THE IMPLEMENTATION AND OPERATION OF A FULL SIZE MOCK-UP FACILITY IN PREPARATION FOR REMOTE HANDLING OF JET DIVERTOR MODULES

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During 1997 it is planned to replace all JET Divertor modules (Mark IIA) with new modules (Mark II Gas Box) appropriate for the following phase of JET operations. This exchange operation will be performed entirely remotely by means of the JET Mascot servo-manipulator transported around the Torus on the Articulated Boom. The Mascot will deploy specially designed tooling to release and handle modules from in-situ and will transport them to a transfer system which will remove and store them outside the Torus.

This paper outlines the preparations being made for the remote exchange by use of a full size mock-up Facility. The mock-up programme comprises of the design and construction of a full size physical model of the JET Torus, which made as much use as possible of realistic prototype components including a spare vacuum vessel octant. The paper describes the Facility construction, its objectives and its validation by means of photogrammetric surveys and other measurements as well as the programme of fully remote operational trials. The JET remote handling equipment has been deployed and tested extensively within the Facility; operational procedures have been developed and operator teams have been trained. The experience gained and the results achieved from these trials is discussed.

1. INTRODUCTION

The need for a full size mock-up Facility was two fold:

- to train in-vessel personnel for manual tasks,
- to prepare to remotely exchange the MKIIA with the MKII Gas Box divertor modules.

The experience gained from previous manual interventions indicated that high efficiency could be maintained if personnel had previously been trained in the tasks before undertaking them in the vessel. This became even more relevent with the higher radiation levels within the vessel, and the need to keep dose exposure rates to personnel to an acceptable level.

It was essential to demonstrate the feasibility of exchanging the divertor modules remotely. This was achieved by undertaking extensive mock-up trials. The result of such trials was to confirm the feasibility, the suitability and reliability of the RH equipment, and to verify the timescales required and the personnel resources needed.

2. FACILITY

2.1. Design

It was essential to create an accurate representation of the in-vessel environment. The following points were taken into consideration at the design phase of the Facility:

- full size.
- components to be dimensionally correct and positioned to the same accuracy as the original.
- lighting to be representative of that in the Torus.
- where possible prototype or spare components to be incorporated into the Facility.

2.2. Construction

Phase one of the construction incorporated representation of four octants of the Torus; octants 3, 4, 5 and 6. Octants 3 and 4 were initially designated for mainly 'hands-on' training of in-vessel personnel for manual shutdown work in 1995/96. Octant 5 and 6 were used for Remote Handling trials. Because of the necessity to train personnel in the handling of components, prior to them entering the Torus, all spare or prototype components were incorporated into these two octants. Dummy components or space frames were used in octants 5 and 6.

Phase two was the addition of octants 2 and 1 and the inner walls of octants 7 and 8. The completed Facility will enable a full rehearsal of the MKIIA and Gas Box module handling to take place.

The Facility was constructed with three principal structural elements, see Fig. 1.

- Support platform
- Upper support columns
- Vessel wall

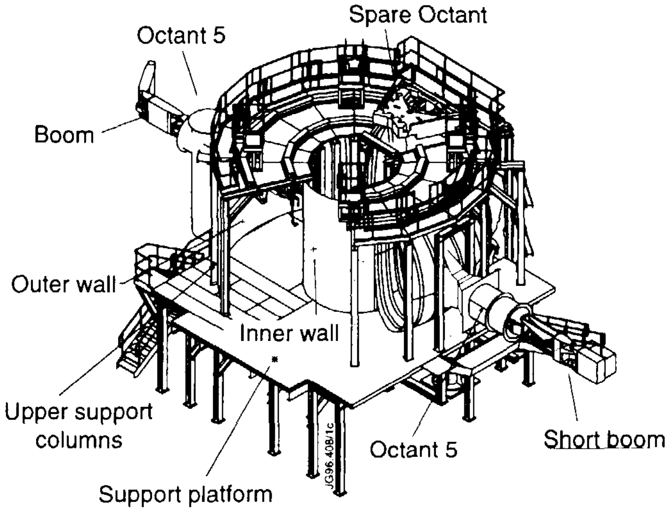

Figure 1. In-Vessel Training Facility

The main horizontal ports at octants 5 and 1 were added, these were manufacture to the surveyed dimensions of the Torus ports. This requirement arose through the need to check access into the Torus of the Boom/Mascot carry components; clearances during this operation are in the order of 10mm. The port at octant 5 interfaces with the Boom Facility [2], whereas the one at octant 1 interfaces with the Tile Carrier Transfer Facility [3].

The inside of the Facility is equipped with components which realistically represent the actual ones, see Fig. 2. In some cases spare components were used, i.e. poloidal limiters, guard limiters, cooling pipes and manifold etc. In other cases detailed mock-ups of components were used and lastly space frames. All components that restrict access for RH equipment or need to be remotely handled have been incorporated into the Facility. The components which need to be remotely handled are; divertor modules, Be evaporator and first wall tiles. All these have been modelled to be a true representation in terms of; size, shape, weight and surface finish. They also have all the remote handling features required for attachment of the special remote handling tools [1].

During the construction of the Facility a computer aided theodolite (CAT) system was employed. This is an optical 3D measuring system based on twin theodolite triangulation [4]. The Facility was used to train and familiarise new operators for the actual Torus surveys. The same survey techniques, as used in the Torus were applied and all structural and plasma facing components were positioned. CAT was also used to align both the Boom assembly and the Tile Carrier Transfer Facility to their respective ports. It was important to have the same relationship between the Facility ports, the Boom and TCTF, as exists in the Torus. This would enable teach files made in the Facility to be repeated in the Torus during operations.

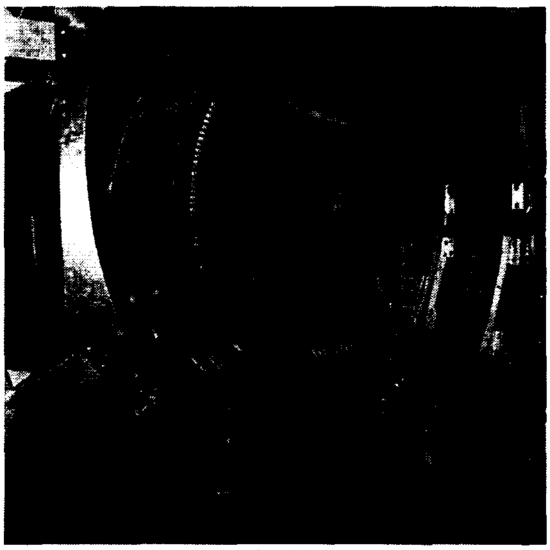

Figure 2. Inside Facility

3. OPERATION OF THE FACILITY

The mock-up programme was divided into two phases:

Phase 1 objectives were:

- Train a team to operate the RH equipment.
- Develop the necessary techniques for remote installation and removal of MKIIA modules.
- Construct teach files for the various module locations.
- Identify any serious problems associated with the remote handling of the modules.

The duration of this phase was ten weeks with only one operation team. This comprised of an Operations Responsible officer (RO), a Mascot Operator and a Boom Operator. The RO's function was to define and co-ordinate the work, record in a daily log book all the activities, record any equipment faults, assist when required in the operation of the Boom, Mascot and Viewing systems. For entry and movements within the Facility the RH equipment was operated in a teach/repeat mode. Teach files were created off line on CATIA using the "as made" drawing models. The advantage of CATIA is that the models are accurate and as such clearances between components and RH equipment can be checked in critical areas. Teach files were transferred from CATIA to the RH Control Room and then to Boom control system. They were all then checked within the Facility to ensure no unforeseen clashes occurred with the in-vessel components. During this period clearances in critical areas between RH equipment and components were measured. These were compared with the corresponding ones as indicated on the CATIA models. This data indicated that the Facility was an accurate representation of the CATIA models. The conclusion was drawn that it was safe to run CATIA based teach files in the Facility without the fear of components clashes.

During this period all the tasks were located in octant 4, 5 and 6 because these areas were identified as the most difficult for RH equipment access.

The conclusion of this phase was to confirm that it was feasible to remotely handle the MKIIA modules. It did however identify some problem areas; the need to shorten the Boom extension; the requirement for a mobile camera in addition to the fixed ones; protection plates for the modules to eliminate any possible damage occurring during RH operations; additional special tools for the torquing of fixing bolts. An indication of the time scale required for the installation of the 33 MKIIA modules during the Divertor installation shutdown was obtained, this was incorporated into the overall shutdown plan.

Phase 2 objectives were:

- Prove both the reliability and functional aspects of all the RH equipment used in-vessel.
- Create and validate both teach files and procedures for all in-vessel tasks.
- Train three teams of operators.
- Fully rehearse the remote installation of 33 MKIIA modules.

This phase of mock-ups lasted nine weeks, working two shifts a day and six days per week. The operation team from phase one trained two further teams in readiness for the shutdown. All the RH equipment was monitored for reliability during this phase; this indicated an availability in excess of 95% [5]. Each task procedure was followed and validated under RH conditions. Operations were all completed from the RH Control Room, driving the equipment through the various Man Machine Interface units. Viewing was with the aid of equipment cameras and the in-vessel cameras. To supplement this an on line graphical simulation system called "KISMET" was used [6]. This can monitor equipment moves and vessel component clearances within the accuracy of the as-built configuration control data. During vessel entry and when the equipment cameras have limited views, KISMET becomes the main aid to monitor operations. In the event of failure of the viewing systems then it can be used to safely manoeuvre the equipment out of the vessel. There were no personnel present in the Facility during the final phase of these mock-ups.

4. REMOTE INSTALLATION OF MKII MODULES IN THE TORUS

During February 1996 thirty three MKIIA divertor modules were installed remotely in the Torus. This was achieved using RH equipment and procedures that will be used during the MKIIA and MKIIB Gas Box exchange. There were no major problems with either the RH equipment or procedures and the modules were successfully installed in the allocated timescale, see Figure 3. The total operation duration was 14 days, working two shifts a day and each shift comprising of 8 working hours. Of this the first four days were used to validate the various teach tiles and to check the calibration between the Torus and the Facility. This confirmed that the Facility was both representative and accurate when compared to the Torus.

Viewing is very critical for successful remote handling operations, and the effort taken to reproduce similar lighting effects in the Facility proved to be most beneficial during this period.

Figure 3. Remote Handling of Modules

5. CURRENT MOCK-UP ACTIVITIES

Preparations are now underway for the final phase of mock-ups. These will culminate in the remote exchange of the MKIIA divertor modules with the MKII Gas Box modules after DTE1.

An essential task within this phase is the recovery from Remote Handling Equipment failure. Trials have been completed to demonstrate the feasibility of withdrawing the boom from the Torus, in the event of a main joint failure. Each joint has a built in quick release mechanism and once the joint is released the booom can be recovered. This is achieved by using the two adjacent joints to control the angle of the failed one, and Mascot constraining the movement of the end of the Boom. The trials showed that with one joint failure the Boom can be withdrawn from the Torus without risk of damage to the in-vessel components.

The integration of the Tile Carrier Transfer Facility to the mock-up Facility is another major task in this phase. All aspects of transferring equipment and modules through octant 1 port into the vessel and their subsequent handover to the Mascot are currently being addressed. A number of other activities are presently being finalized:- Beryllium Evaporator Head cleaning, Diagnostic handling, deployment of videogrammetry equipment, first wall tile handling, vacuum cleaning etc.

6. CONCLUSIONS

The successful completion of the installation of the MKIIA modules was achieved because the following points were addressed:

- A realistic mock-up Facility was available.
- Tasks were all checked and procedures validated.
- Reliable and proven equipment used.
- Well trained operators.
- Planning based on real times.

The effectiveness of the mock-up Facility has been shown to be dependent on the accuracy of the dummy components, their shape, weight and surface finish.

Clearance between components in the Torus are small so it is important that all dummy components are set in position as in the Torus.

Attention must be given to trying to produce a similar overall surface finish in the Facility. Viewing becomes a very important part of any RH operation and glare from surfaces can affect the viewing quality and hence the RH operation.

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