LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Beam Tube Inspection Report

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1 Introduction

During the summer of 2007, it was requested that a plan be formulated for a complete inspection of the Beam Tube slabs and enclosures at LLO. It was decided that the inspection would be made during cool weather to reduce threat to inspection personnel from snakes and insects. A plan was formulated and is reported in LIGO Doc # LIGO.T070265-00-D. The inspection was scheduled for the week of 1/21/08.

2 Beam Tube Inspection Participants

R. Weiss (lead)
Albert Lazzarini, Danny Sellers, Harry Overmier, Gary Traylor, Allen Sibley, Rich Riesen, Bernie Ladnier

3 Summaries

The following are excerpts from log entries posted by Rai and Albert. Complete details and photos can be viewed at LLO detector log, key word “beam tube inspection”.

3.1 X Arm Beam Tube Inspection Summary

The results from the walking inspection on both sides of the X arm beam tube in the enclosure are that the slab does not show cracks (no evidence for settling) and, though there are leaks, the tube is not corroding under the insulation. On average the situation in the enclosure is excellent. There are spiders but no rodents. One of the more noteworthy discoveries was shrapnel from a lightning strike that had hit the side of the enclosure that left concrete pieces several inches across embedded in the insulation.

As can be seen in the LLO detector log, the leaks are due to both holes in the caulking between enclosure sections and from longitudinal cracks at the apex of the concrete enclosures. The cracks in the concrete come in several kinds. One rare type forms stalactites in the ceiling composed of leached calcium while the more common kind are hairline cracks. It could well be that these leaks were more active after construction than they are now. They are most easily found by looking for white mineral deposition on the outside of the beam tube insulation. Both the leaks from the lost caulking and the concrete cracks are not uniformly distributed along the tube. The first section of X1 module had a higher density of leaks than the rest of X1 and all of X2.

3.2 Y Arm Beam Tube Investigation Summary

The results from the walking inspection on both sides of the Y arm of the beam tube in the enclosure are that the slab does not show cracks. There are significant leaks in Y1 in the inter-enclosure caulking, some large enough to cause water to collect between the beam tube and the insulation at the bottom. The beam tube surface does not show overt

corrosion even in those places where water has collected. We find occasional ferritic corrosion marks that are most likely due to the contact of the stainless with ferritic steel such as in chain hoists. There are lightning strikes with shrapnel embedded in the insulation in various locations. As we found on the X arm, the inside of the tubes is clean with little evidence of rodents though lots of spiders. Again, as we observed in the X arm, the leaking is not homogeneous; there are good sections and bad ones. Today the worst leaking was in the 3/4 of the Y1 beam tube closest to the LVEA. Although we have not finished Y2, the part we have looked at so far is much better than Y1.

We are not sure that we looked carefully enough in the X arm for places where there were leaks and there could have been water between the bottom of the beam tube and the insulation. A special investigation will be made to look at those locations where we found leaks in the X enclosure.

3.3 Further Inspection

We completed the final stretch of the Y arm, from about the 2.25 km point to the end of the Y-arm. Rai's summary from yesterday's walk through of the Y Arm applies here also, so it shall not be repeated.

It was raining today, so we could see first-hand how water leaks in and onto the top of the Al vapor barrier of the BT insulation covering. In such places, over time, the Al covering is corroded and water penetrates into the fiberglass cladding. In such cases we regularly find fully saturated blankets: slitting their bottom sides causes water to pour out.

Further, in the steady rain, even "tight" joints not exhibiting daylight had drops forming on their edges. Perhaps this is due to the fact that the backing foam rods were blocking direct view of the holes in the caulking even though water was seeping in.

The gutter along the base of the joint between slab and BTE was very wet, with water accumulation in it, all along the portion of the arm we inspected today.

Of note: there is a significant (largest we found) lightning strike at the roof of the joint between two enclosures, #9 and #10 south of door Y-2-D. It is a gaping gash into which one could easily put one's hand from the top of the BTE. Gary reported seeing it yesterday on his walk along the crest of the BTE.

Based on our experience yesterday, we did not uncover the beam tube -- we were sure of what we would find.

Once again, the slab shows full integrity along its entire length. We did not find a single crack. The inside of the BTE is clean with little evidence of rodents though lots of spiders. Again, as Rai reported, the leaking is not homogeneous; there are good sections and bad ones.

Rai suggested that we revisit the X arm to do spot checks because the Y arm inspection on the second day led us to perform investigations that had not been performed on day one. After completing the Y arm, Harry revisited the X-arm based and reported;

> "We did a spot check on the west arm (it was raining today). We entered the BTE at 11 enclosures west of X-1-G and 8 enclosures west of X-1-7. We saw much less water on the floor and only found two places were water was in the insulation."

3.4 Rai Weiss Meeting with Tom Eagar

Tom explained what we have observed is the concrete being leaded by water, which causes CaOH to be dropped onto the aluminum. Both bases and acids corrode the aluminum; it is not surprising that the aluminum foil has been compromised. The CaOH is very basic (ph > 7). He is far less worried about the stainless steel, which can handle most arbitrary bases but is intolerant to strong acid. The tolerance to the acid is reduced by halides such as chlorine. He suggests that the water samples be measured for ph and for chlorides. He is not in a panic about the stainless being immersed in water and says that if we saw no powdery graininess on the SS and just the dark brown and blue chromium oxide, we are not in danger of losing the tubes any time soon. He certainly encourages us to fix the leaks. He mentioned that caulking concrete in the South is often troubled by algae growing on the concrete. He wants us to make sure that any contractor that offers a solution is aware of this possibility.

4 Follow Up

SpetroChem of Baton Rouge preformed analysis of the samples and results were submitted on Feb. 1, 2008. Results indicate a Ph of 8.6 and total Chlorides (ppm) 2.0. Bother are well below concern levels.

CSRS, a professional engineering firm, has been contacted to perform engineering analysis of the existing waterproofing and research approaches to a solution for our water leak problem.