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Advanced LIGO Quadruple Pendulum Suspension Failure Modes and Subsequent Repair Approaches

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Rev 00 – initial
Rev 01 – correct typo
Rev 02 – use tabular form, add more details
Rev 03 – add Helena's comments from e-mail dated Jul 23, 2004 for modes 1,8 and 10

I. INTRODUCTION

This document details some problems that may occur with the quadruple suspensions after a suspension has been installed in a chamber and the chamber has been closed. Following is a table of some possible failure modes and their subsequent repair approaches. This is a working document and as such, will evolve with the design. It will be updated periodically to capture any changes to the design that will affect the possible failure modes and repair methods.

II. REFERENCE DOCUMENTS

T040072, Pendulum Parameter Descriptions and Naming Conventions

T040080, Advanced LIGO ETM (Quad) Controls Prototype Catcher Jig Design Specification

T040084, ETM Catcher Jig: Design Brief

T040141, ETM Upper Structure Product Design Specification

III. TABLE 1: POSSIBLE FAILURE MODES AND SUBSEQUENT REPAIR APPROACHES

#	FAILURE MODE	REPAIR APPROACH	COMMENTS
1	A fiber breaks, and the test mass sits on its earthquake stops.	a)Lock down the SUS components above & near the stuck one. b) Replace the earthquake stop (ES) assy with the catcher assy, if required. b)Remove the catcher from the chamber. c)Break the fiber at the other ear. e)Weld another fiber. f)Re-install	The earthquake stop assembly – not the catcher – will have to be used to remove the bottom four masses (optic, penultimate mass, reaction mass and reaction penultimate mass) unless the stops themselves are one and the same for both the catcher and the stop assembly, assuming the earthquake stop assembly and the catcher assembly are not in two separate sections. It is not clear yet whether the catcher itself will be in two sections (main, reaction) but it is

2	An ear breaks off of a mass, and the optic sits on its earthquake stops.	a)Lock down the SUS components above/near the damaged one. b) Replace the earthquake stop (ES) assy with the catcher assy, if required. c)Remove the catcher from the chamber. c)Break the fiber at the other ear. d)Remove & replace the damaged optic. e)Weld another fiber. d) Re-install	assumed that the ES assy will probably be in two sections. The process of preparing to remove the catcher involves moving the four bottom masses up into the upper part of the structure, protecting the fibers, unscrewing the clamps from the UIM blades and setting them off to the side (away from the fibers.) Then, the catcher may be removed from the chamber.
3	The core optic hits the reaction mass/electrostatic drive coating and damages the coating.	a)Lock down the SUS components above & near the damaged one. b) Replace the earthquake stop (ES) assy with the catcher assy, if required. c)Remove the catcher from the chamber with all four optics. d) Break fiber of reaction mass and remove the fiber. e)Replace with suitable spare reaction mass. f) Weld on a new fiber. g) Re-install	
4	A glued-on magnet comes off of the penultimate mass. It falls to the floor of the chamber without bothering anything else	Repair may not be required. Actuation is possible with only 3 actuators.	
5	A glued-on magnet comes off of the penultimate mass. It attaches to something (earthquake stop assembly) making the stop assembly unable to move.	Go in the chamber and remove the magnet. Again, repair may not be required.	
6	A glued and bolted-on magnet	Repair may not be required.	

	comes off of the UIM, and falls to the floor of the chamber without bothering anything.	Actuation is possible with only 3 actuators.	
7	A glued and bolted-on magnet comes off of the UIM, and attaches to another magnet on the way down.	Determine if the actuator with the double-decker magnets can be turned off. Make sure that the piggy-back magnet doesn't stop movement of the optic and reaction mass. If this is so, the piggy-back magnet will have to be manually removed. Replace the missing magnet by bolting on another.	
8	A glued and bolted-on magnet comes off of the top mass, not hitting or obstructing anything.	This depends on which magnet it is. It probably won't be the magnets mounted on the top of the mass. It will probably be the side. Determine if the magnet is actually needed. If it is, lock down all suspended items and consider removing the magnet holder. Screw in another holder/magnet assembly.	
9	A glued and bolted-on magnet comes off of the top mass, and it attaches to something on the way down that makes performance diminish.	Go in the chamber and remove the magnet. Again, repair may not be required.	
10	A wire breaks between a penultimate mass and an UIM blade.	a)Lock down the SUS components above & below the broken wire. b) Replace the earthquake stop (ES) assy with the catcher assy, if required. c)Remove the catcher from the chamber with all four optics. d) Protect the fibers. e)Remove the remnants of the broken wire, remove clamps from the blades.	The same issues that came up in the #1 scenario applies here. The penultimate mass will be sitting on its stops. But, the catcher assembly needs to be installed to move the masses up into the upper part of the structure to allow for replacement of the wires. Since the wire will most likely touch the fibers after it breaks, it is best to replace the fibers at the same time.

		f) Move catcher down and away from the penultimate mass, while it is supported by stops. Insert new clamp-wire-clamp assy under optic, between fibers. g) Bring catcher up into place. Attach clamps to UIM blades. g) Re-suspend.	Instead of moving the catcher down, one could move the penultimate mass up, with the ergo arm, to put the clamp-wire-clamp assembly under the mass.
11	A wire breaks between an UIM blade and a top mass blade	Lock everything down and replace the clamp-wire-clamp assembly.	
12	A wire breaks between a top mass blade and a top blade.	Lock everything down and replace the clamp-wire-clamp assembly.	
13	Any of the ECDs have a shorting problem.	Go in and mount the adjustment assembly onto the suspension ECD and move it to the proper orientation.	
14			