

LIGO Laboratory / LIGO Scientific Collaboration

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**The review of production drawings for the ALIGO ETM
Quad End Reaction Mass: support notes**

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Rev 00	26 th February 2008	First draft, response required to action list in conclusions (R. Jones)
Rev 01	18 th March 2008	Updates to action list following review of drawing ¹ and specification By I. Wilmut and G. Billingsley (R. Jones)
Rev 02	10 th April 2008	Updates to the component specification following information exchange between Strain and G. Billingsley (R. Jones)
Rev 03	18 th April 2008	Comment from N. Robertson about choice of wire diameters. Reference to T060283-02 added to conclusion. Confirmation still required. (R. Jones)
Rev 04	14 th June 2008	Updates following response to preliminary design review questions (T080152-01) 20 th May 2008. (R. Jones). Confirmation notes in green . *Details of RODA confirming that the ERM has no wedge still to be added*

1 Introduction

This document introduces the key features of the ALIGO ETM Reaction Mass (ERM) for review purposes.

Production drawings are based on drawings used for the ALIGO noise prototype^{2,3} (NP-type). The drawing of the finished will be used as the main source of manufacturing information, supported by the material selection and inspection information described in the associated component specification.

The final form of the final ETM ERM differs from that of the NP-type ERM as follows:

- **NO FLATS**
- **Material change: from F2 to Fused Silica** (Now specified as: Corning 7980 3F, or vendor preferred equivalent fused silica, subject to approval of LIGO scientists)
- **Changed tolerance on wire groove position (use of symmetry tolerance, regardless of feature size, or RFS)**
- **Extension of wire grooves around full barrel of mass**

The following issues required confirmation before the completion of specifications:

- The ERM has NO WEDGE angle (*confirmed)
- Size and positional tolerance required for earthquake (face) stop recesses (*confirmed)
- Quantity, size and position of reference grooves (*confirmed)
- Confirmation of wire sizes (*not yet confirmed, but not a critical issue)

*A list of actions is tabulated in the conclusion. (These actions are also referenced throughout the text).

¹ Appendix 1: Drawing review by I. Wilmut (29/02/08)

² D050420-A _ALIGO ETM NP-type Reaction Mass

³ E060235-00_DCN_NP-type Penultimate and Reaction Masses

2 Review documents (*numbers to be assigned)

D080116	ALIGO SUS ETM QUAD End Reaction Mass (ERM)
E080089	ALIGO SUS ETM QUAD End Reaction Mass (ERM) component specification

3 Format of production specification

- Drawing⁴ to be used as main source of manufacturing information.
- No billet drawing provided
- Specification⁵ supports drawing, with material selection information and inspection requirements

Key production requirements:

- Precise knowledge of centre of mass position (for the bonding, and suspension in turn)
 - Wire grooves accurately positioned with respect to COM
- Polish area must be appropriate for electrostatic drive (ESD) coating
- Recesses for (earthquake) face stops: size and shape of recess to suit mating design.

4 List of main drawing features

- Diameter
- Thickness
- Chamfer size
- NO FLATS
- Wire grooves
- Associated (final) wire diameter
- Recesses for (Earthquake) face stops
- Reference lines/markings
- Polishing: of surface 'S1' – subject to the gold coating process for the ESD.

5 Discussion and clarification of features

⁴ D080116 ALIGO ETM QUAD End Reaction Mass (ERM)

⁵ E080089 ALIGO ETM QUAD End Reaction Mass (ERM) component specification

5.1 Diameter: $\varnothing 340.0\text{mm} \pm 0.25\text{mm}$ (With cylindricity tolerance of 0.1mm)

Justification: Maintained in accordance with NP-type ERM drawing, where specification was easily met.

**ACTION 1(ERM) - (DONE): Confirmed by successful NP-type deliverable (Glasgow).
[* This was approved/confirmed during the preliminary design review, 20th May 08.]**

5.2 Thickness: $130.0\text{mm} \pm 0.25\text{mm}$ (plus parallelism requirement)

Justification: Maintained in accordance with NP-type ERM drawing, where specification was easily met. Despite the change of material to silica (from F2), experience from the LASTI Compensator Plate purchase would suggest that maintaining this tolerance will not be a cost driver.

**ACTION 2(ERM) - (DONE): Thickness tolerance altered from original $\pm 0.1\text{mm}$ (RJ and KS, following drawing check)
[*This was approved/confirmed during the preliminary design review, 20th May 08.]**

5.3 Chamfer size: $2.0\text{mm} \pm 0.2\text{mm}$, x 45 degree ± 5 degrees ALL ROUND

Justification: Maintained in accordance with NP-type ERM drawing.

**ACTION 3(ERM) - (DONE): Confirmed by successful NP-type deliverable (Glasgow)
[* This was approved/confirmed during the preliminary design review, 20th May 08.]**

5.4 NO FLATS

Justification: This is consistent with drawings used for the NP-type Quad ITM Thermal Compensator Plate⁶.

**ACTION 4(ERM) – (DONE): Confirmed with SUS colleagues (Glasgow/SUS)
[*This was approved/confirmed during the preliminary design review, 20th May 08.]**

5.5 Wire Grooves: $30.0\text{mm} \pm 0.1\text{mm}$ (symmetrical within 0.25mm relative to datum C, regardless of feature size, RFS)

Justification: The NP-type ERM drawing specified the wire grooves such that in the worst case, the centre of mass (COM) could be 0.3mm from the desired COM⁶. The use of the symmetry positional tolerance should minimize any error in position regardless of the eventual thickness of the mass (RFS).

ACTION 5(ERM) - DONE: Confirmed following drawing check, but tolerance on symmetry of grooves has been relaxed since the drawing check (from $\pm 0.1\text{mm}$, to $\pm 0.25\text{mm}$) (RJ/KS, Glasgow)

[* Spacing and tolerances were confirmed during the preliminary design review, 20th May 08. NOTE: The review raised concerns over surface defects that may be present following the creation of the grooves. GariLynn Billingsly offered to look into issues relating to fracture strength/propagation with vendors.]

⁶ Email from I. Wilmut to R. Jones 25th January 2008 “RE: DCN for PM and ERM”

5.6 Wire diameters: \varnothing 0.46mm

Justification: Maintained in accordance with NP-type reaction mass drawings.

ACTION 6(ERM): Yet to be confirmed, but any small change to the diameter (+/- 0.1mm) would have little or no effect on the specification of the wire grooves (RAL)

5.7 Recesses for (Earthquake) face stops: \varnothing 15 mm hole +/-0.25mm, depth 6.0mm (+/-0.1mm)

Justification: Maintained in accordance with NP-type penultimate mass drawings (where the specification was agreed at UK project weekly meeting ALUK Weekly Project Meeting, 07/07/06)

ACTION 7(ERM)) – (DONE): Confirmed by J. Greenhalgh (RAL) at ALUK weekly meeting, 14/03/08.

[* This was approved/confirmed during the preliminary design review, 20th May 08.]

5.8 Reference Markings: 4 off extending face to face across barrel of mass (12 o' clock, 3 o' clock, 6 o' clock, 9 o' clock)

Justification: Markings cover the full width of the mass, at top and bottom, as well as left and right when looking from surface 'S1'. This is consistent with drawings used for the NP-type Quad ITM Thermal Compensator Plate⁷ apart from a slightly reduced tolerance on the groove width (changed to 0.25+/-0.05mm).

ACTION 8(ERM)) – (DONE): Confirmed by J. Greenhalgh (RAL) in email to R. Jones (21/03/08) following discussions with D. Cook at the March LSC Meeting.

[* This was approved/confirmed during the preliminary design review, 20th May 08.]

5.9 Polishing: 80/50 scratch/dig specification on surface 'S1' – for ESD gold coating process

Justification: Specification used for both NP-type ERM (D050420) and NP-type QUAD ITM CP (D060534).

Addition of following text to E080089 following discussions between K. Strain and G. Billingsley⁸:

Material must meet the following requirements:

Index Homogeneity in central 200 mm diameter is $\leq 5.0 \times 10^{-6}$ P-V after subtracting tilt and power.

Total bubble and inclusion cross section within the clear aperture is $\leq 0.5 \text{ mm}^2/100\text{cm}^3$.

Inclusions with a diameter of 80 μm or less are not included in the total.

&

Surface figure (see D080116, surfaces "S1" and "S2") in the central 200 mm diameter clear aperture: nominally flat, with the residual peak to valley $< 100 \text{ nm}$ after subtracting tilt and power.

ACTION 9(ERM) - DONE: Confirmed with SUS colleagues (Glasgow/SUS)

[* This was approved/confirmed during the preliminary design review, 20th May 08.]

⁷ D060534-B NP-type Quad ITM Thermal Compensator Plate

⁸ Email from G. Billingsley to K. Strain "Material requirements verbiage to add to your spec." (09/04/08)

6 Conclusion

The changes to the form of the final ERM (as compared to the form of the Noise Prototype ERM) are as follows:

- **NO FLATS**
- **Material change: from F2 to Fused Silica**
- **Change to the tolerance on wire groove position (use of symmetry tolerance RFS)**
- **Extension of wire grooves around full barrel of mass**
- **The ERM has no wedge⁹.**

Precise knowledge of centre of mass position will be ascertained by assessment of detailed inspection information.

All issues in the table below must be resolved before tender process can begin.

FEATURES	SIZE	Change from NP-type	ACTION No. / who	Confirmed
Diameter	ø340.0mm +/-0.25mm	None.	1-ERM/ Glasgow	Yes
Thickness	130.0mm +/-0.25mm (plus 0.25 parallelism requirement between faces)	Relaxed tolerance from +/-0.1mm to +/-0.25mm.	2-ERM/ Glasgow /SUS	Yes
Chamfer size	2.0mm +/-0.2mm, x 45 degree +/- 5 degrees ALL ROUND	None.	3-ERM/ Glasgow	Yes
NO FLATS	(As per NP-type QUAD ITM CP)	(Note: NP-type ERM had flats)	4-ERM/ Glasgow/ SUS	Yes
Wire Grooves	30.0mm +/-0.1mm (with 0.25 symmetrical tolerance)	Symmetric tolerance to reduce positional error. Reduction to radius at base of groove (from R0.3mm to R0.25mm MAX.)	5-ERM/ Glasgow/ RAL	Yes
Associated wire diameters	ø 0.46mm	(No change, but this issue is no cause for concern)	6-ERM/ RAL	*No

⁹ Email from R. Jones to D. Coyne (12/02/08) Subject: ETM and ERM questions. J. Greenhalgh indicated on 14th March in email to R. Jones that a RODA covering this issue is in progress, and is likely to be finalised imminently. **TBD. Insert RODA details.**

		Possibility of change to use of ϕ 0.35mm wire ¹⁰ , consistent with CP?		
EQ Face stops	ϕ 15 mm hole depth 6.0mm (+/- 0.1mm)	None.	7-ERM/ RAL	Yes
Reference lines	4 off, chamfer to chamfer across barrel (12 o' clock, 3 o' clock 6 o' clock, 9 o' clock)	None - as per NP-type QUAD ITM CP	8-ERM/ Glasgow/ SUS	Yes
Polishing	80/50 scratch/dig on surface 'S1'	Additions of following to E080089. (see section 5.9 above)	9-ERM/ Glasgow/ SUS	Yes

Note: No reference has been made to the need for transportation containers following manufacture within this document.

As noted in section 5.5, the review panel raised concerns over surface defects that may be present following the creation of the grooves. Acid etching was suggested as a possible solution to minimizing risk of any propagation of micro cracks. GariLynn Billingsly offered to look into issues relating to fracture strength/propagation with vendors.

The specifications will remain unchanged until feedback is considered.

Options for the approach to fabricating of the wire grooves are:

1. (Default) Specification unchanged (two grooves extending around the full barrel), close interface with vendors during production to optimise feature quality.
2. Enhance the specification through the addition of a treatment stage following groove fabrication (e.g. acid etch?) to reduce the number of surface flaws.
3. Amend specification such that grooves only extend around half of the barrel (i.e. 180 degrees instead of 360 degrees), as was the case for the NP-type masses. This way, if problems are encountered during the NP-type suspension with cracking/crushing, it will still be possible to choose to suspend without the wire locating grooves.

¹⁰ T060283-02-R Note on Design of the ETM Reaction Chain and ITM Reaction Chain in Advanced LIGO (N. Robertson)

- **Appendix 1:** Review of “D080116” rev00 drawing by I. Wilmut, emailed to R. Jones 29/02/08, and key points subsequently discussed/clarified on telephone.

