CERN ATS seminar on 12/05/2022: https://indico.cern.ch/event/1152246/

ITER, the magnets and the road to first plasma by Neil Mitchell (ITER)

Number of participants: 103

ITER (International Thermonuclear Experimental Reactor, meaning also "the way" or "the path" in Latin) is an international nuclear fusion research and engineering megaproject aimed at replicating the fusion processes of the Sun to create energy on the Earth (https://en.wikipedia.org/wiki/ITER). The long-term goal of fusion research is to generate electricity. It is being built next to the Cadarache facility in southern France and **the first plasma has been planned for late 2025** (with operation end 2035). **In 2020-21, ITER passed the point at which the delivery of components to the site was driving the schedule for the achievement of the first plasma**. From now on, the schedule is driven by the process of assembling the components on site.

The development of the "next generation tokamaks" started in 1982 and ITER really started in 1988. In 2007 the ITER agreement was signed and the project entered the construction phase. **The actual critical path has been buildings and now it is the Tokamak assembly (in the last 2 years, the component delivery rate is much faster than the assembly rate)**. **In April 2022, (only) 8% of the assembly has been completed**. **Neil gave a very inspirational talk**, discussing the 5 phases for the schedule drivers during his presentation, which are:

1) Magnet final design (as eventually realised in the period 2008-2010)
2) Next problem (2011-2015): how to manufacture it
3) Next: overall magnet system and neighbours (2016-2020)
4) Next: Tokamak assembly (2020-2022)
5) Future (challenges 2022-2025)

In conclusions, **despite the delays and costs** (the initial budget was close to €6 billion, but the total price of construction and operations is projected to be from €18 to €22 billion; other estimates place the total cost between $45 billion and $65 billion, though these figures are disputed by ITER), **the ITER tokamak manufacturing and assembly has been a remarkable high technology success story**. There are some significant problems in quality of delivered components but at a basic technology level (weld quality, tolerances etc) which should have been avoidable. The ITER organisation and project management has been challenging. At present both costs and schedule are "not stable". Schedule is a second step, a consequence of first. Once a stable and effective project organisation is established, realistic opportunities can be looked at.

Q&A session:

- How, after 10 years, can you qualify a superconducting nonconformity? We don't expect superconducting issues but high voltage issues. After 10 years the superconductors are expected to work fine, as they have a lot of margin

with respect to the superconducting limits. We do have a test programme but it is different from the usual ones pushing the superconductors to their limits.

- A technological readiness review in the 1990s would have been useful but it was not available back in the 1990s.

- Following a question about the status of the other components (such as instrumentation, etc.), Neil replied that he had no time to cover this but that it is going well. It is the small but numerous activities which will bring delays, not the main ones.

- Following a question about HTS, Neil answered that HTS are only used in the current leads. HTS are thought for other projects to make compact Tokamaks but it is not the driving problem: a Tokamak is not a plasma, it is a nuclear reactor. The nuclear components are more problematic than the magnets.

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