector on 0, potentiometer on 500).
    - Switch to measurement mode.
- Prepare the SB10 unit:
    - For each channel (1 to 3), set the balance multi-turn potentiometer to the value recorded on the labels, next to the strain gage connection pads (***C numbers).

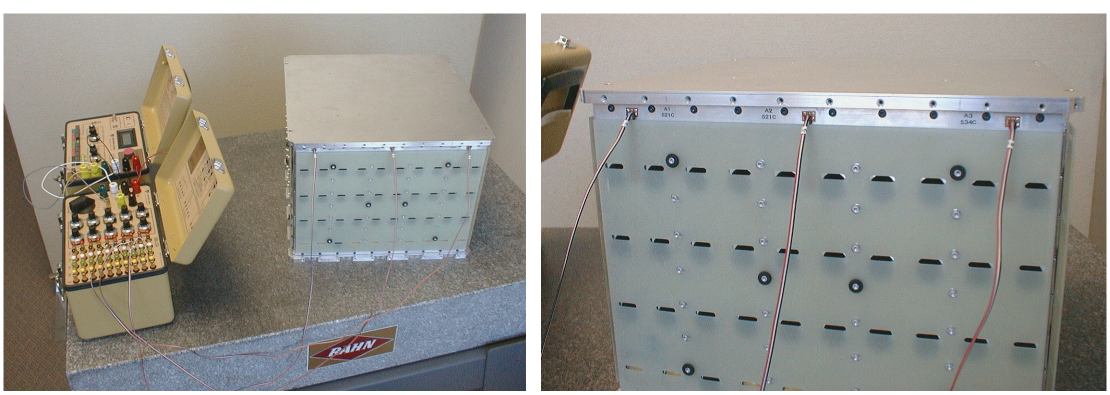

Figure 16: strain gage monitoring of the stack compression.

- Using the channel selector on the SB10, measure strains in the 3 gages (the P3500 displays strain in με). Note that the strain gage setup is <u>not</u> compensated for bending in the containment wall; significant errors (as large as +/- 30 με) will occur if bending is induced in the containment walls (by the PCB for example). Also, note that because the top and bottom panel bend slightly due to the pressure from the stack, the center gage (#2) will almost always show more strain than the edge ones (#1 and #3).
- The approximate tension resultant in the panel is obtained from 'trapezoidal' averaging and a predetermined calibration factor (see Appendix A):

$$F = 7.90 \frac{\varepsilon_1 + 2\varepsilon_2 + \varepsilon_3}{4} \frac{\text{N}}{\mu\varepsilon}, \qquad (1)$$

  where ε_1, ε_2, ε_3 are the 3 measured strains on any given panel.
- Add the forces in the 4 panels A, B, C, and D to approximate the total compression in the stack

$$F = F_A + F_B + F_C + F_D \qquad (2)$$

4.7 Install Shear Panels

- Install the *corner posts* (1012) (note that they are not held in place until the shear panels cover them).

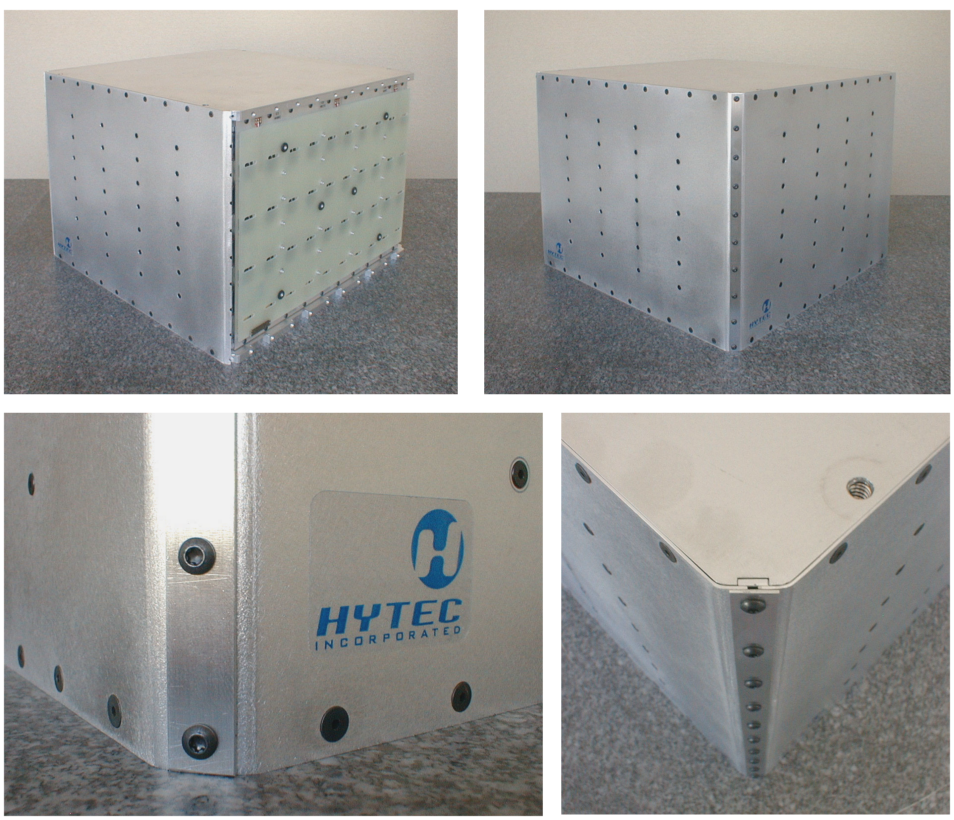

Figure 17: installing corner posts, shear panels, and corner clamps.

- Install the *shear panels* (1013): check for alignement with top and bottom panels and with the spacer spools of the containment panel, insert a few screws in the top and bottom panel (finger tight) to hold it in place.
- Engage all screws (finger tight) in top and bottom panel and the connection posts with the containment panels.
- Repeat for the other 3 walls.
- Install the *corner clamp strips* (1011) and hold them in place with the screws (finger tight).
- Now tighten all screws to the recommended torques, using the torque limiting screwdriver.

5. References

1. E. Ponslet *et al.*, “Conceptual Mechanical Design of a CsI Calorimeter for GLAST,” Hytec Inc., HYTEC-TN-GLAST-03, June 1998.

6. Appendix A: Calibration of Stack Preload Sensors

The containment panels are equipped with permanently installed strain gage as a means to monitor stack compression (Fig. 18). These panels were tested individually to calibrate the sensors for balance and gain (Fig. 19).

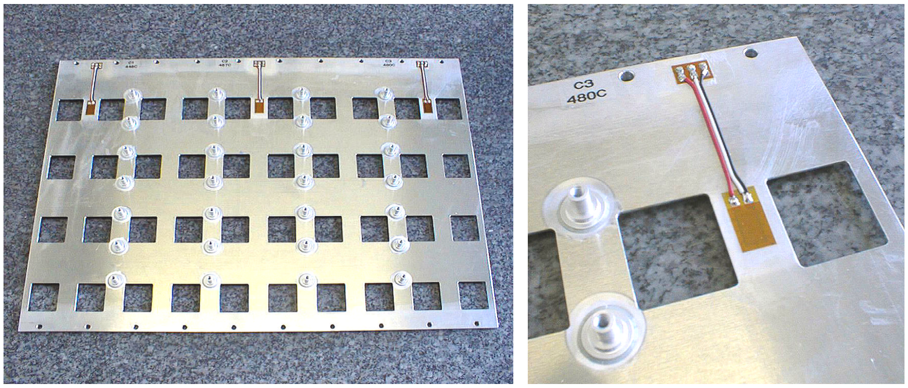

Figure 18: strain gage monitoring of containment panel loads.

The calorimeter compression design load translates to about 4337 N (975 lb) reacted in pure tension in each of the 4 containment panels. During the calibration tests, each panel was subjected to tension loads in the 0 to 4500 N range. The strain gages were balanced (so that they read zero strain when unloaded) and the correlation between total panel load and individual strain gage readings was calibrated and compared to numerical predictions.

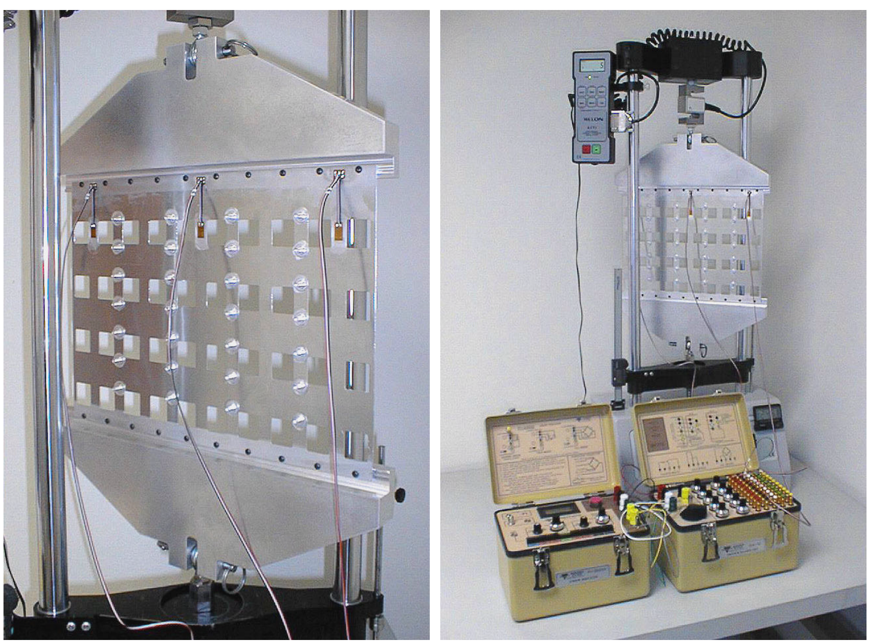

Figure 19: calibrating the load monitoring setup.

The balance values (position of multi-turn balance potentiometers on SB10 switch unit) are listed in table 1 for all 12 strain gages. Those balance values are also indicated on the panels themselves (labels next to the strain gage connection pads).

SG #	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
Bal.	521	521	534	609	540	431	446	467	480	450	536	402

Table 1: SB10 Balance values for strain gages on containment panels A, B, C, and D.

Figure 20 shows the average (in 'trapezoidal' rule sense, i.e. the center gage gets twice the weight of the edge gages, see eq. A1 below) of the readings (in microstrains) of the 3 gages on each panel as a function of the applied traction load. The dashed black line shows the prediction from FEM modeling.

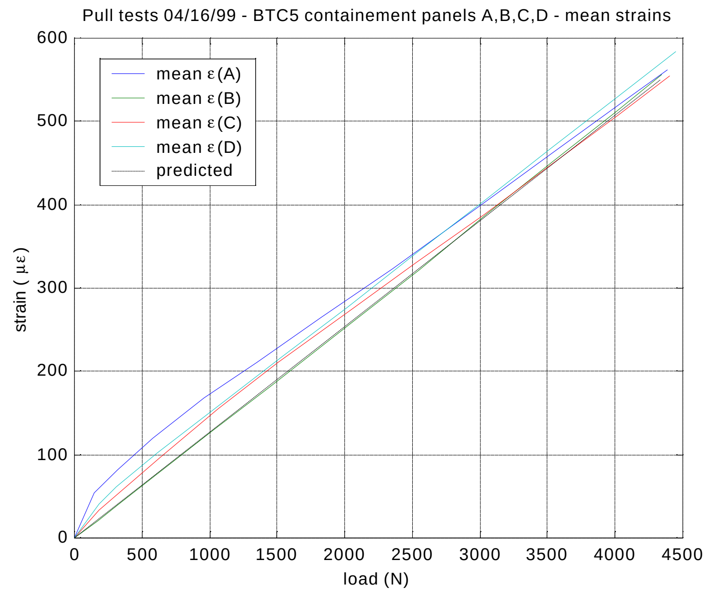

Figure 20: average strain gage readout VS applied load, compared to numerical prediction.

The figure shows good agreement between experimental and numerical results. The resulting panel calibration is

$$F = 7.90 \frac{e_1 + 2e_2 + e_3}{4} \frac{N}{me}, \qquad (A1)$$

where e_1, e_2, e_3 are the 3 measured strains on any given panel.

7. Appendix B: Calibration of Press Coil Springs

Since the coil springs are critical elements of adjusting the preload in the stack, they were tested individually to measure their spring constants and free length. The setup is shown in Fig. 21.

Figure 21: calibrating stack compression springs.

Two types of springs are provided. Both types are standard SPEC heavy duty compression springs. The "small" springs (CV-1500-500-13) can produce loads up to about 1400 N each (5600 N total on the stack), as required for the beam test calorimeter assembly. The "large" springs (CV-1500-4500-300) can produce up to 5000 N each (20000 N total on the stack) and will be used to assemble the mechanical test unit.

Calibration curves for the 2 types of springs are shown in Figs. 22 and 23.

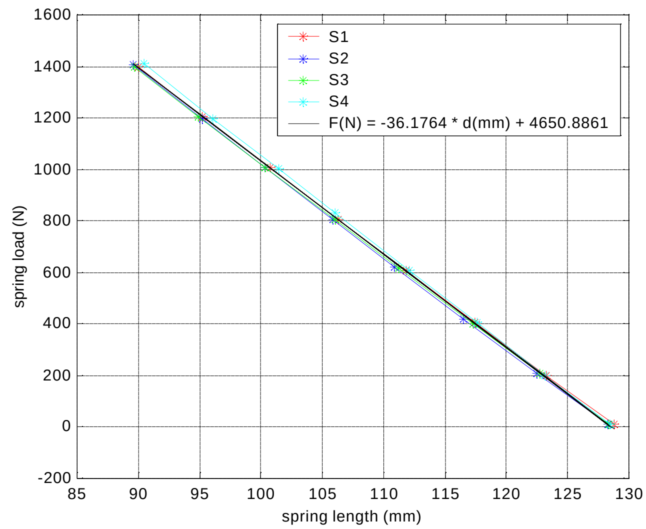

Figure 22: calibration curves of the 4 small springs (CV-1500-5000-135); the average free length is 128.56 mm.

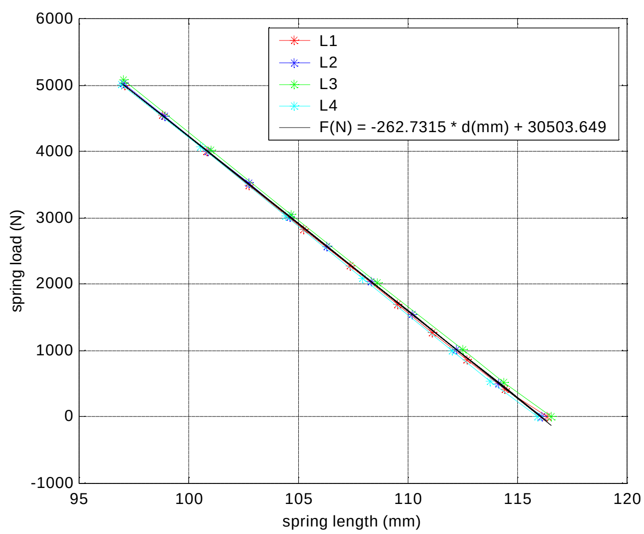

Figure 23: calibration curves of the 4 large springs (CV-1500-4500-300); the average free length is 116.10 mm.

8. Appendix C: Stack Compressibility

The compressive stiffness of a stack, assembled with dummy aluminum logs was measured for compressive loads ranging from 0 to 17.5 kN (the nominal stack compression design load). The test setup is illustrated in Fig. 24. The stack was progressively compressed with the small springs first, then unloaded and compressed with the large springs. The applied load was estimated by measuring the lengths of the springs at every loading step, while the compression was measured with a digital indicator (0.001 mm resolution).

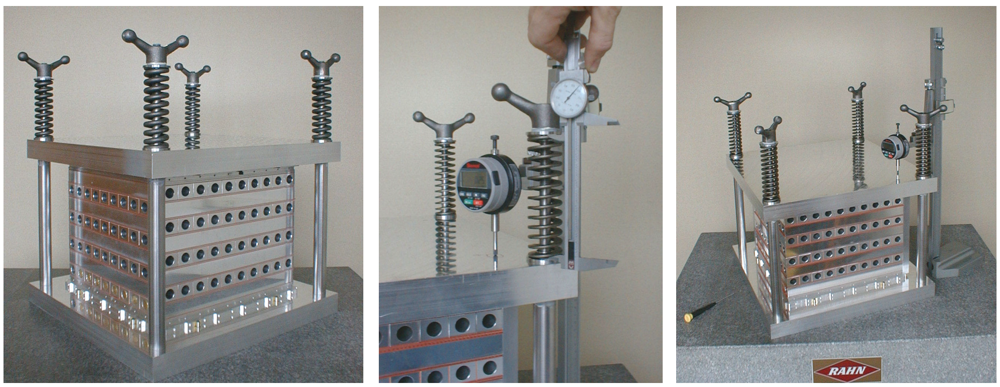

Figure 24: measuring compressive stiffness of calorimeter stack.

The results are summarized in Fig. 25. The stack compression is plotted as a function of the applied load. Some amount of hysteresis is visible in the unloading paths. The final stack stiffness is about 18000 N/mm. Note that stacks built with actual wrapped CsI logs are likely to exhibit lower stiffness because of non-uniform pressure and wrap compressibility.

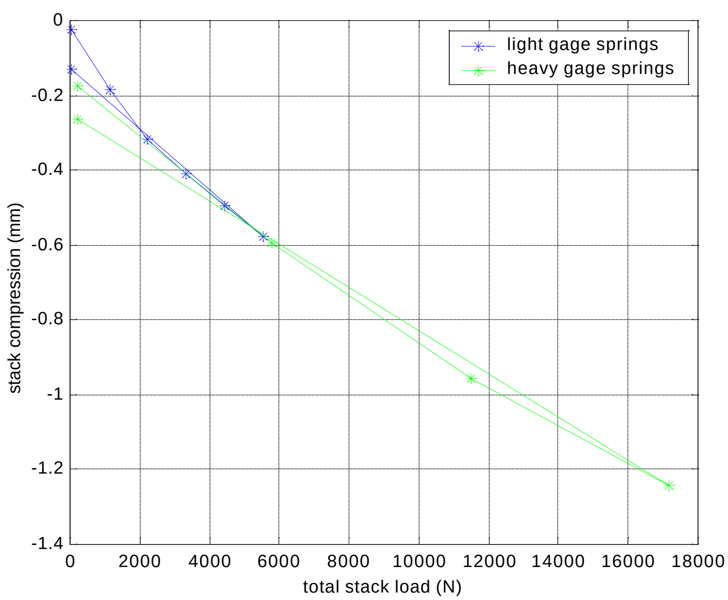

Figure 25: stack compressibility.

9. Appendix D: Recommended Torques for Fasteners

The calorimeter assembly uses only two different sizes of screws: #3 and #4. Because the holes are threaded directly in aluminum alloy, there is a risk of stripping threads by over tightening. Only use the supplied screwdrivers or the torque-limiting screwdriver to tighten the screws; using an L-shaped Allen wrench would almost certainly lead to damaged threads.

We recommend tightening all #4 screws to 6.0 lb.in, and all #3 screws to 4.0 lb.in.

10. Appendix E: Drawings

All drawings are available in electronic form from HYTEC's FTP site (hytecinc.com, anonymous). The following list identifies the most recent (as of May 24, 1999) release of every drawing. Copies of those drawings are included in the following pages.

Calorimeter Assembly (1000 series)

Assembly	GLS-BTC5-1000	Rev a
Containment Panel Assembly	GLS-BTC5-1001	Rev a
Shear Panel Assembly	GLS-BTC5-1002	Rev a
PC Board Assembly	GLS-BTC5-1003	Rev a
Outer Spacer Spool	GLS-BTC5-1004	Rev a
Inner Spacer Spool	GLS-BTC5-1005	Rev a
Bottom Compression Panel	GLS-BTC5-1006	Rev a
Top Compression Panel	GLS-BTC5-1007	Rev a
Containment Panel	GLS-BTC5-1008	Rev a
PC Board 2	GLS-BTC5-1009	Rev a
PC Board 1	GLS-BTC5-1010	Rev a
Corner Clamp Strip	GLS-BTC5-1011	Rev a
Corner Post	GLS-BTC5-1012	Rev a
Shear Panel	GLS-BTC5-1013	Rev a
Outer Shim	GLS-BTC5-1014	Rev a
Inner Shim	GLS-BTC5-1015	Rev a
Perforated Rubber Sheet	GLS-BTC5-1016	Rev a

Assembly Fixtures (2000 series)

Assembly Fixture	GLS-BTC5-2001
Spring Retainer	GLS-BTC5-2002
Guide Rod	GLS-BTC5-2003
Compression Plate	GLS-BTC5-2004
Base Plate	GLS-BTC5-2005
Alignment Plate 1	GLS-BTC5-2006
Alignment Plate 2	GLS-BTC5-2007
Test Plate	GLS-BTC5-2010

Test Fixtures (3000 series)

Crystal Replacement Alum. Bar	GLS-BTC5-3001
Crystal Replacement Brass rod	GLS-BTC5-3002
Containment Board Pull Test Yoke	GLS-BTC5-3003
Containment Board Pull Test Thread Adapter	GLS-BTC5-3004
Shear Plate Forming Tool	GLS-BTC5-3005

Miscellaneous Drawings (NOT FOR FABRICATION) (4000 series)

Assembly	GLS-BTC5-4000
Assembly	GLS-BTC5-4001
Side panel Spacer Assembly	GLS-BTC5-4002