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Implementation of New Techniques for the Remote Delivery of Tooling & Components at JET

C. Belcher, L. Meredith, N. Sykes, S. Collins
and JET EFDA contributors*

JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

[1]Oxford Technologies Ltd, 7 Nuffield Way, Abingdon, OX14 1RJ, UK
[2]EURATOM-CCFE Fusion Association, Culham Science Centre, OX14 3DB, Abingdon, OXON, UK
** See annex of F. Romanelli et al, "Overview of JET Results",*
(Proc. 22nd IAEA Fusion Energy Conference, Geneva, Switzerland (2008)).

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ABSTRACT

For the JET Enhanced Performance (EP2) shutdown a second articulated boom has been developed. Support technologies have been developed to provide an efficient system for tools, services and components to the remote environment. This paper will discuss the challenges involved in the design and compatibility for remote docking of support cradles. These cradles are used to support equipment including:

- Six Task Modules with a capacity of 400kg each.
- Sixteen Sub-frames used to transport components up to 80kg each.
- Multipurpose tray carriers to transport a large variety of equipment and components.
- Specialist equipment for transporting interfacing components.

In situations where people are required to manually load and unload these cradles this paper will discuss the systems implemented to aid:

- Contamination control between the JET vessel and the adjacent man access areas whilst the articulated boom is in use.
- Service feeds for in vessel work (power and data supplies).

There will also be examples of real data and design changes required as a result of the operational tests. This paper will discuss how these developments have increased the efficiency of the remote handling work with an increased protection for the personnel working in the controlled area.

1. INTRODUCTION

EP2 produces significant additional challenges to the remote handling capability. The additional tasks that need to take place require a set of supporting structure, cradles/stillages and service feeds to assist the in-vessel operations. Due to the nature of the in-vessel work the tasks are time critical. Great emphasis is put on the efficiency and function of the equipment. The tasks to be carried out in EP2 are varied and require a large number of bespoke tools which are deployed and used by the two articulated booms, fitted with either End-Effectors (EE) or a two armed (Mascot) manipulator. For the increased productivity required by the EP2 shutdown, exchange of EE's has been designed to be fully remote. An additional requirement was to limit the exposure (radiation & beryllium) of personnel during re-loading of components and tooling trays. To minimize this steps have been taken to limit the flow of contamination into that areas accessed by people.

2. CRADLES FOR END EFFECTORS

Described below are the four main types of EE used on a regular basis that need supporting.

2.1. TASK MODULE

There are six task modules which are used to transport components and tooling to and from the vessel. Each task module has six drawers and has a capability of carrying up to 100kg per drawer with a maximum of 400kg per task module. The task module is held in a stillage that allows the boom to pick and place it remotely. The task modules are positioned in echelon (within the ISO container) to allow the boom to access the lifting interface at one end. The final positioning is guided by angled location tabs. The engagement method is designed to accommodate boom positioning repeatability errors of 20mm (max).

2.2. SUBFRAME END EFFECTOR STILLAGES

The Subframes (fig.2) are used to carry heavier tooling and components into the vessel with up to sixteen used on a frequent basis. The docking of these Subframes is difficult to judge with the use of the boom cameras alone, so a limit switch system was developed to accurately inform the operator that the Subframe has docked correctly (fig.3).

Each Subframe stillages has two park locations on it. There are a total of sixteen locations in the rack of stillages. Each location captures the Subframe and pushes it into a known position so the boom can dock successfully to it.

The centering of the Subframe is done through two dowels locating in 'V' slots. The location of the Subframe is monitored by vertical and horizontal switches. These switches activate two LED's visible by the boom cameras to indicate when the Subframe has docked correctly. The horizontal switches also ensure the Subframe returns to a known datum in the 'V' slots. To ensure the Subframe slides across the stillages with minimal friction there are a series of housed ball bearings that the Subframe runs on (fig.3). Once the Subframe is docked and the boom unlatches and moves clear, the Subframe moves back to the datum position and the switches are remotely tuned off by mechanical means to save the battery life.

2.3. GAS BOX TINE STILLAGE

The Tine is a load bearing End-Effector with a remote latching mechanism for carrying specific components such as Divertor tile carriers or a range of multi-purpose trays and boxes into the vessel.. This tine also needs to be stored when not in use. The Tine stillage is used for this job and enables the operator's access to the tine when needed.

The tine stillage is designed to aid the operator of the boom with the docking and undocking of the tine onto the stillage. This is achieved by vertical and horizontal switches located at the rear of the stillage. The tine is set at 10° so when it is lowered into the stillage, gravity ensures that the tine is located against a datum. The tine enters the stillage at a known height and contacts that horizontal switch and the LED lights (fig. 4). At this position the tine is lowered until the second limit switch is activated and the corresponding LED lights. At this point the tine is a couple of millimeters from the surface of the stillage and the tine can be unlatched safely into the stillage. When the boom is unlatched and reversed away from the tine the horizontal switch forces the tine up against a hard stop to return the tine to a known forward position. In moving to the known datum the LED are automatically deactivated to save battery life.

2.4. ROLL END EFFECTOR PARK

The Roll End Effector (REE) is used as an interface between the Octant one boom and a Subframe or Tine. The REE is used to roll the Subframe or tine to the desired angle to enable larger bulky items to fit through the restricted access port into the vessel. The REE needs to be picked and placed remotely at regular intervals onto a parking position when not in use.

The REE has a pneumatically actuated interface that forces ball bearings to engage onto a corresponding locking ring. If the pressure is lost, the REE will remain locked. The park position utilizes a standard interface ring on which the REE can be mounted. The park is mounted directly onto the Tile Handling Facility structure and needs a certain amount of compliance so to minimize the forces on the structure. This is done by three large compression springs mounted behind the location plate (fig.5).

There are two chamfered location dowels to allow the interface plate movement when the springs are compressed, when the pressure is removed the plate relocates in a known location. The REE is guided onto the park stillage with the use of a target camera and a position switch. The target camera informs the operator of the position in a 2D plan and the LED indication shows the final 3rd dimension informing the boom operator that the REE has docked. When the LED lights this activate a timer circuit to turn the LED off after three minuets, saving battery life.

3. VESSEL ACCESS

3.1. FLOW RESTRICTION

Having persons work in such close proximity to the JET fusion vessel has necessitated an elevated effort for contamination control. Persons working in controlled areas in or around the vessel ports are required to be protected against exposure to Tritium and Beryllium.

One of the main methods of controlling the flow of contamination between the JET vessel and the Tile Cabin Transfer Facility (TCTF) is to keep the vessel at a lower air pressure. This ensures that airflow is predominantly drawn from the TCTF into the vessel and then exhausted via the controlled ventilation system. This minimizes the exposure of contaminated air to the persons working inside the TCTF.

During Remote Handling operations, the Octant one boom is required to move in and out of the JET vessel and therefore a physical hermetic seal between the vessel and the TCTF is not possible. A Flow Restrictor (Fig.6) is used to restrict the amount of air that passes from the vessel into the TCTF. This is particularly important when the Octant one boom is retracting from the vessel as it can pull contaminated air back with it. The Flow restrictor works by creating a physical barrier around the boom. It consists of an aluminium framework which sits inside the Octant one vacuum chamber. This framework supports a ring of rubber flaps which brush against the side of the boom, therefore closing any gaps between the boom and the local environment. Prior to the EP2 shut down, there was no other system of flow restriction and the contamination control efforts were entirely reliant on the vessel having a reduced air pressure. The use of a Flow Restrictor is an important step forward in reducing worker exposure to air borne hazardous contamination.

It was a design requirement that the flow restrictor, when installed, did not inhibit remote operations through the vessel port. The design as implemented in figure 6, has been proven to be effective during the EP2 shutdown, allowing end-effectors, tooling and components passing through it while inhibiting (contaminated) air flow to ex-vessel areas. The end of the Flow Restrictor is pneumatically actuated to be widened and narrowed at the operators command to allow for larger components and end effectors to be passed through without interference. A series of electromechanical sensors indicates the state of the Flow Restrictor to the operators even though the Flow Restrictor is almost entirely hidden from view.

When the boom is retracted and is parked in the TCTF, a pneumatically driven door is closed sealing off access and air flow into the vessel. This door is part of the Flow Restrictor Assembly.

3.2. SERVICE FEEDS

A number of services are required for various remote handling tasks inside the JET vessel. These services include power and data cable supply. During the EP2 shut down, a temporary ‘wand’ is inserted into the vessel (Fig.6). The end of the wand that sits in vessel houses a number of plug points into which various pieces of remote handling tooling are plugged for power and/or data connectivity. Examples of this tooling include high definition cameras, vacuum cleaners and remote handling band saws. The wand also houses three health physics monitoring pipes that enable air samples to be taken from inside the vessel for various monitoring and analysis purposes.

In vessel, the wand hooks onto the in vessel wall at Octant one. The rear end is attached to an intermediate chute that sits inside the vacuum chamber. This chute also enables the installation of the service feeds and acts a base for the Flow Restrictor. All of the cables and pipes that are transported along the wand travel by the side of this chute and pass into the TCTF where they are terminated.

3.3. MANUAL ACCESS

There are a number of phases during the EP2 shutdown where people require access to the vessel to carry out a number of tasks that are deemed not cost effective to be undertaken remotely. The Octant one port is used during manual phases to access in-vessel. To facilitate manual access, the Flow Restrictor is removed from its installed position and stowed in the TCTF and a large ’man access chute’ is laid over the top of the intermediate chute. A set of steps are then attached to the end of this chute and sit down on the vessel floor. This chute and step arrangement provides a flat, smooth surface on which persons can crawl into the vessel to carry out tasks. When persons are in the vessel, the port is kept open. When persons are out of the vessel, blanking plates are bolted to the main port flange to create a closed barrier between the vessel and the TCTF.

4. ACKNOWLEDGEMENTS

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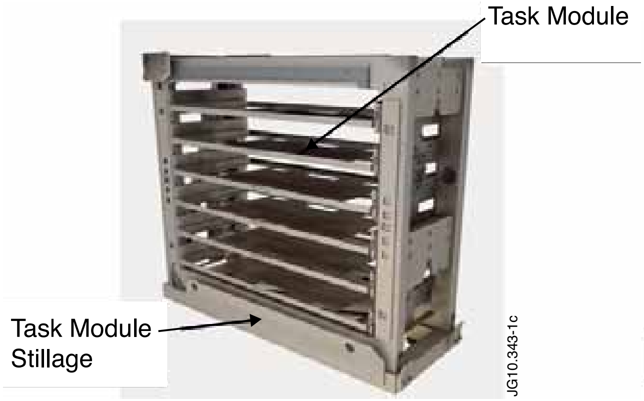

Figure 1: Task Module Parked on the Stillage

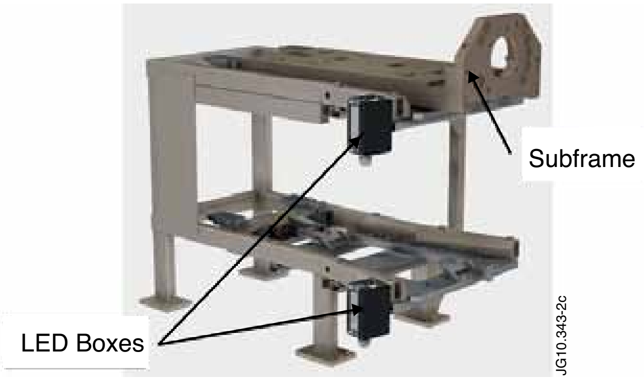

Figure 2: Subframe Stillage with Subframe Parked on Upper Location

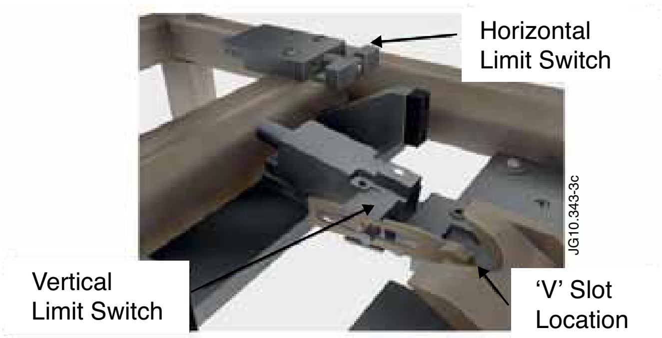

Figure 3: Subframe Stillage Location and Switching

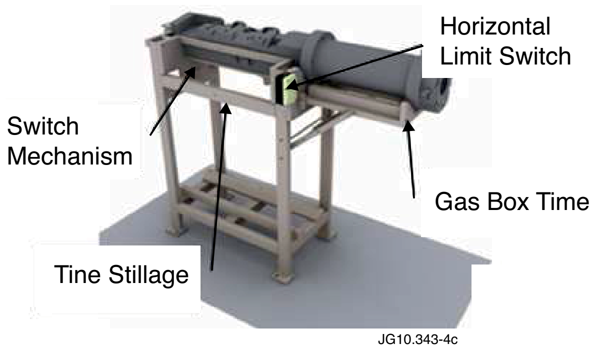

Figure 4: Gas Box Tine Mounted onto Stillage

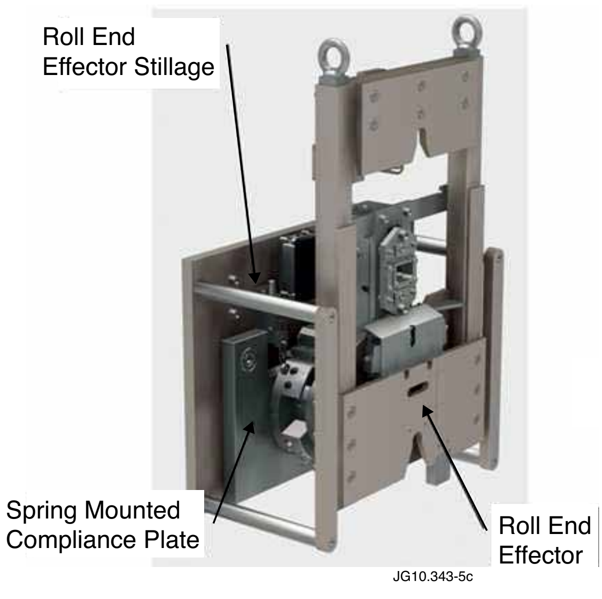

Figure 5: Roll End Effector Park

Figure 6: Flow Restrictor Assembly