SUMMARY OF THE WORK DONE FOR THE ASSEMBLY OF ONE ENDCAP OUTER THERMAL ENCLOSURE

L. Sospedra, J.V. Civera, P. Modesto, C. Garcia
R. Oliete, F. Gonzalez, J. Nacer, S. Gonzalez

version 3 14.03.06

- **Introduction**

The perimeter of the OTE Airex cylinder according to drawings along different diameters is:

Perimeter of the inner OTE diameter:	**Pi * 1196.75 =**	**3759.7 mm**
Perimeter along the neutral axis:	**Pi*(1196.75+8) =**	**3784.84 mm**
Perimeter along the Outer diameter:	**Pi*(1196.75+16) =**	**3809.97 mm**

Following P. Ford's suggestion, based on his experience, we defined the length of the sheet of Airex to be cut larger than along the neutral axis to compress it later when gluing on the cylinder, ensuring a good edge contact.

Needed length has been calculated multiplying the perimeter along the neutral axis by a constant factor obtained by experience:

Sheet lenght (including extra material): pi* (1196.75+8)*1.00625 = 3808.49 mm

After some test with Airex + Aluminised kapton in both sides (before receiving the Cu-Kapton) we realized that the needed distance was smaller than this one, and fix it at **3790 mm.**

Now with the Cu-kapton, as in a real assembly, the required distance increased up to **3810 mm** as it does not expand as much as the previous one.

04.10.05 Assembly steps:

- **Prepare the Airex**

1. The dimensions of the OTE cylinder are:
   - Length 1924.24 mm
   - Perimeter of the Outer diameter 3809.97 mm
2. We strongly recommended to start working with bigger dimensions so that material could be cut off later on.
3. So the dimensions of the Airex sheet (obtained by gluing pieces) is:
   - Length 1950 mm (extra 25,76 mm)
   - Perimeter 3898 mm (extra 78 mm)
4. This surface is obtained by adding together 3 pieces of Airex of the following sizes:
   - (1) A full Airex sheet of 2800*1350 mm.
   - (2) A strip of Airex 2800*600 mm width.
   - (3) A strip of Airex of 1100*1950 mm.

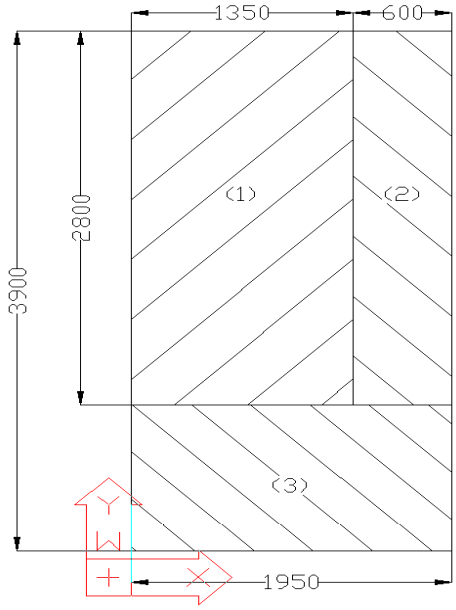


Fig 1. Gluing of the Airex sectors.

5. The gluing was done in two steps; first we glued (1) and (2) pieces and the next day we glued them to sector nº(3).
6. The steps to be followed are:
7. Use a flat and uniform table as a working area.
8. Sheets are in edge to edge contact. Place a protective film underneath the gluing line avoiding the glue to stick on the table.
9. Place the pieces of Airex edge to edge checking that no lateral step due to misalignment of the pieces appears. Two metal bars are located on the table and fixed with G clamps to a distance of 1945 mm thus leaving 5 mm of Airex to be compressed. After removing the pressure the Airex will move to its original width again.
10. Prepare the glue and mix it:

    Mixed 9 gr Not Used 2 gr Used 7 gr
11. Extend the glue along the contact line.
12. Place a rigid bar, longer than the joint to be glued, on top of it and also protected with film. Fix this bar with G clamps, compressing the extra material over the junction and thus, increasing the pressure.

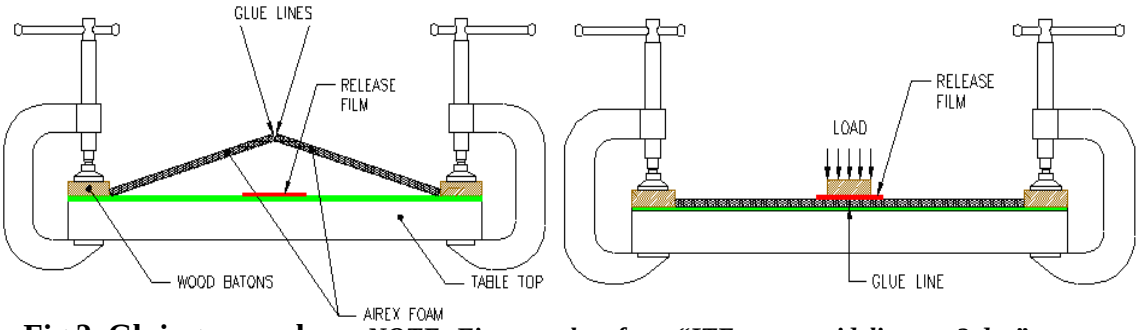
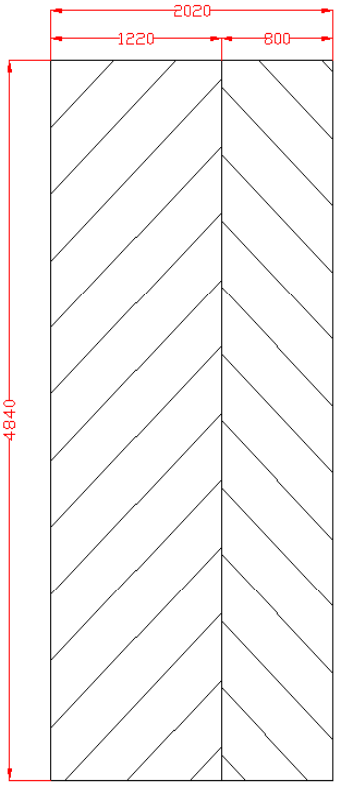


Fig 2. Gluing procedure. ***NOTE: Figures taken from "ITE_assy_guideliness_v2.doc".***

13. Leave it curing until next day.
14. Remove the bars and the protective layers and check result. It should present a continuous glued line without steps and with both surfaces in good and full contact.
15. Repeat steps from 7 to 14 for gluing sector (3).
16. Clean the edges of the glued strips, removing any debris from the cutting process or any excess of glue, ensuring that no steps are presented. Use a sandpaper to smooth it if needed.
17. Mark and cut a line few mm inside the 1950 mm sides of the sheet, having two parallel sides and leaving **a total distance of 3820 mm**. The remaining extra 10 mm will be removed just before gluing on the cylinder.
18. **The width of the Airex is maintained as 1950mm.**

- **Prepare & Glue the external Cu-Kapton layer**



1. Cut a strip of Cu- Kapton layer of 4840*1220 mm
2. Cut a second layer of 4840*800 mm
3. There will be **1 cm overlap** so final width of Cu-K is 2010 mm (60 mm wider than Airex)
4. This overlap is free of glue. Mark the overlap line on one sheet, to be followed when placing sheets relatively each other.
5. Overlap them following the line and fix it with tape. Do it carefully avoiding bumps that could generate creases when glued to Airex.
6. Roll over the Cu-k layer on a cylinder so that it can be easily extended over the Airex with glue on it.
7. Place the Airex on the table.
8. Prepare the glue. Mix it and extend it over the Airex surface until having a uniform colour, so uniform glue layer distribution.
9. Place the Cu-Kapton layer over the Airex and manually extend it. Place it with some extension over one short edge of the Airex and project the Cu-Kapton over the opposite side.
10. The Cu-K extends laterally at both sides and also over the Airex length.

Fig 3.Al-k pieces dimensions

11. Fix it with tape.
12. Place one piece of Airex underneath the Cu-k layer that projects over the Airex short edge and in contact with it. A tape on the edge of the added piece prevents it from gluing. It provides a support to the Cu-k avoiding it to bend and glue laterally if there is some excess of glue.
13. Measurement of used glue:

    Mixed:1828 gr Remaning: 337gr USED:1491gr.
14. Apply the vacuum bagging system, bringing components together. Leave it curing the rest of the day.
15. Release the vacuum.

16. Evaluate the quality of the gluing. Reject it if large areas remain unglued or there are creases on the Cu-k or the glue spread over the Cu surface.
17. Cut the extra length of Cu-Kapton leaving 20 mm to overlap when gluing the cylinder. Still do not cut the extra width.
18. Remove the tape that covers the overlap.

- **Prepare the Airex + Cu-K prior to be placed on the cylinder**

1. Now Airex have to be cut to dimensions.
2. Using as reference the 1950 mm Airex edge from the side where the Cu-k projects over the Airex, mark a square line some mm inside along one long edge and cut it following this line and having a clean edge finishing.
3. Starting from the same reference edge, measure a distance of 3820 mm along the length of the Airex sheet and mark a line. (Perimeter is 3809 mm but we left some extra material to be cut off just before gluing on the cylinder) and
4. Cut along the line removing the extra material from the edge opposite to the reference one.
5. Finally measure the width of the Airex staring from the long cut edge and mark a new line at a distance equal to the length of the cylinder on drawings (1924,24mm)
6. Make a straight cutting removing the extra material.
7. This side must have a sloped cut, so a dedicate tooling is used. The blade has the angle of the slope and having as reference the straight cut already done on the Airex, the tooling is moved and the angled cut is made.
8. As it is, this composite will be brought to the cylinder to shape it cylindrical. This operation helps to eliminate any small bubble or crease remaining from the glue step.

- **Prepare the inner Kapton layer**

1. **The length of the OTE is 1924.24 mm** but is recommended to cover a longer distance allowing the Al-k to be fixed from its edges, cutting the extra material once glued. **So total length to cover was fixed at 1960 mm.**
2. Cut a sheet of Aluminised Kapton of **4100 *1220 mm.**

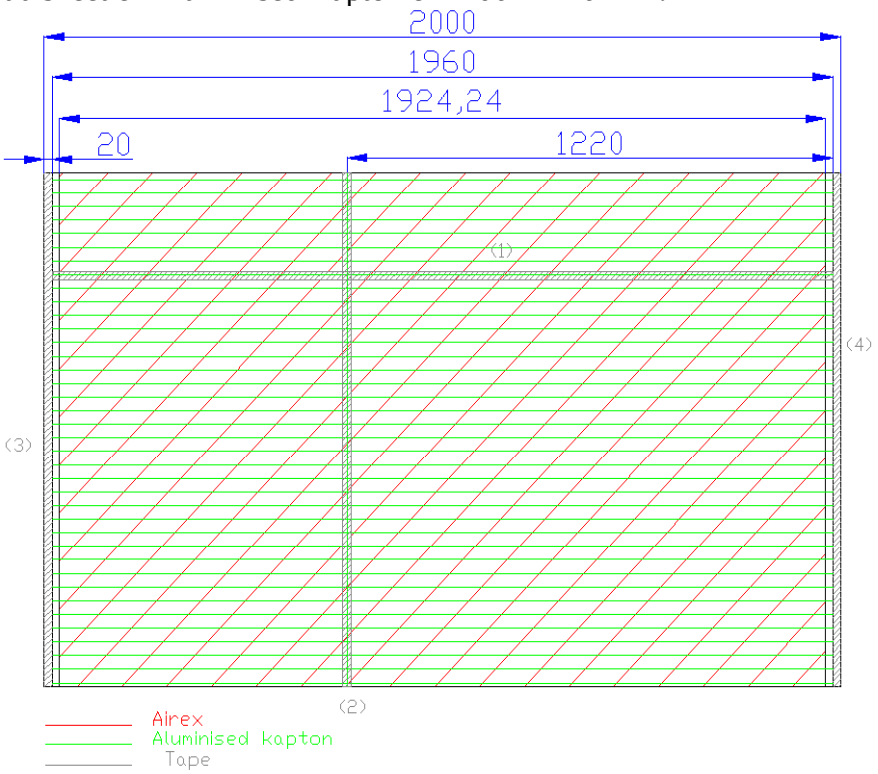


Fig 4. Distribution of the Al-k on the mould

3. Cut a second piece of Al-k. The needed width is calculated including the 10 mm of lateral overlap between pieces. So dimensions are: **4100*750 mm**
4. Place the first sheet of Al-k on the mould cylinder. Tape one end of the Al-kapton (1) on fig 4, to the mould avoiding any movement when extending the film.
5. Manually extend the kapton film while rotating the cylinder tooling to eliminate any crease, fixing it at the lateral flange ends (2) and (4) on Fig 4 until 360 degrees has been covered.
6. Place a second tape over the existing tape nº 2 (tape (b) on Fig 5).This second tape will cover the first one (tape (a) on Fig 5) at the same place. The purpose of it is to provide a surface that, if stained while applying the glue, could be later on removed.
7. At edge nº (2) on Fig 4 , mark a line 10 mm from tape nº 2 and inside the Al-k sheet and place another tape (tape (c) on Fig 5) following this line. This will define a 10 mm strip, to be filled with glue.
8. Measurement of used glue:

Mixed:18 gr Remaning:15 gr USED 3 gr

9. Apply the glue and remove the tape (b) & (c) on Fig 5. Tape (a) remains on place.

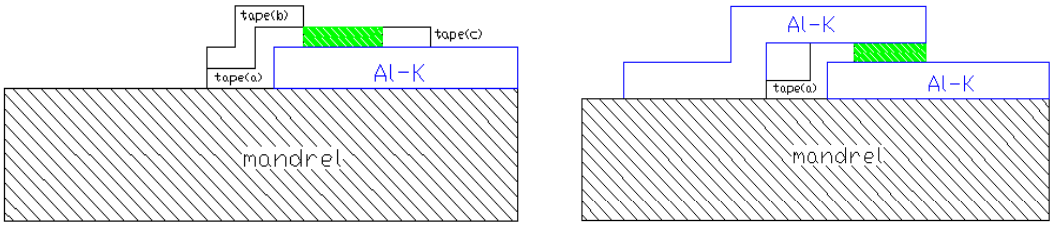


Fig 5. Adding the glue and gluing the overlap between Al-k layers

10. Place the second piece of Al-k, aligning the edge of this sheet with the glue line and fix it, as with the other sheet, at point (1) on fig 4.
11. Extend along the perimeter maintaining the 10 mm lateral overlap along it.
12. Fix it with tape at point (3) on Fig 4.
13. The other end is fixed by the glue that sticks both sheets together.
14. Leave it curing
15. Once glued the two Al-k sheets it has to be taken off from the mandrel in order to remove tape (a) that remains under the lateral overlap.
16. Take off tapes (1), (3) and (4) and bring the glued sheets to the working area.
17. Place it upside down on a flat surface, remove tape (2) and finally add glue on the area where the tape was.
18. Leave it curing.
19. Once glued, move it back to the mandrel fixing it laterally at points (1), (3) and (4) again.
20. Cut off 307 mm as the sheet overlap was bigger than needed (the perimeter of the inner OTE diameter is 3759.7 mm). **So final length was 3793 mm with 33 mm overlap.**
21. Remove tape (1) on Fig 4 as the Al-k is well fixed by the lateral tapes.
22. Add some glue at an area of the inner face of the sheet overlapping material ensuring that it will not contact the Aluminium tooling.
23. Pull the overlapping material and hold it with tape.
24. Leave it curing.

- **Glue the Airex to the internal Al-k layer on the cylinder**

1. **Dimensions of the Airex surface were: 3820*1950 mm.**
2. **Cut the 1950mm width to the needed length of the OTE: 1924.24 mm** (proceed as at previous cutting, measuring the distance at different points, drawing a line, putting a ruler and then cutting precisely.)
3. **From the side where the Airex+ Cu-k are on edge, cut the 10 mm extra length of the Airex to reach the perimeter one: 3810 mm.**
4. **So final dimensions of the Airex is: 3810*1924.24 mm**
5. Place the Airex facing down over a flat surface, so having the Cu-k side backwards and the plain surface of Airex shown.
9. Prepare the glue. Mix it and extend it on the Airex until having a uniform colour, so uniform glue layer distribution.
10. Also extend the glue along the short length of the Airex edges.
11. Measurement of used glue:

    Mixed:1260 gr Remaning:325 gr USED:935 gr
12. Bring the Airex + Cu-Kapton to the mould and place it over the inner aluminised kapton layer. Do not meet the cut on the cylinder mould with the one on the Airex trying to get a better round shape.
13. Put glued edges in contact having at the same time the sloped circumferential edge well positioned and without lateral step on it.
14. Wrap around the mould and check that the adjustment of the Airex to it is good enough with full contact. If Airex is longer that needed must be cut to dimensions before gluing.
15. Mark a line at 20 mm from one open edge of the Airex (the one where the Cu-k is cut on edge) place tape following this line and fill the area with glue. Bring the overlapping Cu-k from the other end and stick it there.
16. Fix the Airex over the mould with some straps.
17. Add tape along the overlapping Cu-k layer, perpendicularly to the Airex contact line and pull it down tighten the overlapping material and also fixing the diameter of the Airex. Clean the excess of glue. Then remove the straps. Some people are needed to support the Airex on place during this phase.
18. Put the protective film over the gluing line and the vacuum bagging covering everything.
19. Apply vacuum.
20. Add several straps over the vacuum bag increasing the pressure and also ensuring that some pressure will be applied if the vacuum pump fails. Straps should be distributed along the length of the OTE always but having one at each end of the cylinder where it tends to increase the diameter.
21. Leave it curing.
22. Remove the straps, the vacuum bagging system and the tapes over the junction.
23. Remove the tapes from the Al-k sides and move the OTE cylinder to one side removing the excess of Al-k.
24. In order to electrically connect the internal Al-k to the external Cu-k up to 8 strips of conductive material per side of the OTE cylinder are glued. The strips are made from Cu-k with the Cu side facing down. A small rectangular dented piece of Cr is soldered to the Cu side.

- **Subassembly of the Rear Flange**

1. The assembly is managed by the tooling. It has been designed with a 0.5 mm step to allocate the external CF and it also has 5 mm holes precisely machined where pins are placed.
2. Cut the pieces of material to be glued together:

The Al-k and CU-k layers have been cut bearing in mind all the extra material needed:

- 15 mm extra material per side on the Al-k and also on the Cu-k to laterally overlap the neighbour sectors.
- The Cu-k sectors have been cut to an external diameter 10 mm longer than the Rear Flange one so that this area could be later on cut into tabs spaced 15 mm and glued along the top edge of the Rear Flange.
- Finally the inner diameter of both layers, the Al-kapton and the Cu-kapton one, is 21 mm smaller. Once glued, the Al-k extra length has to be cut into tabs spaced 15 mm to be glued on the bevel edge of the Airex cylinder and the Cu-k tabs, spaced 18 mm, are glued over the OTE cylinder providing electrical connection.

3. Put the Rear Flange tooling in a horizontal position apart from the main tooling.
4. Place all the components on it and run a dry vacuum test before gluing.
5. Spread the glue along the contact surface of the **Rear Flange reinforcement strip** element (TD-1012-553) and place it on the tooling. A small area around the holes of the CF must be without glue so that it could not stick on the positioning pins.
6. Add the **aluminised kapton** layer. This film has been previously cut to shape and with the needed holes already on place. Laterally 1.5 cm extra has been added to overlap with the neighbour ones. Add glue on the overlap.
7. Allocate the ULTEM inserts on place once glue has been applied on its side perimeter and also on the base of the insert.
8. Put the pins on place, sliding the 5 mm diameter from above along the ULTEM insert, the Al-k layer, the CF sector and the tooling and projecting the 8 mm side upwards to guide the 5mm Airex, the upper CF sector and the Cu-k layer.
9. Place then the 5 mm Airex already with the holes to allocate the ULTEM inserts in it. Previously the side in contact with the Al-k layer has been covered with glue.
10. Add glue on the visible Airex surface (already on the tooling), and also on the ring surface of the ULTEM inserts.
11. Add the **Rear Flange reinforcement strip** element (TD-1012-497) with glue already spread over the top side.
12. Place the **copper kapton layer**, gluing it to the Airex and also to the carbon fibre segment.
13. Add glue on the overlap.
14. Measurement of used glue:

    Mixed: 324 gr Remaining: 172 gr USED: 152 gr
15. The gluing will be done under vacuum, so to avoid the bending of the Cu-k layer that projects over the Airex, some pieces of Airex are placed in between the Al-k and the Cu-k layers providing a uniform support. The inner edge of these pieces is covered with tape to avoid it gluing to the Airex sector of the RF.

16. Pins are projecting over the layers of material and thus the vacuum bag is not pressing the material close to them. As a result the Cu-k is not well glued to the Airex.

To improve the gluing use a plastic ring resting over the Cu layer (with fabric to protect it) and the vacuum bag on top. Another option is cutting the pins to the required length.

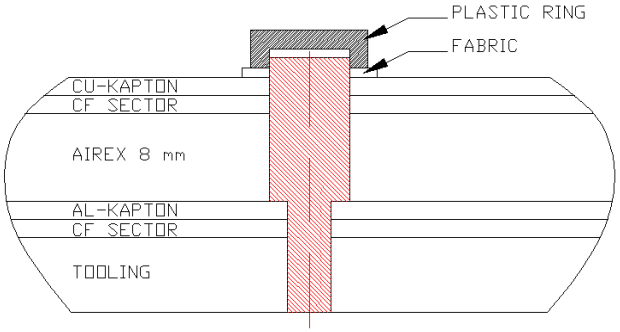


Fig 6. Gluing close to the pins

17. Place the tool inside the vacuum bag and cover it with breathe clothes.
18. Apply vacuum and let glue curing.
19. Remove the vacuum and take out the RF and check results. No crease should appear on the surface and the gluing must be good without areas of unglued material.

- **Glue the Rear Flange to the OTE cylinder**

1. Place the Rear Flange on a flat surface and add glue on the 5 mm Airex thickness that will contact the cylinder. This strip is visible between the Al-k and the Cu-k. *Glue nº (2) on Fig 7.*
2. Add glue on the cylinder. We have to fill with glue a surface covering not only the thickness of the Rear Flange (2) but also the Cu-k tabsthat projects over the OTE cylinder (1) . Measure 21 mm from the edge of the cylinder and place a tape following this line. Fill it in with glue.

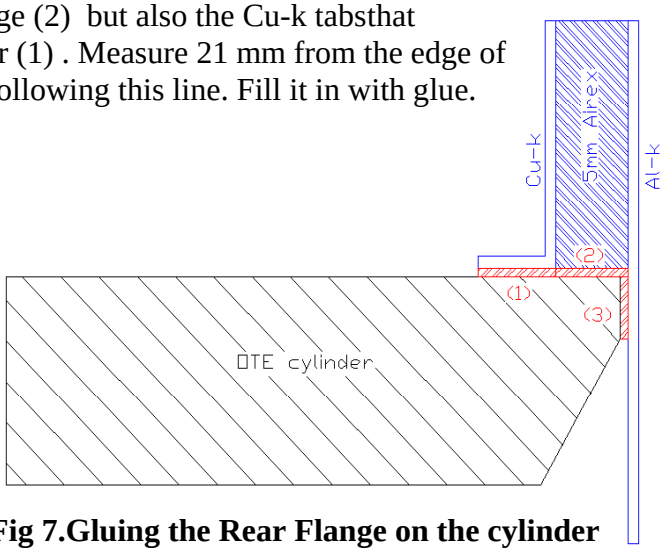


Fig 7.Gluing the Rear Flange on the cylinder

3. Add glue also on the square edge of the cylinder (3) gluing some of the Al-k tabs.
4. Measurement of used glue:
   Mixed: 36 gr **Remaining: 27 gr** **USED: 9 gr**
5. Place the Rear Flange on its tooling.
6. Put the RF on the mould and move it close to the OTE cylinder.
7. To get a full contact we project the cylinder over the mandrel, adjust the RF on it and then move the whole system back until being at the mandrel end again.
8. Screw the RF tooling to the mandrel rib.

9. Place a stopper from the other end to maintain the pressure of the OTE cylinder over the RF along the curing time.
10. Lay down the Cu-k tabs and glue them. Remove any excess of glue.
11. Put a tape on top of them with a flexible metal bar in between to keep them on place. The metal piece is placed against the square of the tab and the RF to obtain a real square corner, not a sloped one.
12. After gluing, remove the tooling and start gluing remaining length of the Al-k tab still unglued.
13. Prepare the glue and cover the sloped edge of the OTE cylinder.
14. Glue the Al-k tabs and fix it with tape.
15. Measurement of used glue:
    Mixed: 16.2 gr Remaining: 11 gr USED: 5.2 gr
16. Let it curing.
17. Remove the tape and cut the excess of material.

- **Glue the Front Flange to the OTE cylinder**

1. Place one of the CF sectors on a flat surface and clean it.
2. Apply glue over the contact surface to the inner side of the cylinder.
3. Bring it to the OTE cylinder and left it at a place where the ends of the CF are at a different location that the joining lines of the Airex or de Al-k on the cylinder trying to make the OTE more rigid.
4. Check with a square that the CF is at the same edge that the OTE cylinder one and fix it with tweezers.
5. Place as many as needed until cover the ½ circumference sector.
6. Remove the excess of glue and let it curing.
7. Remove the tweezers and do the same with the second sector.
8. Measurement of used glue (both sectors):
    Mixed: 18 gr Remaining: 14 gr USED: 4 gr
9. Put a drop of glue at the inner side of the contact lines.
10. Seal this lateral of Airex by covering it with glue(without colorant).
11. Let it curing.

- **Solder the Cu-kapton**

The aim is getting like a faraday cage by connecting all the metal sheets. We used a 3.2 mm width Cu strip. An schematic view :

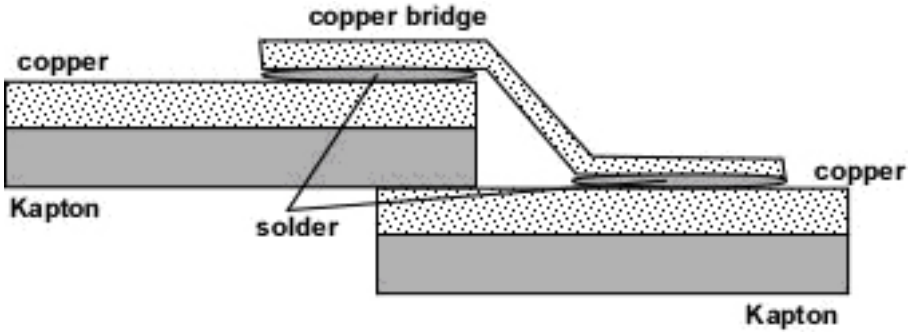


Fig 8. Graphical view of the connection between cooper sheets.

1. Place an adhesive kapton tape spaced 3,2 mm defining the working area. Here you can see how the edge between sheets is centred at the width of the working area. This tape is temperature resistant and also prevents from damage the surrounding area.

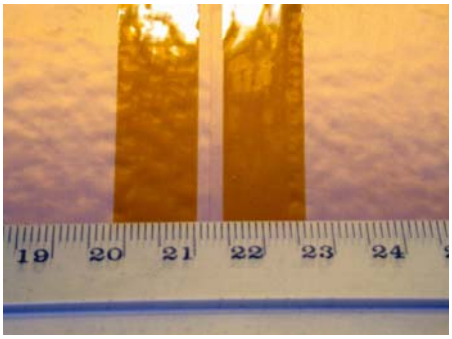


Fig 9. Width of the working area.

2. Add two extra pieces closing a window of 20 cm length. This length is a compromise between ease of use and time needed to solder smaller pieces.

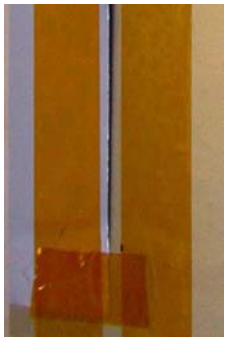


Fig 9. End point of the strip to solder.

3. Make a slight abrasion of the surface in order to improve the adherence
4. Add the solder paste until having a uniform distribution.
5. Put the cooper tape and solder it.

6. Apply some preassure over the tape with a flat ceramic surface (or any heat resistan material) while heating it with the solder iron. It produces a flan fnishing surface.
7. Make a slight abrasión again.

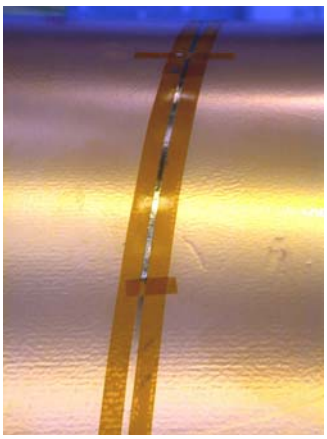


Fig 10. The 20 cm strip already soldered.

8. Remove the adhesive tape.
9. Clean the working area.

PICTURES OF THE ASSEMBLY PROCESS

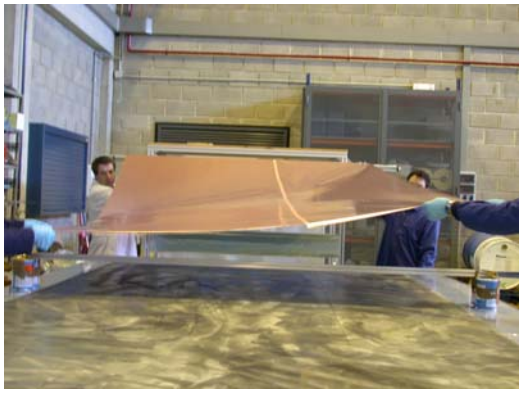


Fig 11. Placing the Cu-k layer onto the Airex sheet covered with glue.

Fig 12. Cu-k layer already glued to Airex substrate.

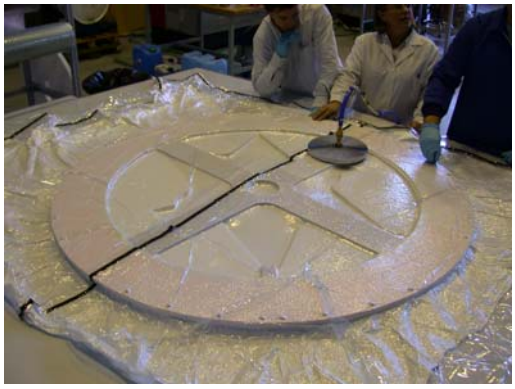


Fig 13. Apply vacuum for gluing the Rear Flange.

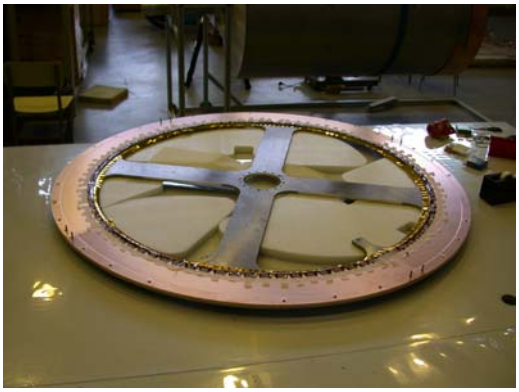


Fig 14. Rear Flange assembled. Tabs on the Al-k and also on the Cu-k already cut.

Fig 15. Al-k inner layer placed on the mandrel. Two sheets used to cover the length.

Fig 16. Apply glue on the back side of the Airex + CU-k subassembly before gluing to Al-k layer

Fig 17. Main cylinder assembly. Vacuum used on the mandrel

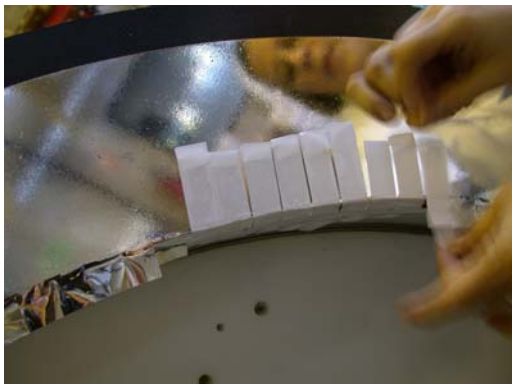


Fig 18. Gluing the Rear Flange Al-k tabs over the sloped edge of the OTE cylinder

Fig 19. Tweezers used for gluing one CF sector of the Front Flange.

Fig 20. Surface finishing of the Al-k side of the OTE cylinder

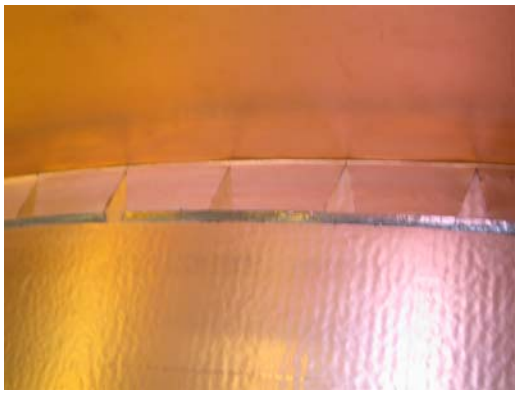


Fig 21. Soldering of the Cu-k tabs to the Cu-k layer of the cylinder.

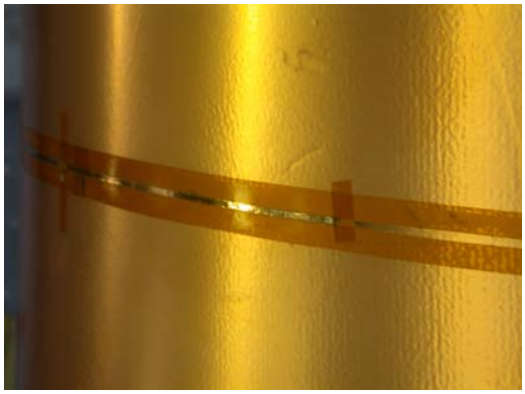


Fig 22. Soldering the two sheets of Cu-k used to cover the OTE length.

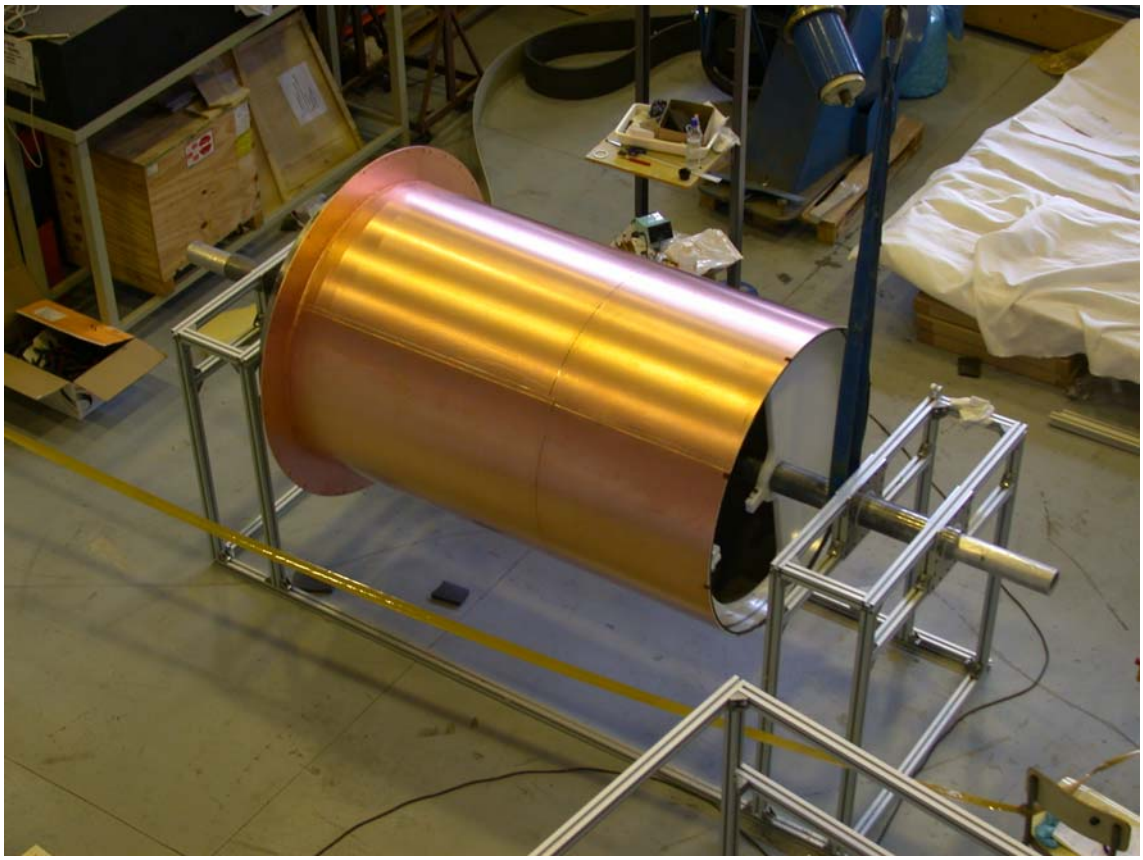


Fig 23. OTE for the END CAP C assembled at Valencia.