U.S. TRITIUM PLANT ACTIVITIES FOR ITER

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The US has contributed to ITER Tritium Plant activities since the beginning of the project. Initial contributions were made to the Conceptual Design Activities in the late 1980's. Both R&D and design contributions were made to the Engineering Design Activity in the 1990's. As ITER now moves to construction, the US is slated to build and deliver the Tokamak Exhaust Processing (TEP) system. The main purpose of this system is to recover hydrogen isotopes including those bound in molecules such as water and methane, and deliver purified hydrogen isotopes to the isotope separation system. The TEP construction activity will begin with finalizing the detailed design. Then industry will fabricate the system. This will be followed with factory testing, transportation to the ITER site, installation and final acceptance testing. This system is highly integrated with other Tritium Plant subsystems, so close interactions are expected with other procurement package owners and the ITER International team

I. INTRODUCTION

The US contributed to the ITER Tritium Plant since ITER started with the Conceptual Design Activity and through to the completion of the Engineering Design Activity. The US made contributions based on a long history of tritium processing R&D and operating experience. Key fusion-relevant tritium processing experience was developed at the Tritium Systems Test Assembly at Los Alamos National Laboratory and the Tokamak Fusion Test Reactor (TFTR) at Princeton Plasma Physics Laboratory. The former was a stand-alone (no fusion reactor), full-scale, integrated fusion fuel (DT) processing R&D facility. The latter facility included a tritium processing system to support first-of-a-kind DT fusion experiments.

While separated from the ITER project for a time, the US has now rejoined ITER negotiations and has provisionally been assigned responsibility for the Tokamak Exhaust Processing system, one of the Tritium Plant procurement packages. This paper will describe the current status of these US Tritium Plant activities for ITER.

II. TRITIUM PLANT OVERVIEW

The purpose of the Tritium Plant is to process tokamak effluent and other gases—purifying the DT for reuse and disposing of detritiated gases. The Tritium Plant construction is broken into seven procurement packages summarized as follows:

- Tokamak Exhaust Processing (TEP)
- Isotope Separation System (ISS)
- Storage and Delivery System
- Water Detritation System
- Atmosphere Detritiation System
- Analytical System
- Automated Control System

These systems have been described previously.[1,2] The TEP procurement package has been provisionally assigned to the US. It is expected that procurement package assignments will be finalized when an international ITER construction agreement (currently being negotiated) has been finalized.

III. TOKAMAK EXHAUST PROCESSING SYSTEM

The TEP performs the following functions:

- Recover hydrogen isotopes from tokamak effluent including hydrogen isotopes bound in impurities such as water and methane;
- Deliver purified, mixed hydrogen isotopes to the ISS; and
- Produce tritium-free gases for disposal.

There are a variety of technologies which can perform these functions.[3,4] In recent years the ITER TEP technologies were chosen.[5] An outline schematic of the process is shown on figure 1. The front-end permeators use a metal membrane (shown as a diagonal line on the permeators) which allows only hydrogen isotopes (shown as Q_2) to pass through to recover the major portion of the hydrogen isotopes. That which does not pass through the membrane consists primarily of water, methane, and helium. It also contains Q_2 which is not recovered in the front-end permeator and may contain other impurities

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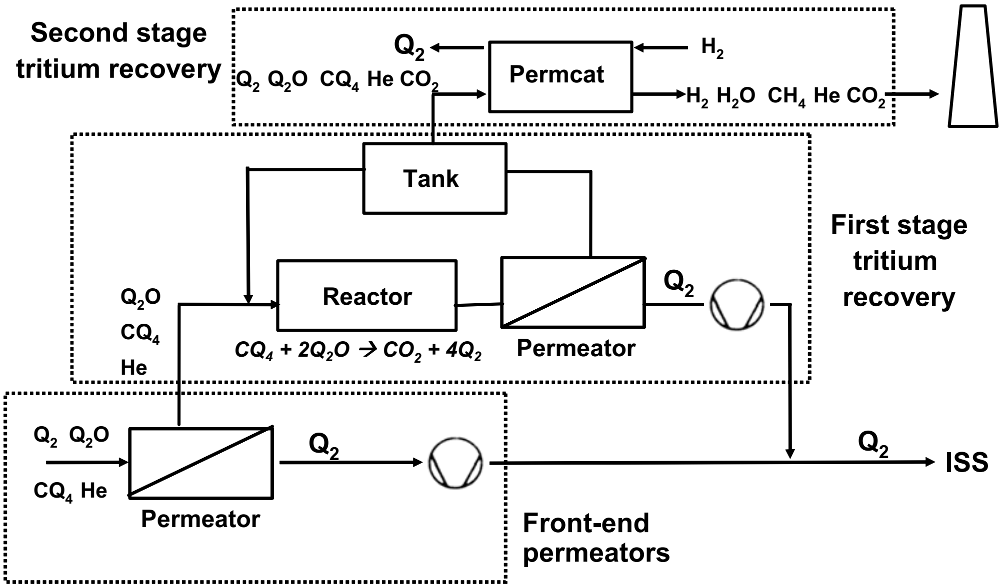

Figure 1 TEP Outline Schematic

(e.g. ethane and argon). This stream is sent to a TEP section called "First Stage Tritium Recovery". This is configured as a circulating loop, but it can also be operated once-through. This section consists of a reactor, a permeator and a tank. The reactor uses reactions such as water-gas shift and methane-steam reforming (the combined result of these two chemical reactions are shown on figure 1) to convert impurity-bound tritium to Q_2 and the permeator recovers the Q_2. After processing in this section is complete, the remaining gases are sent to the final TEP section referred to as "Second Stage Tritium Recovery." This consists of a counter-current permeator packed with catalyst referred to as a Permcat. H_2 is fed to chemically exchange (or replace) with tritium bound in impurities (e.g. tritiated water and methane). This leaves impurities which are largely tritium-free to be discharged from the TEP. It is expected that these impurities will receive a final detritiation in an oxidation/adsorption based waste processing system prior to be discharged to the environment via a stack. The Q_2 recovered from each of the three stages is sent to the ISS.

Key TEP design specifications are:

- Exhaust no more than 1 Ci/day
- Achieve an overall decontamination factor of 10^8 at design conditions
- Process gas from ITER pulses which last between 450 s and 3000 s during which the TEP feed flowrate is 253 Pa m^3/s (150 SLPM)

This design flowrate has increased substantially from the ITER Final Design Report (1998) flowrate of 127 Pa m^3/s (75 SLPM). A few other design requirements have been added since that time such as the addition of holding tanks to allow activated gas (^{41}Ar) time to decay.

IV. TRITIUM PLANT DESIGN INTEGRATION

While the Tritium Plant is divided into distinct subsystems, the overall system is highly integrated. i.e. the output from one subsystem is, in general, sent directly to the next system without the use of accumulation tanks or other inter-system buffers. However, the seven Tritium Plant procurement packages will be assigned to several of the ITER parties (each package will be assigned to one party). While there are clear advantages to this division of labor, it will create the challenge of insuring that Tritium Plant subsystems are smoothly integrated.

To address this, a management structure such as the one shown in figure 2 has been proposed. As shown, each procurement package is assigned to an owner, i.e. one of the ITER parties. As a procurement package owner, the party utilizes its fabrication expertise as it constructs to the package according to specifications. Key to developing these specifications is the Tritium Plant Integration Group (TPIG). This group consists of Tritium Plant technology experts from the various ITER parties. It is intended that this group convenes periodically for a variety of functions such as 1) subsystem design coordination, 2) establishment of standards, 3) sharing of expertise, 4) reporting of fabrication and supporting R&D results, 5) coordination with other closely-linked ITER systems such as vacuum and fueling, and 6) consideration of design changes recommended by fabricators. A key function of the TPIG will be to recommend design specifications to the ITER

International Team (or Central Team) which serves as ITER management. It is this team which will have design authority, so this team will accept, modify or reject TPIG recommendations. When new specifications are issued, it will be ITER management's responsibility to formally incorporate design changes and to properly communicate these to the parties.

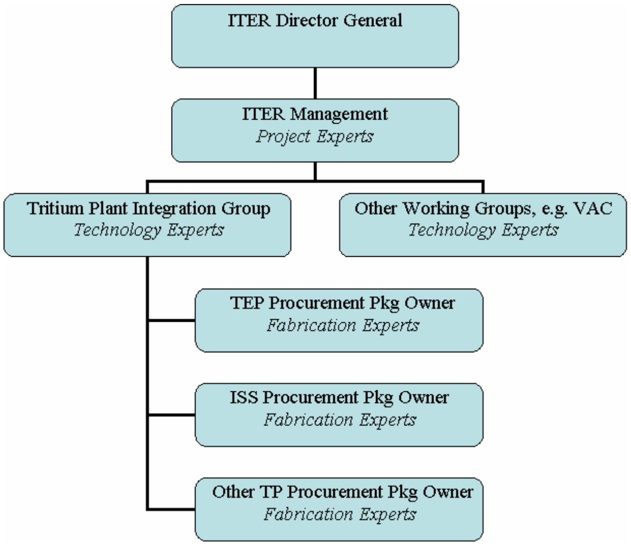

Fig. 2. Proposed Tritium Plant procurement management structure

While this structure is presently at the proposal stage, elements are already being adopted as the first TPIG meeting is scheduled for October, 2004.

It is recognized that it would likely be better to incorporate all needed Tritium Plant expertise on the ITER International team. However, this limited expertise is dispersed world-wide, and it is unlikely that all necessary expertise will quickly relocate to the International Team. Thus, this management structure incorporates an extra layer, i.e. the TPIG layer, to include this essential expertise into the project while recognizing the difficulty associated with co-location.

V. TEP DESIGN STATUS

Having been provisionally assigned responsibility for the TEP fabrication, the US performed an initial assessment of the TEP design status. Presently the TEP design includes process flow diagrams, detailed process and instrumentation diagrams, and many pages of documentation. However, further design will be needed prior to the start of fabrication. When this is completed it is expected that industry will be called on to generate fabrication drawing and to proceed to construction.

Presently the ITER schedule calls for the TEP and other Tritium Plant subsystems to complete their fabrication late in the overall ITER schedule. This schedule allocates approximately one year for bringing the Tritium Plant up to DT operations. This seems ill-advised for a system of this kind. Compared to present, best experience, the ITER Tritium Plant will have to operate at flowrates scaled up by a factor of ~20, and it will operate with a tritium inventory scaled up by ~10x's. And, with extended ITER pulse times, the Tritium Plant will have very limited time to produce the on-specification product needed for the next pulse. With considerations such as these in mind, this study concluded that it would be advisable to complete the ITER Tritium Plant construction approximately five years prior to ITER DT operations. This will allow time for 1) hydrogen/deuterium subsystem testing, 2) tritium subsystem testing, and 3) Tritium Plant integrated testing with hydrogen, deuterium and tritium. Being essentially a first-of-a-kind system, it will be likely that the Tritium Plant will require significant modification during this time. Minor modifications to procedures, control systems and minor hardware are likely. But, significant hardware modifications may also be needed. This extended break-in period will also be needed for operator training. Fig. 3 shows a proposed revised TEP procurement schedule which includes this break-in period.

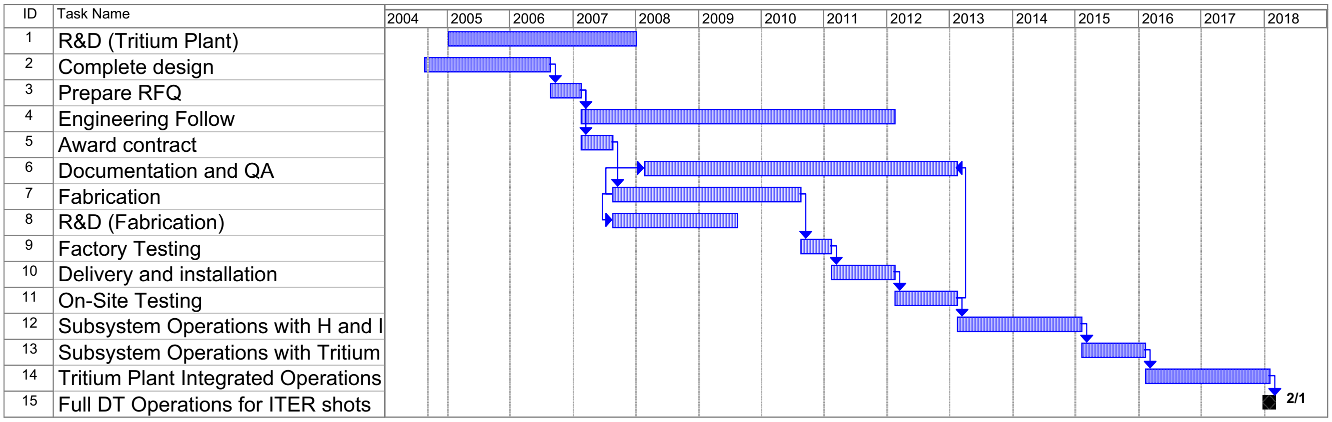

Fig. 3. Proposed revised TEP procurement schedule including extended break-in period

VI. NEXT STEPS

Having recently rejoined the ITER process and having been provisionally assigned the TEP procurement package, there are a number of next steps that the US needs to take. The US, along with other parties that have recently joined ITER, need to be incorporated into the Tritium Plant design and fabrication process. This is taking place through bi-lateral and multi-lateral meetings. The US needs to study and understand the current state of the Tritium Plant design. This has begun with the TEP and needs to continue. For the US to serve as an effective member of the TPIG, other subsystem designs also need to be studied and understood. Once the ITER site is selected, it is expected that the ITER International Team will be staffed. The US will need to consider sending a US Tritium Plant representative to this team. It is also expected that the new ITER Director General, when selected, will want to conduct a major ITER design review. The US Tritium Plant participants will need to participate in this review.

It is expected that the majority of the near-term work will involve TEP design and pre-fabrication activities. This will include updating the existing TEP design through documents and drawings, documenting the TEP design basis, preparing request for quotation packages for industry, performing supporting R&D, and generation and incorporation of design standards as part of TPIG meetings and work assignments.

Longer term, it is expected that the TEP will be fabricated by industry. Performance of the system will be assessed with factory testing. When ready, the system will be shipped to the ITER site. There the system will be installed, and on-site, acceptance tests will be performed. Next the system will be integrated with other ITER subsystems. It will be commissioned with tritium and operated with other Tritium Plant subsystems. Along this path, modifications will likely be necessary to achieve target performance. Ultimately, the TEP will operate routinely as part of the integrated Tritium Plant. This will supply DT to the ITER tokamak, facilitating first-of-a-kind magnetic fusion energy experiments.

VII.CONCLUSIONS

The US recently reengaged in ITER and has been provisionally assigned responsibility for the Tokamak Exhaust Processing procurement package. The US has performed an initial assessment of this procurement package. From this, an outline of the tasks required to construct and deliver an operating TEP at the ITER site has been prepared. Given the close interdependencies of the various Tritium Plant subsystems, it is apparent that close integration of the TEP design with the other subsystems will be essential. A Tritium Plant Integration Group is being formed to ensure that effective integration is maintained. It has also been noted that Tritium Plant scale-up from present experience to ITER is quite striking. Targeted supporting R&D will be needed to ensure that the Tritium Plant can perform its aggressive requirements. It was also concluded that present plans do not allow sufficient time for proper “break-in” of the ITER Tritium Plant which is effectively a first-of-a-kind system. It is recommended that work on the Tritium Plant begin earlier to allow time for a number of essential activities such as system commissioning, debugging, tuning, operator training and regulator readiness reviews.

REFERENCES

[1] YOSHIDA, H., M. GLUGLA, T. HAYASHI, ET AL., “Design of the ITER tritium plant, confinement and detritiation facilities”, *Fusion Engineering and Design*, **61-62**, 513 (2002)

[2] GLUGLA, M., R. LÄSSER, L. DÖRR, ET AL., “The Inner Deuterium/Tritium Fuel Cycle of ITER”, *Fusion Engineering and Design*, **69**, 39 (2003)

[3] WILLMS, R. S. AND S. KONISHI, "Fuel Cleanup System for Fusion Fuel Processing", *Fusion Engineering and Design*, 18, 53-60 (1991)

[4] YOSHIDA, H., O. KVETON, J. KOONCE, D. HOLLAND AND R. HAANGE, “Status of the ITER Tritium Plant Design”, *Fusion Engineering and Design*, **39-40**, 875 (1998)

[5] GLUGLA, M., L. DÖRR, R. LÄSSER, D. MURDOCH AND H. YOSHIDA, “Recovery of tritium from different sources by the ITER Tokamak exhaust processing system”, *Fusion Engineering and Design*, **61-62**, 569 (2002)