SCT End Cap Thermal Enclosures

Observations and Recommendations on the Valencia OTE Prototype

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Introduction

The OTE prototype arrived at RAL on 25.08.05. This was the first attempt at manufacturing a full size but shortened length (0.5m) composite cylinder using Airex foam, sandwiched between an outer Cu-polyimide film and an inner aluminised Kapton film (FIG. 1).

FIG. 1

After several months of early construction trials at RAL using smaller diameter specimens, it was clear that the construction of a full-size model was not going to be easy. The Airex foam sheet was clearly a material that could be cold formed with high precision using vacuum bagging or strapping around a suitably accurate forming tool. The polyimide films were found to be very difficult to handle and in particular the Cu-polyimide film did not possess much elasticity/resilience and was thus very easily creased.

The team in Valencia decided to adopt different manufacturing methods than the ones suggested from the earlier work at RAL, largely resulting from the difficulty in handling the large surface areas of Cu-polyimide on the outer surface of the cylinder. It was clear that the team were under a lot of pressure to explore techniques that would involve less complexity in the processes to make the cylinder. It was pointed out by the Valencia team that the prototyping was still 'work in progress' and there were issues that still required attention and scope for improvement.

The method chosen firstly to apply the Cu-polyimide film to the foam before forming the cylinder resulted in a surface finish of high quality and very little creasing. However, it was felt that this would result in difficulties in forming the cylinder to the required precision due to the poor elasticity of the Cu-polyimide film once glued to the foam.

Gluing the Cu layer to the Airex did not add difficulties in forming the cylinder. When testing the procedure we realized that as a result of having the Cu layer glued the deformation of the Airex on the mould was smaller, so the length of Airex to start with had to be increased in 10 mm, from 3810 to 3820 mm.

We have to improve the way we apply the pressure when gluing trying to make it more uniform. We are setting a vacuum system to be used together with some pressure to get a good glue spread and uniformity.

In previous trials at RAL the Airex foam was able to be moulded to the tooling with reasonable ease and resulted in high accuracy cylinder dimensions, but only if the inner Kapton film was bonded at the same time as the cold forming and not with the Cu-polyimide already in place. It was concluded that the best way to attach the Cu-polyimide film was after the cold forming process by dispensing it from its roll using a tensioning system as depicted in FIG. 2a (an example of such a system used for a different application is shown in FIG 2b). Clearly this would involve the construction of additional apparatus with cost and schedule implications, which at first sight might appear to be a little extravagant. But the nature of the Cu-polyimide film with its vulnerability to creasing, suggested that this approach should have been tried to arrive at an accurate and dimensionally stable end-result.

It is worth noting that a method of dispensing films from a roll with added pre-tension was used at RAL on previous assemblies with very successful results. This should ensure the film is free from creases and delivers a tensile circumferential load in the outer film, helping to maintain dimensional stability and circularity.

Some further attention is clearly required in the manufacture of the flange and in particular the attaching of the films to the flat surfaces of the foam. Examples of the creasing of the Cu-polyimide films and the poor adherence of the aluminised Kapton to the foam is shown in FIG. 3 and FIG. 4.

FIG. 3

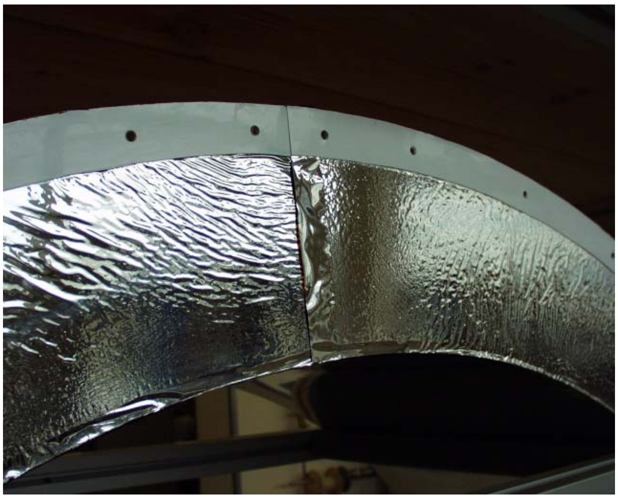

FIG. 4

Detailed Observations

Cylinder

1. Inner surface: Mainly good surface, although some areas where Al-Kapton not stuck down well and creased (3 strips each of roughly 3 cm wide). See FIGs 6 & 7.
   The main reason for concern is regions which might catch on the Rails or other features on the End-cap.

Fig 6 shows the creases in the open side of the tooling. It can be solved by making coincident this sector with the strip of Al-kapton not glue initially to the Airex at this point and gluing it later on.

Fig 7 shows something to be improved. The edges of the cylinder must be better glued. It can be solved by gluing it in a second step, as done at TRT.

2. Outer surface: Looks very good except for the Joint. By construction, this is close to the Airex Joint. Maybe a separate strip of Cu-Kapton would have been better (every separate piece of foil needs to be connected with solder). Since the method of construction does not compress the Airex, the resulting cylinder will have a tendency to be somewhat larger than intended.

As I said before the method of construction does compress the Airex to shape, some elasticity is lost but we still apply compression. As smaller we have the overlap better the results are, so reducing the overlap and trying to improve the gluing technique could result in better finishing.

3. We have some concerns that the adhesion of the Cu-Kapton to the foam may be variable – a “tap test” suggests some areas of delamination, as does examination of the cut edge. It would be interesting to peel open on of the early Valencia prototypes to examine the adhesion.
   This is probably not a significant problem, but variable stresses may lead to distortions. Pre-tensioning the Cu-Kapton should reduce this effect.

We have to improve the way we apply the pressure when gluing trying to make it more uniform. We are setting a vacuum system to be used together with some pressure to get a good glue spread and uniformity.

4. Joint: There is a discontinuity of 2 mm longitudinally. This indicates that the Airex was not square on the Mandrel and may account for the observed distortions of the Flange (see below).

The cutting of the Airex is good and we try to positioning it precisely edge to edge, but when glying there are movements that spoil the alignment so this discontinuity is done. To solve it we will add a stopper rigidily fixed and in contact with lateral of the Airex foam to avoid displacements.

5. There is only a~1 cm overlap of the Cu-Kapton across the Joint. This will not provide much strength. Instead more overlap would be desirable; if this is difficult to arrange, then a separate strip could be used.
   If the Cu-Kapton were applied separately, then the joint of the Cu-Kapton could be well away from the Airex Joint and 1 cm would suffice.

The strength is not only obtained by means of this Copper kapton layer , but also the Airex is glued to itself edge to edge and to the kapton layer. This layer of Al- kapton is continious along the joint of the Airex, having its joint far away fro this point.

6. None of the Cu-Kapton joints were connected with solder (presumably to save time). It would have been nice to see an example of a solder joint.
   The design proposes that the overlap of the Cu-Kapton should be 1 cm, and the overlapping Foil should not be stuck down so that there is no interference of adhesive with the solder.

A comentar. Dicen que el material que solapa no debe estar pegado, solamente soldado si entiendo bien. ¡!!!!!!!!!!!!

Flange

7. This does not look so good. We would like to understand what aspects of the manufacture Valencia was trying to test with this. From Luis' mail of 19 Aug, we know that Valencia had some problems with this.
   The Al-Kapton bonded to the Airex is quite wrinkled (FIG 45) – we have always got good results with vacuum-bagging, and so wonder how this was done.

We really wanted to test everything. As we had not much raw material to be used for testing we could only make a quadrant of the Rear Flange prior to the final assembly of the prototype. Also we had to simulate the carbon fibre pieces and the ULTEM inserts.

This dummy material did introduce errors to the assembly. Due to the assembly process, if pieces were not precisely cutted, creases were produced when placing it on the tooling. MEJORAR PLANTILLAS¡¡¡¡¡ FOTO

We are now trying a vacuum-bagging gluying method, that if works will be implemented to the assembly process.

8. The Flange is not perpendicular to the Cylinder, by several degrees in parts – it tends to bend away from the Cylinder.

The tooling was not levelled. There is a procedure to do so that will be used from now and on.

9. The cuts for the tabs of Cu-Kapton need to be closer together to avoid stresses.

If the stresses you mention are related with the progress of the cuts along the rear Flange, they are caused by the cutting and the manipulation itself, not because stresses after gluing. As far the most difficult operation to be done when bringing the Rear Flange to the cylinder was the handling of this tabs as they tend to bend towards the inner flange diameter closing the gap to slide the flange over the cylinder.

10. The extra band of Cu-Kapton used to cover the joints on the Cylinder is fine, although we note that it has some creases in it.
    Further if this is really used, much soldering will be required to ensure that the foil on the Flange is well connected to that on the Cylinder. This would be difficult in the corner between the Flange and the Cylinder.
    We recommend this band is not used but effort is made to do a good job with the tabs.

As from the assembly point of view not having these tabs is the preferred option. If they finally have to stay maybe adding the Cu- kapton layer after the Rear Flange without it could solve the problem the really exist of handlyin these tabs.

11. We note (and do not understand how) that the Flange extends to smaller radii in parts than the Cylinder. This controlled the fit to the STC (see below), although for the production OTEs, this edge will be bevelled.

Transport Box

12. This was sturdy, but the panels were falling off when it arrived at RAL. Longer nails should have been used! Since it could have been left outside, it would have benefited from a polythene wrapping.

Cylinder Metrology

The average diameters of the Cylinder were determined by measuring the circumference with a tape and dividing by π. Corrections were made for the tape thickness of 0.3 mm. The ID was determined from the OD by subtracting the measured OTE wall thickness.

The diameter was measured at 3 locations: ~5 cm from the Flange, in the middle and ~5 cm from the far (open) end.

The measured thickness was 8.16 ± 0.10 mm to be compared with a nominal design dimension of 8.27 +0.1 –0.2. This is good (mostly controlled by 8 mm of Airex).

The error on the circumferential measurements was better than 1 mm, so the errors on the measured diameters are the order of 0.3 mm.

	Outer Diameter (mm)			Inner Diameter (mm)		
	Measured	Nominal	Difference	Measured	Nominal	Difference
Flange-end	1214.9	1213.29	1.6	1198.5	1196.75	1.8
Middle	1215.7	1213.29	2.4	1199.3	1196.75	2.6
Far-end	1216.5	1213.29	3.2	1200.1	1196.75	3.4

The tolerance on the diameter is +1 –0 mm. We appreciate that the tolerances are tight, but it is **important that the maximum OD (1214.3 mm) is not exceeded**, else the clearance with the TRT will be reduced, potentially causing problems for Integration. If there are problems with this tolerance, then we will have to re-examine the ID.

It can be seen that the diameter of the Cylinder is too large and the Cylinder seems to be conical.

To check the circularity at the Flange-end, the inner diameter was measured with a ruler at 4 locations separated by 45°. The measurements were 1198, 1196, 1198, 1195.5 mm with errors of 1-2 mm. It was quite difficult due to poor adhesion of the Al-Kapton film, excess glue etc.. It is not too surprising that the mean of 1197 mm is less than that deduced from the outer diameter. Nevertheless, the circularity appears good, and there are no significant indications of non-circularity at the Flange-end of the Cylinder.

We would recommend that Valencia construct some sort of gauge disc (or better still, a gauge cylinder) to check the diameters (they already have one for the ID).

Testing on STC

The Short Test Cylinder (STC) was measured with a tape measure to have an outer diameter of 1165 mm with an error of less than 1 mm. This compares well with earlier CMM measurements (ATL-IS_TR-0015). The actual diameters of the production Support Cylinders are 1165.0 mm (to the CF surface).[1]

The proposed height of the Rails to ensure clearance of the on-Cylinder Services is 15 mm above the Support Cylinder surface. With the Rails set to this height, the effective diameter of the STC became 1195 mm. The dummy Rails (metal strips) were flat to within 1 mm.

It was found that the OTE Prototype slid on to the STC relatively easily with several mm excess in parts – consistent with the measured diameter. At the Flange-end, there was very little clearance – the proximity seemed to be determined by the imperfections resulting in the inner radius of the Flange being slightly less than that of the Cylinder at some places. Towards the middle of the Prototype, the summed gap between diametrically opposite Rails was 6 mm at one extreme, and 3 mm perpendicular to this (see FIG. 13). The location of the gap could be easily modified by moving the Flange.

Fitting the Prototype over the STC was not totally trivial because:

- It was important to align the axes to ensure the Prototype was "square" to the STC. For the real assembly, there will be a cradle to hold the OTE.
- There may have been some deviations from roundness of the Prototype (the STC diameters were consistent within 1 mm).
- There was a tendency to catch the edge of the Prototype on the start of the Rails – some tape was used to produce a gradual change in diameter. For the real assembly, some guides will be constructed.

Since things may be quite tight on the SCT, with things at the edge of envelopes, we increased the height of the Rails by a further 1.5 mm, giving a diameter of the STC + Rails of 1198. It was expected that there would only be a 0.5 mm diametric gap at the Flange-end. It was still reasonably easy to get the Prototype onto the STC (we started with the wider end). As the Flange-end of the Prototype engaged with the Rails, there was increased friction, but it was not difficult to slide the Prototype on. It was even possible with some force to get the Flange itself on to the Rails, despite the additional protrusions.

Clearly, if the clearance between the OTE and the Rails is very small along the complete length, the friction will increase. However, provided the cylindricity is good especially near the Flanges, this should be OK, and by design, the Rail heights can be adjusted.

[1] The envelope for the STC (and production Support Cylinders) is 1167 mm. The Inserts and Aperture Closeouts protrude an additional 0.5 mm radially, giving a diameter of 1166.0 mm.

Released Drawings

The final checked drawings should be released by 11 Sep.

Noteworthy changes include:

- Change to suggested proposed procedure for soldering, corresponding to note written by Martin Gibson (20 Jun 05).
  See http://hepwww.rl.ac.uk/atlas-sct/engineering/ec/endcap/TE/solder_tests.doc

- Change to way in which the Cylinder length and Flange location in z are specified.

- Bevelled edge at STFT end of OTE to increase radius of curvature of exiting fibres.

Conclusions

It is clear that to make the OTE is not trivial, and the Valencia group have made a good attempt. Nevertheless, there are several features of the OTE Prototype which cause some **concern**. The most significant concern is associated with the dimensions of the OTE cylinder.

It is essential that there is now a **review of the manufacturing techniques** and a chance to consider whether it can be made within spec, or if not whether the design needs to be modified or extra space needs to be found.

Depending on the outcome of the review, a **further prototype** may be desirable to verify any changes in the manufacturing techniques used and ensure that suitable dimensions can be achieved

Additional Photos

FIG 5
Good inner surface.

FIG 6
Imperfections on inner surface.

FIG 7

FIG 8
The Flange is not flat.

FIG 9
The Airex joint, showing some delamination.

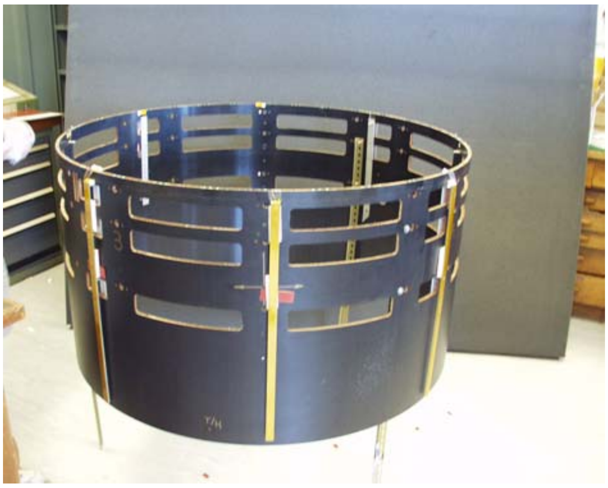

FIG 10
STC on supports, with dummy Rails.

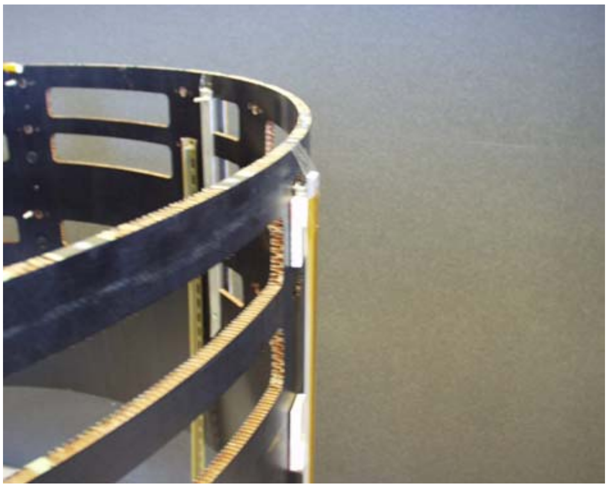

FIG 11
Close-up of dummy Rails.

FIG 12
Prototype OTE on STC.

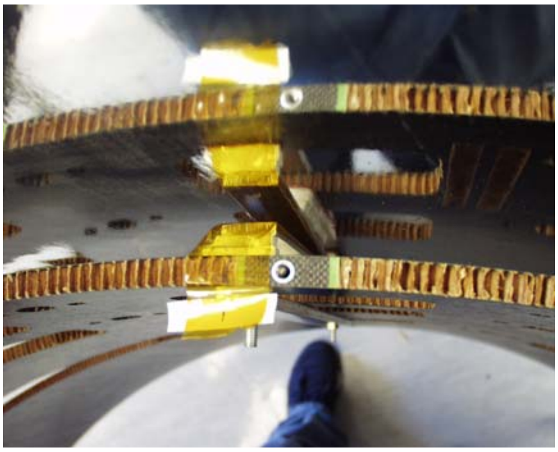

FIG 13
The gap between Rail and OTE (Rail & STC are reflected in aluminised surface).