9/24/2004

ACD Photo-multiplier Tube (PMT) Recovery Effort
Review held on 8-30-04
Peer Review Recommendations

Peer Panel Members:

Science Dr. Bob Streitmatter/661	**Structural Analysis** Scott Gordon/542 Cengiz Kunt/Swales
Mechanical Design Armando Morell/544 Rodger Farley/543	**Thermal** Tom McCarthy/545
Glass/Reliability Walt Thomas/302	**Electrical** Jose Florez/560 Art Ruitberg/563

Overview:

The Peer Review was held on 8-30-04 in the Building 30 conference room. The review was well attended by personnel closely affiliated with the project, as well as the review team listed above. The PMT team was praised for their efforts to date and for their grasp of the problem and its solution. Comments and suggestions were solicited from the panel members both during the review and afterwards via e-mail. What follows is a summary of those recommendations sorted by category with the redundant comments eliminated. Also appended are the unedited written inputs by e-mail from the reviewers.

General Recommendations

1. While a majority of the panel members agreed with the chosen solution path (Partially CTE compensated/spring), it was not unanimous. It was strongly suggested to invest time/effort to also mature the Grooved/potted design as a back-up.

   Response/Comment : ACD will do this. Doing this in parallel was not favored some higher level personnel. This will now occur after most of the work on the primary solution is done. We have already managed to slip in initial assembly work on the back up solution though.

2. Given the known flaws in the PMT's, along with the statistical nature of glass failures, can the stated maximum on-orbit failure rate of 3% be achieved? The

ACD reliability model has been revised to include an input for the PMT Pf; however, there is no/insufficient data available (to date) to define that number. To mitigate this risk it was recommended that new tubes using the improved process be used.   There were reservations regarding the approach to recover use and existing PMT's for flight.

This was looked into and is attractive to us because the new PMTs have less glass flaws. PMTs are assigned to channels via their performance which varies. However the new PMTs are coming in at a narrower performance range. This means many of the already potted are needed for ACD to meet its performance requirements. How many will have to wait until re-analysis and reassignment work is done based on how many of those PMTs get through removal or thermal screening. General reliability prediction is a tough issue here, we are considering if we may be able to infer at least some reliability data related to this particular glass failure mode from results of the qualification testing of the new design which now involves higher numbers combined with results from some kind of thermal screening we will likely do to all PMTs prior to assembly

3. Whatever new approach is selected, take the required time to analyze it and understand it before embarking on the development.

   We are working on that as we prepare for qualification tests. Trying to balance money pressures from above with technical desires.

Design/Process Recommendations

1. Determine and use Minimum Required Wavy Washer Stiffness in order to minimize thermally induced stresses in the glass tube. Size spring stiffness to maintain a sufficiently high frequency and to keep the vibration induced motions of the PMT sufficiently low.

   Preloads with the chosen spring seem enough to prevent likely motion under vibration but low enough to keep preloads and thermal loads under criteria. Fiber preloads could erode this some but they can't be predicted until assembly

2. Resolve the parylene migration concern.

   Initial parylene tests look promising, Modifications to allay corona concerns where combined with a more sensitive test. The results are now being analyzed (9/22)

3. Resolve the grounding concern with the spring.

   The retainer on the bottom has been changed from Delrin to Al to aid this grounding. Note that at high voltage surface properties matter less.

4. Perform PMT dimensional measurements, using/based on the lot records from Hammatsu, since the PMT tubes likely would be fabricated as groups and between-tube dimensional variances likely would be related to the fabrication "sequence," i.e., manufacturing lots. You should be able to establish "within lot" variability through these measurements to size the custom delrin parts.

   We initially tried this but it turned out to be more reliable and faster to just measure the PMTs as received

5. If there is room at the base-end of the tube, consider using a "ring" of Kapton insulation between the metal washer and the high voltage leads - Kapton has a very good dielectric constant per thickness and already has been used extensively for spacecraft and space instruments for it outgassing properties.

   Based on iterations with Art Ruitburg we have modified the Delrin insert so that it centers the spring not allowing one side to get closer to the leads and added a lip which acts as an insulative shield between the leads and the spring

Analysis Recommendations

1. Address the possibility of local bending (hence tension) at the ends of the glass tube, where load is applied through contact with the delrin inserts. No strain data or stress predictions were presented for these areas. Perform stress analysis of the PMT ends under nominal contact conditions. Also check sensitivity of stresses to non-uniform loading of ends due to tolerance build-up.

   Attached is a brief powerpoint with two slides. Slide 1 shows results of the discrete loading of the wavy washer (Recommedation item #3) and results from a line contact at the top between the delrin and the glass tube. Plot 2 shows the results from this line contact. We see that because the line contact is not over the tube wall centroid, there is a moment created. However, this eccentricity does not cause a large peak tensile stress (~700 kPa).

   Slide 2 shows the maximum and minimum principle stresses at the bottom of the tube under nominal contact conditions for a 780 psi compressive load on the tube. We see that at the point of contact in plot 2 there is a peak compressive contact stress of 6.5 ksi and is very localized. Plot 1 shows the corresponding tensile stress in the inside of the tube due to the contact of the delrin and it shows a max of 545 psi. Keep in mind that this is for a 780 psi compressive loading in the tube and strain data shows that we are well below that so this analysis is conservative. Analysis shows that the results are pretty linear so we could probably extrapolate if we need to.

2. Develop a compressive stress allowable for the glass tubes. The compressive loading is being applied to a thin walled cylinder so buckling rather than the

material compressive strength may be the governing upper bound to stress. The buckling allowable should be checked to ensure that the correct upper bound on compressive load is understood when sizing the mechanical design(s) for preload and final stress state under cold conditions. Thin-wall cylinders are notorious for buckling under compressive stress in either the axial or radial direction There are large de-rating factors on the bulk material properties which must be applied in the cylindrical configuration

The compressive stress allowable for the glass tube is approximately 6-7 ksi. Bear in mind that this 6-7 ksi allowable should be used in comparison to a larger area stress state, NOT for a localized contact stress as discussed in item 1. Strain data and analysis shows that the compressive stress in the tube is approximately 250 psi.

A quick check was performed on the critical buckling stress. Analysis shows that the critical buckling stress is very large (~480 ksi) and is not an issue.

3. Check compressive stress peaking near the glass tube end under point loading of the wavy washer. Recommend representing the discrete nature of wavy washer loading on the delrin insert to determine the extent of compressive stress peaking in glass. Combine with results of 1 above.

   Slide 1, plot 3 of the powerpoint attachment shows a contour of the compressive stress peaking due to the discrete contact points of the wavy washer. For conservatism, this analysis assumes a very stiff spring and results in a compressive peaking of approximately 1.5 ksi (10627 kPa) and can be considered an upper bound for this case. The peaking is localized and extends up the tube approximately 0.090".

4. Resolve Glass Compressive Stress Discrepancy between test and analysis and make sure to fully understand the stress state in the glass. Recommend representing stiffening of the spring washer in FEA as it gets flattened out under thermally induced compression. Make hand calculations to check FEA results.

   Recent strain gauge test results show compressive stresses in tube on the order of 250 psi which corresponds to analysis within the strain gauge error bar. We see a more accurate correlation when we use an unloaded pmt in the assembly to zero out the cte effects of the strain gauge.

5. Determine and use Minimum Required Compressive Preload in order to minimize stresses induced in the glass tube. Use a Safety Factor of at least 1.25 to unsure no gapping under maximum expected vibration load. Show derivation of minimum preload clearly.

   Assuming mass of glass pmt is 11 grams and it sees a 50g load we get a longitudinal force of 5.4N (1.2lbs). The wavy washer carries approximately a

10lb preload so there is no risk of overcoming the preload the wavy washer puts on the tube. The 10 lb preload does not induce a high enough compressive stress to raise any flags. I believe the use of this wavy washer fits well within our requirements.

6. Justify use of Housing Strains to screen PMTs. Use FEA to analytically show that when the glass strains are high so are the housing strains.

   We have had one of the 10 tubes which 'passed' strain screening, fail the thermal screening. So we now will be removing most of the potted PMTs. The only exceptions may be some of the PMTs with coated Resistor networks which may be thermaly screened and used only as spares – have not made decision on those yet

7. Regarding the notch-potted-debond option: Although it is very low (18 psi), it was not understand why the outer surface of the glass is in tension in the cold condition. Despite a post-meeting discussion of the local-element forces on the glass, it seems that the outer surface would be in longitudinal compression as the RTV contracts. The inner surface might be in tension, in the manner that a loaded beam has tension on the underside surface while having compression on the upper surface. In which case there would be a tension gradient in the radial direction.

   Answered by Ryan Simmons by email on 9/3. Ask us for a copy if you did not get the email and want to see it

Test Recommendations

1. Concern was expressed about the accuracy of strain gauge readings. Discrepancies in stress levels with similar (identical) assemblies have been explained with the differences in the RTV properties, but now having much higher than expected stress on the spring mounted design warrants further investigation and the need to rule out errors in the measurement itself. Suggest instrumenting the qualification PMT's with strain gages on both the aluminum housing and the glass tube and testing under thermal cycling.

   Further tests reveal that the errors are within strain gauge error limits and that although small differences are possible, we are looking for such a small strain that the error encompasses the predicted strain and test result strain. More to come on this.

2. Strongly recommend reducing the cooling/heating rates to match the expected operating environments. Stress resulting from a through the thickness gradient could easily be a large contributing factor in the type of failures experienced and it needs to be understood and managed. The 20 deg/hour rate should be proved to be a non problem or it needs to be reduced.

We will reduce the rate, bit we have not decided on the final rate yet. Right now chamber settings make it likely 12 deg/hour will be used. This is still faster than flight rates.

3. Conduct a life test program for the redesigned units for the remainder of the project, such that it completes before we launch.

   We will do this once production starts