2.11 ITER Decommissioning Procedures

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The present document gives a brief description of the ITER decommissioning plan, its phased pattern, and some indications of the activities expected to be required.

2.11.1 Decommissioning Phase 1 – De-Activation

The aim of phase 1 is to bring the machine into a safe state soon after the end of operation, in preparation for the subsequent phase 2 tasks, utilizing the facilities and manpower still available on site from the previous operation phase. The responsibility for phase 1 belongs to the ITER organization and will terminate with the handing over of the facility to a new organization inside the ITER host country in a ready-for-decommissioning status. Phase 1 will consist mainly of the removal of mobilizable tritium from the in-vessel components and of any recoverable activated dust (beryllium, tungsten, carbon). Also, the in-vessel components are removed.

During phase 1, hot cell operations are expected to be intensive due to the large number of components that needs to be processed prior to disposal.

Tritium will first be removed from the surfaces of the in-vessel components by established techniques and stored prior to its removal from site. Beryllium dust and any recoverable activated dust will also be removed to the greatest possible extent from the vacuum vessel using the existing remote handling equipment.

During phase 1, the de-activation of the coolant in the loops of the tokamak cooling water system (TCWS) will start with the removal of activated corrosion products and the de-tritiation of the (water) coolant. Throughout this period, the WDS plant is required to assist continuously the hot cell operations (with the ADS and VDS, atmosphere and ventilation de-tritiation systems), the tritium plant normal ventilation de-tritiation system (N-VDS) and the stand-by atmosphere de-tritiation systems (S-ADS/S-VDS - this is used only in case of a tritium release accident). As for the tokamak vault dryers/coolers, the WDS plant is needed only until after complete TCWS dismantling. As a result, it is estimated that approximately 50% (i.e. 10 kg/h) of total WDS capacity can be used to remove tritium from the TCWS coolant water (max 600 t). Under this condition, the TCWS coolant tritium removal process time can be estimated at about 8 years. This figure may possibly be reduced to about 5 years, depending on the WDS requirements in other parts of plant.

2.11.1.1 Removal of In-Vessel Components

The aim of this phase is to remove all in-vessel components, i.e. blanket, divertor, and all upper, equatorial and divertor port-mounted systems. All in-vessel components are dismantled according to established procedures that are part of the facility remote maintenance plan. This means that only a minimum amount of additional equipment and procedures need to be provided for phase 1.

During phase 1, the following operations could also be carried out, mainly to take advantage of the available remote handling equipment already deployed inside the vessel. After removal of the in-vessel components, the vacuum vessel may be cut from the inside along the field joints and the corresponding interspace shielding blocks removed. The outer vessel skin would not be cut to preserve structural integrity and guarantee confinement during the radioactivity decay period and during the early part of phase 2, provided that the structural integrity against SL-2 earthquake can be retained with outer skin only. The poloidal rail required to drive the cutting tools is left in place for future use in phase 2.

The vacuum vessel is eventually cleaned to remove any remaining dust prior to the start of the radioactivity decay period. Shielding plugs are installed inside the equatorial and divertor ports, and the vessel is sealed.

2.11.1.2 Removal of Ex-Vessel Components

Two options are available:

Option 1 – Anticipate the dismantling of some ex-vessel components during phase 1

According to option 1, some activities could be performed inside the cryostat and pit in parallel with the in-vessel operations. In order to be performed under hands-on conditions, although still time limited, such activities must wait at least ~ 4 years after end of machine operations before the following operations are safely initiated:

- opening of the cryostat top central bioshield/lid assembly and of other cryostat access points as required;
- dismantling of cryostat thermal shield (part), all coils feeders, central solenoid, PF1 coil;
- possibly disconnect and remove CS;
- possibly cut and remove correction coils;
- possibly lowering onto cryostat floor of PF5 and PF6 coils;
- close cryostat openings.

The above operations can be performed using the existing equipment plus, possibly, some additional new equipment and tools, as required. However, new staff would have to be recruited because it has been assumed that for the initial ~ 4 years waiting period no such staff would be required on site (at least not for the above operations). The above operations will not increase the duration of phase 1 because they are entirely in parallel with the in-vessel operations and they are not on the critical path. Removed ex-vessel components, which are not activated, are transferred outside the tokamak building for temporary storage or size reduction, prior to disposal, re-use or material re-cycling.

Option 2 - Ex-vessel components are dismantled during phase 2

This option is desirable if:
- overall decommissioning time is not an issue;
- early re-cycling or re-use of some machine components is not required;
- there is an advantage or a specific requirement by the host country organization;
- there is a decision to delay the decommissioning work and related expenditure until later, i.e. in phase 2.

2.11.1.3 Other Plant Systems Decommissioning

Other activities performed during phase 1 are:
- removal of the remaining activated/contaminated systems, such as parts of the neutral beam (NB) injectors/diagnostics;
- at the end of hot cell operation, the tritium plant is not further required - all tritium in the plant is removed and the plant is dismantled;
- all tritium and beryllium can be removed from the ITER site;
- the hot cell radwaste processing operations are completed and the hot cell is decontaminated and dismantled;.

2.11.1.4 Disposal

Disposal of radwaste will take place during and/or after the dismantling operations, depending on the policy adopted by the host country organization at the time. Depending on the local requirements, disposal may be preceded by temporary storage.

2.11.1.5 Hot Cell Building Operation

During phase 1, hot cell operation is expected to be continuous due to the large number of components that needs to be processed prior to disposal. It has been identified that, during phase 1, the hot cell may be the bottleneck in the components waste processing and disposal path, creating hold-ups in the flow of components from the machine to the hot cell building. To ensure that the hot cell activities do not take longer than other phase 1 work, additional hot cell building equipment must be provided. The hot cell needs to be provided, for increased radwaste processing efficiency, with the following equipment :
- 2 or more vacuum furnaces for tritium removal from components;
- 2 or more cutting stations for components size reduction;
- equipment and tools for the removal of beryllium pellets and breeder material from the breeding blanket modules;
- facility for materials re-cycling;
- additional radwaste temporary storage.

2.11.1.6 Phase 1 Duration

The estimated duration of phase 1 is approximately 5 years. The drivers of phase 1 duration are:
- hot cell building waste processing activity duration;
- tritium removal from the coolant.

2.11.1.7 Radioactivity Decay Period

During this period, radioactivity inside the vacuum vessel will continue to decay. The estimated duration of the time at which the contact dose rate for hands-on operations falls, on average, below 10 µSv/h is estimated as approximately 23 years. During this phase, site activities are reduced to a bare minimum and consist mainly in the following:

- vacuum vessel radioactivity monitored to establish when final dismantling (in phase 2) can be initiated;
- cranes periodically maintained in preparation for phase 2 activities;
- plant systems (such as ventilation, etc.) required for phase 2 maintained as necessary (possibly not running continuously, but inspected periodically);
- monitoring of the environment from a safety point of view.

2.11.2 Phase 2 – Final Dismantling and Disposal

2.11.2.1 Final Dismantling – General Description

The main activity during phase 2 is the removal of the machine 40° sectors (each consisting of a vacuum vessel 40° sector and its thermal shield, and two TF coils) and the dismantling of the vacuum vessel. Further, if option 2 of phase 1 is adopted, all ex-vessel dismantling operations are also performed in phase 2. Phase 2 operations are carried out using, in part, components and plant, which have been maintained or kept in an operational state during the radioactivity decay period. Dismantling of the vacuum vessel is done using remote techniques. Dismantling of any ex-vessel components is mostly done hands on. In principle, remote handling equipment used previously for the removal of the in-vessel components could be used. However, it is expected that because of its age and the intensive usage in previous years, this equipment will require upgrading or, most likely, will need to be entirely replaced. Other, general, handling equipment (for example cranes) would have been maintained during the radioactivity decay period and will be used for both the vessel and ex-vessel dismantling. Other activities during this phase include the completion of the dismantling of the NB lines and the removal of the vacuum vessel pressure suppression system (VVPSS) and drain tanks. Separation of the TF coils from the associated VV sectors is performed hands-on or remotely inside a cutting bay which has to be provided and equipped with all the associated systems before the start of the cutting operations. The two major sources, which may contribute to the dose during phase 2, are:

- the torus: after the removal of one or more machine 40° sectors a large opening is exposed;
- the machine 40° sectors : during their transfer from the machine to the shielded area of the assembly hall (cutting bay) where the TF coils are separated from the vessel sector and the vessel sector reduced in size for disposal.

The requirement that radiation doses of a member of the public and workers due to the two sources should be maintained ALARA is satisfied after approximately 23 years decay period from the end of machine operation. After this period, the machine 40° sectors can be extracted and transferred to the cutting bay without time limiting restrictions. Further, the additional sky-shine and direct radiation from the machine after removal of one or more TF/VV sectors is insignificant.

2.11.2.2 Removal of Ex-Vessel Components

During this phase, all ex-vessel dismantling operations are, with a few exceptions (as indicated below), carried out hands on. In case of the option 2 of phase 1, all operations described in 2.11.1.2 must be carried out. In addition, the following operations must be performed:

- PHTS pipes cutting (semi-remote operations);
- coils PF3 and PF4 are removed;
- remaining sections of the cryostat thermal shield are removed;
- all VV ports are cut and removed (semi-remote);
- coils PF5 and PF6 and any remaining correction coils are cut and removed;
- top part (above the equatorial ports) of the cryostat cylinder is cut and removed;
- install TF coils lower support structure;
- TF intercoil structures are disconnected.

2.11.2.3 Machine Sectors Removal and Vacuum Vessel Cutting

Vessel sector separation is achieved by cutting, from within the vacuum vessel, the inner vessel skin (if not done in phase 1) and the outer vessel skin. The vessel thermal shield at the outer field joint region will also need to be cut through using new remote handling equipment. The divertor, equatorial and upper ports extensions are progressively cut and removed. During port extension removal and after the start of the external vacuum vessel splice plate cutting, human access inside the cryostat will be time limited or semi-remote. Tables 2.11.2-1 and 2.11.2-2 gives the basis for the time estimates for these operations.

Table 2.11.2-1 Vacuum Vessel Inner Wall Cutting

OPERATION	TIME	Total
Assumptions: 16 h/day, 6 days/week, 380 mm/min cutting speed using plasma cutting, 4.3 weeks/month		
9 vacuum vessel inner skin poloidal cuts, processing time	˜ 26 m outer wall perimeter x 9 40-degree sectors x 2 cuts (inner splice plate) /380 mm/min plasma cutting = ˜ 0.9 days	˜ 1 d
Tools set up & remove, cleaning area, using transfer casks for vacuum vessel inner skin poloidal cuts	(8 h insertion + 8 h disengage/tool exchange/removal + 8 h cleaning) x 18 sectors	˜ 18 d
Tools set up & remove, cleaning area, using transfer casks for ports cutting	(8 h insertion + 8 h disengage/tool exchange/removal + 8 h cleaning) x 18 sectors x 3 port levels	˜ 54 d
TOTAL		73 d
Contingency 30 %		22 d
TOTAL		˜ 95 d

After cutting, the machine 40° sector is lifted out of the cryostat and transferred to a cutting bay in the adjacent assembly hall. The bay consists of a work area surrounded by steel walls. The bay top can be removed to allow use of a crane. The top is needed to prevent the escape of dust during cutting. Near the cutting bay a temporary facility is set up to allow for the transfer of the cut VV sections into containers prior to shipment. The facility also provides space for the storage and maintenance of the equipment required throughout the VV cutting period. Within the cutting bay, the sector is positioned on a special purpose stand (possibly similar to or the same which was used for initial machine 40° sector assembly). . The stand should be such as to prevent collision between a sector and the wall due to earthquakes during storage. The vacuum vessel is first cut into two halves, which are separated from the

TF coils. The vessel halves are then cut into pieces, which are placed into containers for disposal. Table 2.11.2-3 gives the basis for the time estimates for the cutting bay operation.

Table 2.11.2-2 Vacuum Vessel Outer Wall and Thermal Shield Cutting

OPERATION	TIME	Total
Assumptions: 16 h/day, 6 days/week, 380 mm/min cutting speed using plasma cutting, 4.3 weeks/month		
· Cut and remove all cryostat ports and ports extensions	Assume 5 days/port x 54 ports	˜ 270 d *
· 9 vacuum vessel outer skin poloidal cuts, processing time	˜ 30 m outer wall perimeter x 9 sectors x 2 cuts (outer splice plate) /380 mm/min plasma cutting = ˜ 0.98 days	˜ 1 d
· 9 vacuum thermal shield poloidal cuts, processing time	˜ 38 m outer wall perimeter x 18 sectors /380 mm/min plasma cutting = ˜ 1.22 days	˜ 3 d
· Cutting of vessel divertor, equatorial and upper ports, processing time	˜ 6 m cut length through the port double wall x 18 sectors x 3 port levels x 2 cuts (inner+outer port wall) / 380 mm/min plasma cutting = ˜ 1.2 days	˜ 2 d
· Tools set up & remove, cleaning area, using transfer casks for vacuum vessel outer skin poloidal cuts	(8 h insertion + 8 h disengage/tool exchange/removal + 8 h cleaning) x 18 sectors	˜ 18 d
· Tools set up & remove, cleaning area	(8 h insertion + 8 h disengage/tool exchange/removal + 8 h cleaning) x 18 sectors x 3 port levels	˜ 54 d
· Vessel port sections handling and removal	Assume 30 % of the above time	˜ 16 d
TOTAL (operations from 2 to 7)		94 d
Contingency 30 % (operations from 2 to 7)		28 d
TOTAL (operations from 2 to 7)		˜ 122 d
TOTAL (operations from 1 to 7)		˜ 392 d

* This can be done in parallel with the in-vessel cutting activities. Some series operations expected where ports are used for in-vessel access therefore the overall period can be somewhat shorter, about 1 year

Table 2.11.2-3 Vacuum Vessel Cutting - Cutting Bay Operations

OPERATION	TIME	Total
Assumptions: 16 h/day, 6 days/week, 380 mm/min plasma cutting speed, 4.3 weeks/month		
Rig up, lift, transfer and drop TF/VVsectors in cutting bay	4 days/sector x 18 sectors	72 d
Poloidal cut to free TF coil	˜ 30 m av.VV perimeter x 2 walls x 3 cuts (inner splice + 1 outer cut) x 12 sectors / 380 mm/min = 3.9 days	4 d
Removal of shield blocks (after inner splice plate cut and removal above)	Assume 36 blocks x 2 h/block x 18 sectors = 54 days	54 d
Rig up 1/18 VV sector, remove TF coil	7 day x 18 = 36 days	126 d
Cut 1/18 VV sector in pieces	Assume 45 cut pieces x 6,000 mm perimeter x 18 sectors x 3 cuts (2 inner wall cuts + 1 outer wall cut) /380 mm/min	27 d
Transfer 1/18 VV sector from tokamak pit into cutting bay	3 day x 18 sectors = 8.5	54 d
Cut pieces removal time, clean up area after each cut sector, put pieces into container, transfer to hot cell/storage	(650 shield blocks+810 vv cut pieces) x 3 h	183 d
TOTAL		520 d
Contingency 30 %		156 d
TOTAL		676 d 1.8 yr

Once the vacuum vessel is completely removed from the pit, the remaining components left inside the cryostat (gravity supports, tools and fixtures, etc.) are removed and final cryostat dismantling can take place.

2.11.2.4 Disposal

Disposal of radwaste will take place during and/or after the dismantling operations, depending on the policy adopted by the host country organization at the time. Depending on the local requirements, disposal may be preceded by temporary storage. Further information and details of the ITER general decommissioning waste management policy can be found in 5.

2.11.2.5 Re-Cycling or Re-Use

Materials re-cycling after dismantling or components re-use is desirable. This depends on:

a) for re-cycling:
- ability to rescue base material without extensive intermediate processing (i.e. reduced smelting requirements) while still retaining sufficient commercial value;

b) for re-use:
- ability of the original components (designed some forty years earlier) to satisfy the functional requirements of the new plant.

Preliminary indications suggest that ex-vessel components like the magnets (except for the central solenoid) and the cryostat will have a contact dose rate of ~ 10 μSv/h after a machine decay period varying between 5 and 50 years. Therefore, depending on the component irradiation history and decay time, it may be possible to re-cycle materials either under supervised conditions (and the re-cycled portion of such material will have to be treated as radioactive for some time) or, in the best case, without any specific precaution. Similar considerations apply to entire components (toroidal field coils, poloidal field coils). Materials and components originally installed beyond the biological shielding and which have never been in contact with active gas, fluid, dust or affected by neutron flux, can be re-cycled or re-used without specific precautions.

2.11.2.6 Phase 2 Duration

The estimated duration of phase 2 is approximately 6 years. This duration is essentially driven by the vacuum vessel removal and size reduction/waste processing operations.

2.11.3 Overall Schedule

The estimated decommissioning schedule is summarised in Figure 2.11-1.

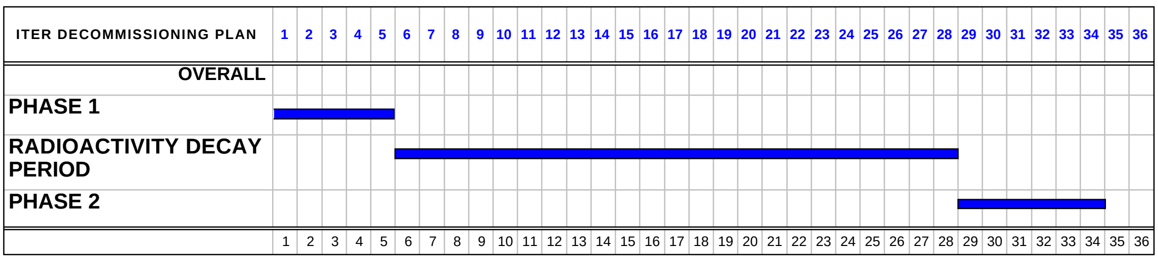

Figure 2.11-1 Estimated Overall Decommissioning Schedule