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JET Work Effort Data Collection for ITER ORE Optimization

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The occupational radiation exposure (ORE) assessment is one of the pillar in the licensing process for ITER, the first experimental fusion reactor, under construction in Cadarache (France). Being this machine a first of a kind, the maintenance activities for the components replacement and repair are foreseen to be frequent and complex. In this context the remote handling (RH) will play the main role due to the high radiation field inside the tokamak building. But in any case, the hands on maintenance will be unavoidable, at least to prepare the areas in which the RH is planned to be used.

The knowledge of the work effort (WE), that is the time necessary to perform a task multiplied by the number of worker engaged in the task, is the first step to build an ORE assessment.

At this scope the collection of the WE data during the JET maintenance shutdowns has been planned and performed in the last years in the frame of the Eurofusion WPJET3 program to build a validated WE data base (WE-DB) essential for the ITER ORE analyses. The the WE-DB ver.1.0 dated back to the ORE studies for ITER-FEAT, but at that time they included several data based on engineering judgement that needed to be confirmed and validated versus WE data gathered in the fieldwork.

The methodology of the WE collection will be described in this work together with the updating of the WE-DB on the base of the monitored activities at JET. In addition the comparison with the WE data used in the previous ITER ORE assessments will allow not only to tune correctly the WE for the tasks traced but also to apply the ALARA process by means of a fast and simple tool.

Keywords: JET, Occupational Radiation Exposure, Work Effort, ITER, ALARA

1. Introduction

For any nuclear plant to be built there is the need to assess the occupational radiation exposure (ORE) in advance of the construction, because in the framework between the design phase and the delivery of the whole facility ready to operate an iterative process for the dose reduction (As Low As Reasonably Achievable, ALARA) is requested by the licensing authorities.

This process of optimization is normally based on a large amount of data about the maintenance tasks if they are available, as it occurs for the fission plants. A different approach has to be used for the nuclear fusion plants. In such a case the ORE data come from experimental facilities, much smaller than ITER and having limited dose rates in the maintenance zones if compared with the dose rates foreseen for ITER. It means that several tasks performed by hands-on on the experimental plants have to be done remotely in ITER.

In spite of this limit the maintenance experience collected in JET [1] is a significant basis for speculations on the ITER work effort and the consequent ORE optimization.

2. Need of data for ITER ORE construction

The first step to approach the ORE assessment is the definition of the work effort (WE) that is the time spent by each worker to perform the elementary tasks necessary for the complete maintenance of a component or a system (examples: weld a pipe, mount a scaffolding, etc.) multiplied by the number of worker necessary to carry on the task.

The scope of WE data collection in JET, performed in the frame of the EUROFUSION WPJET3 work-program is to build a data base useful for the ITER ORE assessment, establishing a link between the activities foreseen in JET that can be applicable also in the ITER environment.

A premise is necessary: the dose rates, the tritium concentration and the dust contamination that are possible to collect at JET, in any condition (normal operation and maintenance during shutdown), are not comparable with the same conditions in ITER, but they can be useful if they are put in relation to the work effort data and to the dose to the workers.

Collecting the dose rate in the maintenance zones and the time spent by the workers to perform the tasks it is possible to build a theoretical collective dose. It can be compared with the effective collective dose measured by the personal dosimeters worn by the workers to understand how far the theoretical collective dose and the measured one are far each other.

The difference between the two data (theoretical and measured collective dose) gives the order of the approximation affecting the ITER ORE prevision that can be calculated as theoretical collective dose only.

In the past years (2005-2011) a WE data base (WE-DB ver.1.0) (Table 1) was used for the calculation of the worker doses of the ITER ORE assessments for some of the most important systems such as neutral beam injector (NBI), ion cyclotron heating, electron cyclotron heating, lower hybrid heating, diagnostics and test blanket module [2]. Several of the WE data used derived from the nuclear

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fission and industrial plant experience. Others were based on the engineering judgement of the ORE experts.

Currently the data base needs to be updated, validated and populated by other data, taken from the JET operational experience. A first effort, of the same type, was done in 2007 but it remained limited, in terms of data achieved. The current activity on WE data gathering in JET should implement the former data base WE-DB ver.1.0, harmonize the data collected and organize them. At the end the data base can be used as a common tool for the ORE assessment not only for ITER but also for the future fusion facilities as the DEMO reactor.

It is important to underline that, in spite several activities in ITER will be carried on by remote handling (RH) due to the high radiation field, the preparatory work for the RH often has to be done by hands on because of the complexity of the operations, the narrow spaces available and the significant costs of the RH tools. The impact of the preparatory work on the whole WE necessary in a task is not negligible as it is possible to note in Figure 1, where the WE for removal of the XOMOS spectrometer in JET is monitored in which one of the most significant contribution to WE is due to scaffolding erection.

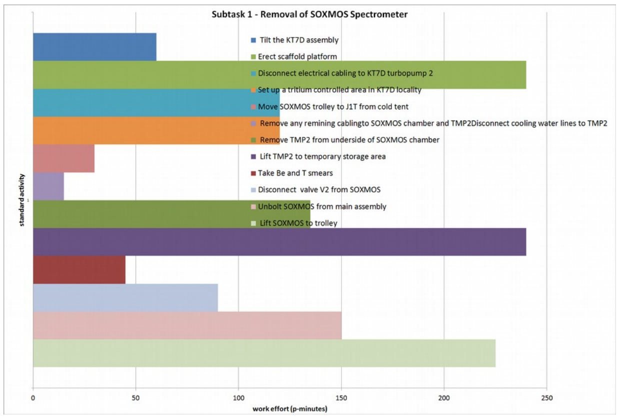

Figure 1 - Work effort for the standard activities to remove the SOXMOS Spectrometer in JET

Table 1 - Example of the WE-DB ver.1.0 structure

Category	**Standard activity**	**Elem . Act (h)**	**N. of people**	**El.WE (p-h)**	**Notes**
Elephant trunk – installation & removal	Install a temporary “elephant trunk” ventilation system	0.5	2	1	
	Remove temporary “elephant trunk” ventilation system	0.5	2	1	
Equipment supports temporary (set-up/remove)	Equipment support temporary, low-elevation - set-up	0.5	2	1	<waist level
	Equipment support temporary, low-elevation - removal	0.5	2	1	<waist level
	Equipment support temporary, medium-elevation - set-up	1	2	2	waist<level<head
	Equipment support temporary, medium-elevation - removal	1	2	2	waist<level<head
	Equipment support temporary, high-elevation - set-up	2	2	4	>head level
	Equipment support temporary, high-elevation - removal	2	2	4	>head level
Flange - bolting/unbolting/protection	flange small - bolt	0.5	2	1	<5 cm
	flange small - unboldt	0.5	2	1	<5 cm
	flange medium - bolt	0.75	2	1.5	5-10 cm
	flange medium - unboldt	0.75	2	1.5	5-10 cm
	flange large - bolt	1	2	2	>10 cm
	flange large - unbolt	1	2	2	>10 cm

3. Methodology for WE data collection in JET

The WE data have been gathered directly by a staff member of the JET Health Physics team attending the activities in the area in which the maintenance was done.

A report was prepared for any task monitored. Pictures were taken during the data collection to help in the task maintenance description (Fig. 2).

Maximum dose rate in the zone was recorded together with the results of the dust smearing and tritium concentration measurement, when present.

The operator detailed the complete intervention step by step taking note of the people involved (identified as person #1, person #2, etc.), the single actions, the duration and the local dose rate, when requested by the procedure, if the workers used masks, pressurized suits or other equipment for the personal protection.

Measured doses are recorded by the workers' electronic personal dosimeters (EDP) and noted in the report, when available. In some cases the EDP records were not available for all the workers involved.

In the analysis of the data to evaluate the theoretical collective dose to overcome these lacks the higher dose between those of the colleagues is attributed to the operator for which the dose is missing.

An example of the synthesis of the WE and dose data report for a task is shown in Table 2. The measured dose obtained by EDPs and the collective dose calculated on the base of the maximum dose rate in the zone have been compared at a validation scope (see §5).

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4. WE data gathered in 2016-2017 JET shutdown

The set of data collected during the 2016-2017 shutdown are those relating to five preparatory standard activities for the maintenance of the JET NBI:

Figure 2 - Person #1 removing Drain flange bolts.

1. Disconnection of Electric Cables,
2. Removal of Drain Flange,
3. Fit Front Central Support Column (CSC) Lifting Plug,
4. Magnet Cable Disconnection.

Three additional tasks not relating to NBI have been monitored too:

5. Attach support clamps around vertical pipes,
6. Cut CSC Calorimeter Door 4-inch Water Pipes,
7. CSC Health Physics Contamination Survey.

The interest for the first 4 tasks (1, 2, 3 and 4) was essentially because they affect the NBI, one of the system more studied in ITER from the ORE point of view, for which three assessments have been done. Besides the results of the NBI ITER ORE is classified and then not available to be published, the standard activities used as basis for the ORE are included in WE-DB ver. 1.0 and it possible to compare with those monitored in JET.

The other three tasks (5, 6, 7) are of general interest because necessary in several different maintenance activities.

Table 2 - JET WE and collective dose for task 3) Removal of Drain Flange

Specific activity	Standard activity	N. of people	Duration (min.)	WE (p-h)	Peak dose rate (μSv/h)	Measured dose (μSv)	Collective dose (max) (μSv)
Working zone preparation	Scaffolding erection	2	60	2	0.23	Person #1: 0.2 Person #2: 0.2(1)	0.046
Removal of Drain Flange	ingress	2	5	0.17	0.17	Person #1: 0.02 Person #2: 0.02	0.0283
	Drain flange unbolt	2	15	0.50	0.17		0.0850
	Drain flange removal	2	8	0.27	0.17		0.0453
	Contamination smears	2	4	0.13	0.17		0.0227
	Isolator fitted to drain flange port	2	13	0.43	0.17		0.0737
	Exit	2	2	0.07	0.17		0.0113
Total			**107**	**5.13**		**0.44**	**0.7263**

(1) hypothesis

5. Analysis of JET WE data versus ITER WE data base

The WE data collected in JET 2016-2017 shutdown needs be integrated in the WE-DB ver. 1.0 used in the past studies for ITER ORE assessment, after an analysis to verify their congruency.

The JET standard activities monitored for the different tasks have been compared with the similar ones existing in the WE-DB ver. 1.0 (Fig. 3).

Sometimes the type of task is exactly the same for JET and in WE-DB ver. 1.0, sometimes similar but not identical, sometimes a scaling was necessary to account the different size of the affected component and in several cases the activity was not yet foreseen.

In Figure 3 JSA identifies the duration of JET standard activity and ISA the duration ITER standard activity included in WE-DB ver.1.0.

The result of the comparison allowed to tune better and update the WE-DB versus ITER.

In particular:

- the disconnection of the electrical cables in the NBI has a certain complexity then the presence of 3 operators is necessary. The number of people involved has to be increased in the DB-WE ver. 1.1, updating of the previous data base;
- the duration of the unbolt operation for the small flanges has to be halved in DB-WE ver. 1.1;
- take smears strictly depends on the size of the component and or the zone affected by the maintenance. The scaling in small, medium and large component/area have to be introduced in DB-WE ver. 1.1;

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- the activity of make press and fit connection needs the intervention of a larger number of worker respect to that foreseen in DB-WE ver. 1.0, because they have to operate at different levels of the scaffolding to align the components to be fit;
- visual inspection has to be refined in DB-WE ver. 1.1 because, after a complex maintenance intervention, all the operators involved in the work participate to the visual inspection, then a note to highlight the point has to be included in DB-WE ver. 1.1. The duration of the standard activity is coherent between JSA and ISA (0.15 h versus 0.13 h);

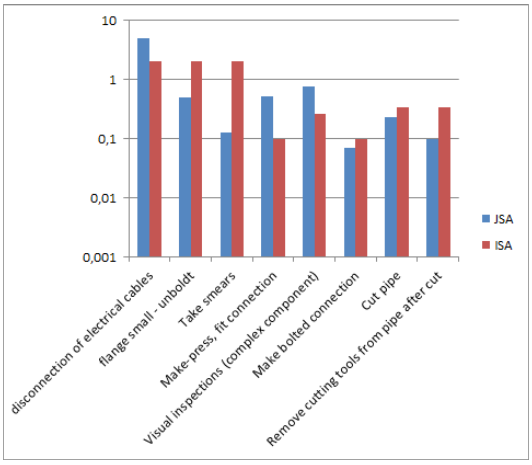

Figure 3 - JET WE (JSA) versus WE-DB ver.1.0 (ISA)

- bolt tightened is coherent between JSA and ISA. Correctly ISA foresees two operators for the activity;
- cut pipe duration is similar in JSA and ISA. The presence of two operators will be preserved for security reasons;
- the removal of the tools after the pipe cut shows a larger WE in ISA versus JSA, but the presence of two operators is necessary in the maintenance zone and then the datum will not be changed in DB-WE ver. 1.1.

All these data have been included in the WE-DB ver.1.1, as a result of the JET WE data collection.

By means of the WE-DB is it possible to evaluate rapidly the impact of the single action on the total amount of time requested for a maintenance task, screen the activity not requested, optimize the interventions, and then, as a consequence apply an ALARA approach, that is the main request of the licensing authorities in the ORE assessment.

6. Collective dose validation by means of JET data collection

The calculated collective dose for any single activity is the product of the number of people involved in the task, the duration of the task and the maximum dose rate measured in the zone and reported by EDPs. The approach is conservative because the maximum dose rate is supposed in the whole maintenance zone affecting all the workers.

The calculated collective dose for any standard activity is compared with the measured one in JET (Fig. 4) as an attempt for the validation of the approach used for the ORE assessment.

The calculated collective doses resulted always higher than the measured ones. The ratio between the two collective doses is between 1.5 and 7, then a correction to the approach was necessary. In fact the workers performing the maintenance were not permanently in the area of the maximum dose rate.

In the future applications of the validation method for the collective dose of any elementary activity, the effective dose rate of the maintenance area has to be used, when available. Otherwise half of the maximum dose rate in the affected zone will be the reference to calculate the collective dose. It guaranties sufficient margins against the underestimation of the worker doses.

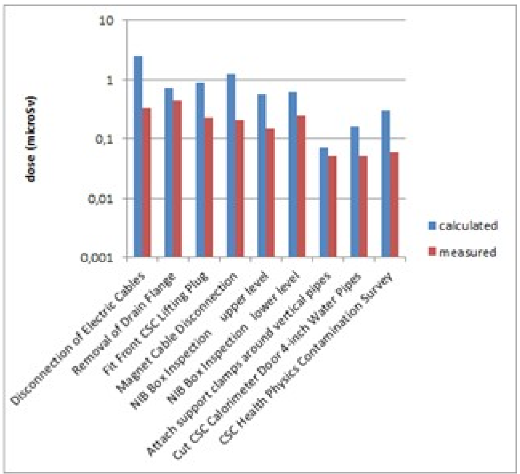

Figure 4 - Measure and calculated collective dose for the JET maintenance tasks monitored

7. Conclusions

The WE data of some standard activities performed for the maintenance of the JET have been collected and implemented in the WE-DB ver. 1.1, data base containing the work effort data tuned for the ORE assessment of the fusion facilities.

A limited validation of the method to evaluate the collective dose applied in ITER in the past has been done comparing the doses recorded by the personal dosimeters of the JET workers with the collective dose calculated for any standard activity monitored in JET.

The method resulted to be too conservative because of the use of the maximum dose rate in the affected zones. The average of the dose rate in the maintenance zones seems more appropriate to approach the measured one. In this case the results showed a limited overestimation but confirmed the validity of the approach.

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