Lessons learnt by manufacturing > 100 km of varied type of Cable-in-Conduit-Conductors


what we've done so far

Wide range of CICCs:
- Nb3Sn, NbTi, MgB2, ReBCO
- Very large (DEMO TF) to relatively small (NAFASST)
- Final rectangular or round shape:
  - Al-coated structures;
  - Round or Circle-in-Square tubes;
- Long and Short twist pitch cables;
- Central or distributed cooling channel;
- Short samples or 800 m Unit Lengths.

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Activity Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>2010</td>
<td>Supply of ITER TF conductors, ITER PP18 conductors and 216km TF conductors</td>
</tr>
<tr>
<td>South Korea Rep.</td>
<td>2011-14</td>
<td>ITER TF conductor and 110km TF conductor</td>
</tr>
<tr>
<td>International Body (France)</td>
<td>2012-2013</td>
<td>8 × ITER CS samples for the &quot;crash-program&quot;</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>2013-2015</td>
<td>Manufacturing of 3 × ITER PT samples for test in the SULTAN facility</td>
</tr>
<tr>
<td>Italy</td>
<td>2013</td>
<td>Manufacturing of low pitch cables for the NAFASST large bore magnet</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>2014</td>
<td>Manufacturing of low pitch cables for the NAFASST large bore magnet</td>
</tr>
<tr>
<td>South Korea Rep.</td>
<td>2014-2015</td>
<td>Manufacturing of 1 × ITER TF conductor (jacketing only)</td>
</tr>
<tr>
<td>South Korea Rep.</td>
<td>2015</td>
<td>Manufacturing of 6 × ITER TF conductors</td>
</tr>
<tr>
<td>Italy</td>
<td>2016</td>
<td>Manufacturing of 6 × 2700 km additional lengths</td>
</tr>
<tr>
<td>Italy</td>
<td>2016</td>
<td>Manufacturing of Nb3Sn Samples for EU-NM0 TF Cable</td>
</tr>
<tr>
<td>International Body (Switzerland)</td>
<td>2016-2017</td>
<td>Manufacturing of MgB2 and cables for the SC demo (SANDY) project</td>
</tr>
<tr>
<td>International Body (France)</td>
<td>2017</td>
<td>ITER in-board cable Conductors</td>
</tr>
</tbody>
</table>

TOTAL > 105 km

Impact of cabling process and cable layout on SC strands
Possible defects may be caused to strands during cabling, in particular when very short Twist Pitch values are chosen. Measurements showed that only very large defects cause performance degradation.

[5. Freda et al., “Performance Test of Superconducting Wires Subject to Heavy Deformations”, http://doi:10.1109/6363]

Cabling is a standard process, but handling of superconductor is not

In principle, cabling SC is a standard process for any cabling company. BUT handling of SC wire requires adequate skills and attitude (mechanical stress limits; full traceability; relatively short unit lengths; management of leftovers; no joints and no breakages allowed; etc.).

In addition, the risk in cabling SC is high in term of money and compared with transformation cost, so that a very specific control system and manufacturing process must be put in place.

THE LESSON – FLEXIBILITY

Manufacturing flexibility plays a key role.
- address technical issues on a case-by-case basis.
- manage unpredictable obstacles arising in the conversion of conductor design to prototype and then to actual production unit length.

How to keep industry involved?
Transfer of know-how from applied research to industry, leading to the set-up of production lines for CICCs in kilometric scale for large experiments as ITER TF-SC-A. Challenge keep up the cabling and jacketing lines after that ITER procurement is over. Build up and export, as well as confidence from industry to research have to be maintained to grant continuity for future purposes. Is it a real business?

Connect industry & applied research
Industrial expertise is highly effective during conceptual phase to find the best and simplest manufacturing solution for innovative CICC design, thus avoiding useless and time consuming prototyping iterations.

Cable insertion can partially affect last stage TP
When inserting long (400 m or higher) cables into jacket assemblies, large pulling forces in combination with large friction factors may easily cause rotation of the cables.

THE LESSON – FLEXIBILITY

Manufacturing flexibility plays a key role.
- address technical issues on a case-by-case basis.
- manage unpredictable obstacles arising in the conversion of conductor design to prototype and then to actual production unit length.

JACKETING: the flow of material within the conductor cross-section during the lamination process is influenced by the cable-jacket engagement.

Cable insertion can partially affect last stage TP
When inserting long (400 m or higher) cables into jacket assemblies, large pulling forces in combination with large friction factors may easily cause rotation of the cables.

THE LESSON – FLEXIBILITY

Manufacturing flexibility plays a key role.
- address technical issues on a case-by-case basis.
- manage unpredictable obstacles arising in the conversion of conductor design to prototype and then to actual production unit length.

Dummy and qualification lengths are never enough
Qualification of a conductor design and a manufacturing process can only be conclusively assessed by the manufacture of a complete unit length using the actual material.

The successful accomplishment of QAQC programs (as e.g. those demanded by ITER Organization) ensure conductor production uniformity and full traceability of intermediate assemblies across numerous suppliers.

Short samples vs. long length production
CABLEING: short samples may not be fully representative of manufacturing process on large-size industrial machines, owing to: Cu-to-cu. transition regions, stresses distribution and relaxation, etc.

www.icasweb.com