

## 3.6 Site Layout and Buildings

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### 3.6.1 Site Layout

The site layout (Figure 3.6.1-1) and the buildings have been designed for a generic site<sup>1</sup>. Before construction, certain design modifications shall be implemented to meet actual conditions on the selected site such as seismicity, topology, geology, hydrology, and access routes.

The layout has been designed for the minimum floor area, to reduce the complexity of system interfaces, and to minimise the connection distances, by following these key design strategies:

- a general layout policy to avoid the crossing of different service types such as electrical power, cooling water, and waste handling - clearly, the extent to which services can be segregated decreases as they get closer to the tokamak;
- separation of services: with the tokamak building located in the centre, the site is arranged so that electrical services enter from the west, cooling systems are located on the east, personnel-related functions are concentrated on the south, and waste management functions are located on the north (these directions are for identification purposes only);
- staged construction and expandability: to the maximum extent possible, the design of systems, buildings, and the site will be such that future additions in system capacity are not precluded.

The ITER site is enclosed by two fence systems. The outer fence encompasses the compulsory area, which means all the land area under control of the ITER operating entity. The inner fence surrounds a high security area and prevents unauthorised entry by persons or vehicles. All ITER buildings and structures except the cooling basins and structures, the laboratory office building, and the pulsed and steady state switchyards, are inside the high security area. In addition to the space required for buildings, structures and areas, the site layout allows for access, roadways and future expansion.

Space is allowed for the passage of services such as electrical power, cooling water, and movement of personnel and materials. Access is available for all phases of the project, including construction, operation, maintenance, and decommissioning.

During the construction of the tokamak itself, the primary access is from the south, but alternative construction accesses for the site are available from other points as well.

### 3.6.2 Buildings

ITER buildings house, support, protect, control access to, provide suitable environmental conditions for, and provide services to the components, systems, and operations which are selected to be located within them. The ITER buildings have been optimised to provide the lowest cost design solution which adequately meets the mission requirements and the appropriate standards for the public and workers, as well as investment protection.

The ITER buildings can be grouped in two main classes:

- the radiologically controlled buildings;
- the conventional buildings.

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<sup>1</sup> Plant Design Specification (PDS)

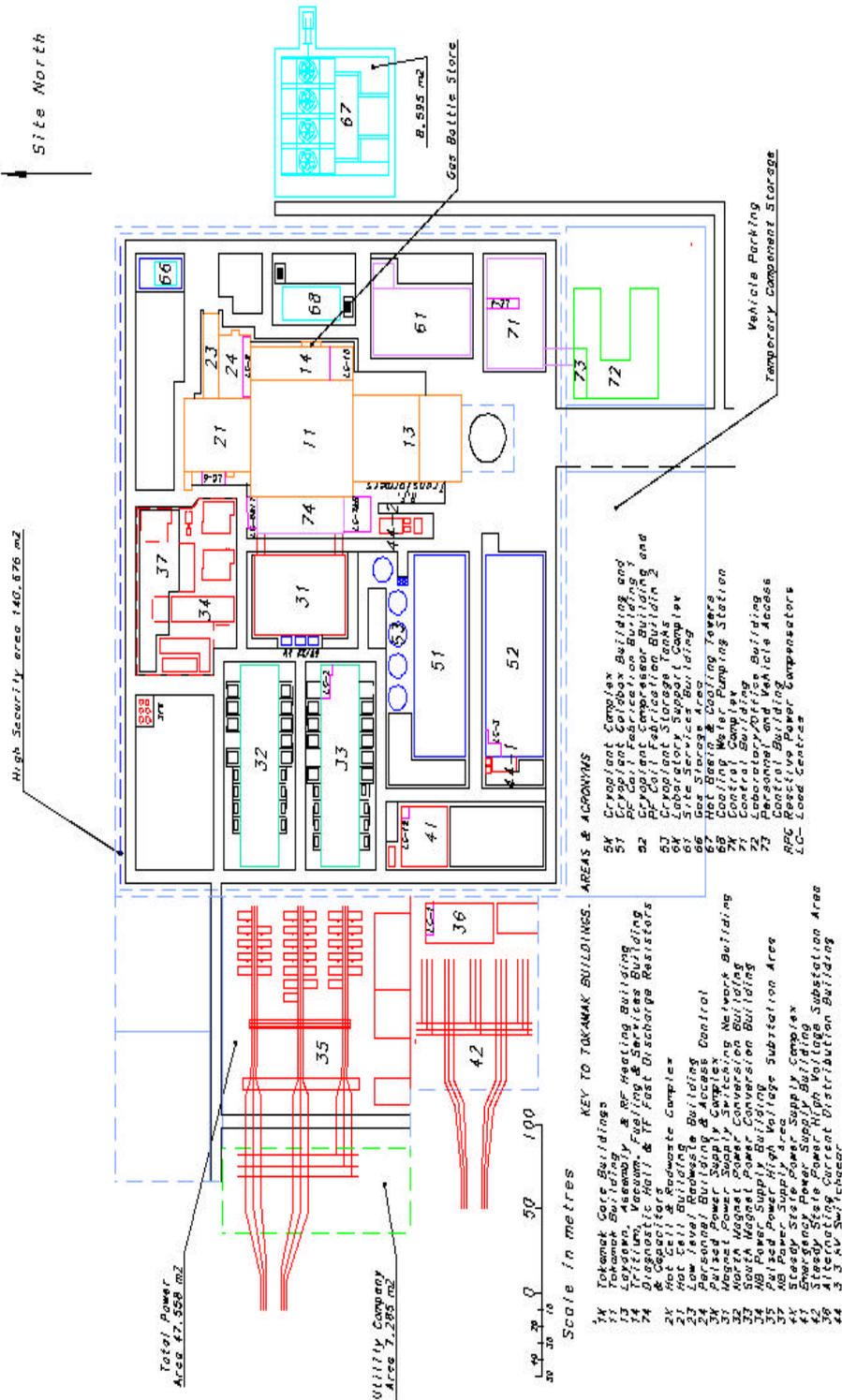


Figure 3.6.1-1 ITER Site Layout

The following description concentrates mainly on the radiologically controlled buildings.

### 3.6.3 Specific Design of the Radiologically Controlled Buildings

The radiologically controlled buildings include the tokamak building (11), tritium building (14), hot cell building (21), low level radwaste building (23), and personnel access control building (24).

These are the core of the ITER plant and, beyond their specific functional requirements, have been designed

- to complement the protection of the personnel from exposure to radiation and contamination;
- to complement the confinement barriers that limit the spread of contamination to the external environment in accidental conditions.

As a consequence, the radiologically controlled buildings have been designed to provide appropriate radiation shielding, ventilation, drainage, and access control. They are designed to resist an SL-2 earthquake<sup>1</sup>.

#### 3.6.3.1 Radiation Shielding

The general philosophy in the design of the ITER buildings that enclose radiation sources or potentially radioactive components or may become contaminated by radioactive products, is to provide shielding using the building structure itself to keep radiation exposure to the workers as low as reasonably achievable (ALARA).

The radiation sources are of three main types:

- radiation deriving directly from tokamak operation (mainly during the DT phase);
- radiation deriving from activated components removed from the vacuum vessel during maintenance;
- radiation deriving from the inventory of radioactive materials directly (e.g. tritium) or indirectly (activated corrosion products and dust) connected with tokamak operation, but present also when the tokamak is not in operation.

The radiation deriving directly from tokamak operation is primarily a factor in the tokamak building. During tokamak operation, the radiation sources include X-rays, gamma and neutron radiation from neutral beam injectors, gamma and neutron radiation from inside the vacuum vessel (VV), and gamma and beta (tritium) radiation from activated coolant. The radiation fields which will exist during and after the start of the DT phase have been estimated throughout the tokamak building (see 2.14). The shielding in the latter case is required to limit gamma ray fields from activated materials in the volumes where human access is required. These fields are constituted by the emissions from a few isotopes. The field strength decreases rapidly as short-lived isotopes decay, then remains fairly constant as longer-lived isotopes dominate. Shielding thickness is, in general, sufficient to reduce the dose rate in the tokamak galleries and in the tokamak crane hall below 10  $\mu\text{Sv/h}$ , within 24 hours of a DT pulse, allowing personnel access without special supervision or requirements.

The shielding for this tokamak radiation is initially provided by the bioshield, a hollow cylindrical concrete structure located around the cryostat, forming the “pit”. Bioshield plugs installed in front of each of the ports, designed for removal in pieces, provide access for remote maintenance activities inside the vacuum vessel. The tokamak crane hall is shielded

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<sup>1</sup>Plant Design Specification (PDS)

from radiation effects by a 2 m thick bioshield lid on the top of the cryostat. The lid is made up of removable concrete blocks to allow controlled access into the pit should any repairs be required.

During maintenance, gamma and beta radiation comes from the plasma-facing components which have been extracted through the ports from inside the VV. These components are handled in casks which move on floor-supported air-bearing vehicles (see 2.9). To reduce the weight of the casks, no shielding materials are used in the casks themselves. The shielding function is performed instead by the buildings, structures, and passageways through which the casks move. Most radioactive components and materials are moved to either the hot cell building or the low level radwaste building. Objects will exit the tokamak building via a lift shaft located in the gallery space and be delivered to the hot cell complex. Shielding is provided, along this path, by the building structural elements. A concrete thickness of 1 m is provided in the floor slabs; in certain locations, a wall thickness of 500 mm is used where it provides both adequate strength and sufficient shielding.

All other radioactive materials are located in the tokamak complex, the hot cell, or the radwaste buildings, except for packaged radioactive waste which has been prepared for off-site shipment and disposal. Also for this source of radiation the shielding is provided by the thickness of the building structures supplemented, where necessary, by local shielding.

### 3.6.3.2 Radioactive Contamination Confinement

The ITER plant is designed to limit releases of radioactive material to the environment, and radioactive exposure to workers and the public. Buildings where tritium or tritium-bearing components/materials or activated components/materials are handled have been designed accordingly.

Confinement is achieved by establishing barriers around the various radionuclide sources. In certain areas, the buildings provide a confinement barrier. In addition, building atmosphere pressures are arranged to ensure that the pressure gradient is always in the direction towards higher potential contamination, and discharge flow is always directed to the plant exhaust.

The vault that houses the TCWS equipment is connected to adjacent rooms and volumes and the overall volume is designed to limit overpressures resulting from postulated accidents within the capacity of the structure, especially an ex-vessel coolant leak. This building volume is called the “containment volume” (Figure 5.2.4-1), and includes:

- the TCWS vault;
- the CVCSs area;
- the TCWS vault annex;
- the NB cell;
- the vertical pipe shafts;
- the upper and lower pipe chases;
- the lower pipe chase sump.

The structures of the “containment volume” are designed to withstand an internal absolute pressure of 0.2 MPa (absolute) and to keep the leakage under 10% per day at this pressure. In case of an ex-vessel coolant leak, this overpressure is reduced to sub-atmospheric as the resulting gas and vapour is processed by the vault coolers and the vent detritiation system.

The heating, ventilation, and air conditioning (HVAC) systems are designed to provide suitable air change rates to remove heat released to air in the building as well as to maintain acceptable levels of airborne radioactive contamination within the ITER plant and to limit or eliminate contamination spread in the external environment, both for normal operation and for a number of postulated off-normal events.

The radiologically controlled buildings are divided into areas (see Table 5.4.2-1), based on their potential contamination ranging from "white" (uncontaminated) through "green" and "amber" to "red" (with different degrees of airborne and surface contamination). The design of HVAC systems ensures appropriate pressure and flow gradients within the buildings so that air flows from areas of lowest probability of contamination towards areas of higher probability. The HVAC air flow is passed through appropriate filters, and, if necessary, through the detritiation systems, before being released through the plant exhaust. The HVAC system is specifically designed to respond to potential off-normal events. In locations that may be involved with such events due to loss of vacuum or coolant leakage, the HVAC systems are equipped with high-efficiency particulate filters. Areas where the release of elemental tritium or tritiated water is possible are equipped so that the exhaust flow can be passed through a vent detritiation system (VDS).

Floor drainage from radiologically controlled areas is collected in tanks where it can be monitored and, if necessary, treated before it is released to the environment. Details of the detritiation capabilities of the HVAC system are given in 3.1.

#### 3.6.3.3 Personnel Access Control and Evacuation Routes

During operation, all access (personnel and vehicular) to the ITER high-security area of the site is through the single access control gate and gatehouse (73), located on the south side of the site, outside the security fence.

For workers operating in the radiologically controlled buildings, access is through the personnel access control building (24). This is contiguous with the tokamak complex and provides a controlled pathway and change facilities for personnel access to the potentially contaminated zones in the radiologically controlled buildings.

Access control to the tokamak complex is through the common stairway between the tokamak and the tritium buildings, in the north end of the complex on a floor-by-floor basis, with an air-lock that incorporates card readers as well as "step-off-pads" and hand and foot radiation monitors at each point of access. This airlock provides for radioactive contamination control to avoid spreading contamination into the stairways and into other floors of the building.

Access to the other radiologically controlled buildings is controlled in a similar manner. For the hot cell building and the low level radwaste building, truck access is required periodically.

The areas of the plant where access is normally forbidden under certain operational conditions include:

- the tokamak galleries (the areas below the crane hall of the tokamak building) during tokamak operation (including baking);

- the tokamak crane hall during tokamak operation, due to the intensity of the magnetic field ;
- the parts of the hot cell building where radioactive components have been accepted;
- the tokamak galleries and hot cell, and the passageway between these buildings, during the non-operational shift when casks transfer radioactive components.

Protection of workers from beryllium inhalation and contamination is according to common industrial practice by personal protection and ventilation. Access control is implemented according to the beryllium zones defined in Table 5.4.2-5.

The radio-frequency power guidelines defined in the Table 5.4.2-7 are used to ensure that the limits recommended by the international non-ionising radiation committee (INIRC) for high frequency radio-waves are not exceeded for personnel working in areas adjacent to sources of hazard.

Access is also controlled to limit exposure of personnel to potentially harmful electromagnetic fields, according to Table 5.4.2-6.

There are at least two independent emergency evacuation routes from each location or room on each floor of each of the buildings, including the tokamak building, leading to the evacuation stairways and to an outside exit. The routes of exits as a rule do not exceed a length of 60 m. The width of the emergency escape doors are not less 800 mm and the height of doors and escape routes are not less than 2 m. Evacuation exits lead directly to, or through a lobby to, a street or to an outdoor area.

#### 3.6.3.4 Decommissioning

At the end of ITER operations, the radiologically controlled buildings and their internal walls (including the bioshield) will not have become significantly more activated than when they are built. The hot cell and radwaste buildings may have some local contamination, but the walls and floors will be pre-treated with epoxy paint which can be removed to clean them. It will therefore be possible to re-use all the buildings on the site, if necessary to return the site to a “green field”, once the final packages of radwaste are removed from the site following the plant decommissioning process (2.11).

#### 3.6.3.5 Quality Assurance

The buildings and structures which are safety importance classified (SIC) are designed and constructed in accordance with American Concrete Institute (ACI)-349 (or equivalent), and ACI-318 (or equivalent) for specified seismic conditions, and all the quality assurance and inspections contained therein, plus any additional requirements specified by the ITER QA program.

### **3.6.4 Tokamak Complex**

The tokamak complex includes the tokamak building (11), the laydown, assembly, and RF heating building (13) and the tritium, vacuum, fuelling and services building (14). The tokamak building and the tritium, vacuum, fuelling and services building are integrated into a large reinforced concrete structure on a common rectangular basemat with dimensions of approximately 79 m in the north-south direction, and 90 m in the east-west direction. The

main reason for placing the tokamak and tritium building on a single foundation is to minimize possibilities of relative displacement due to seismic events in any of the large number of pipes and ducts that run between them.

The tokamak complex design is capable of accommodating seismic isolators if the actual ITER site requires an SL-2 earthquake tolerance significantly greater than the generic site design basis of 0.2 g peak horizontal and vertical ground acceleration.

#### 3.6.4.1 Tokamak Building

The building arrangement is designed to permit assembly and operation of a tokamak with 18 sectors with radial ports at three vertical levels. The general architecture is arranged around the cryostat. The development of floor levels and radial wall or pillar positions is directly related to port access and the remote handling cask docking and transport system. On the north side, the layout accommodates the space requirements for the secondary confinement of the NB H&CD system (the NB cell). A plan and an elevation (east-west section) of the tokamak building are shown in Figures 3.6.4-1 and 3.6.4-2, respectively.

The tokamak building is arranged in three major volumes:

- the pit
- the galleries
- the crane hall.

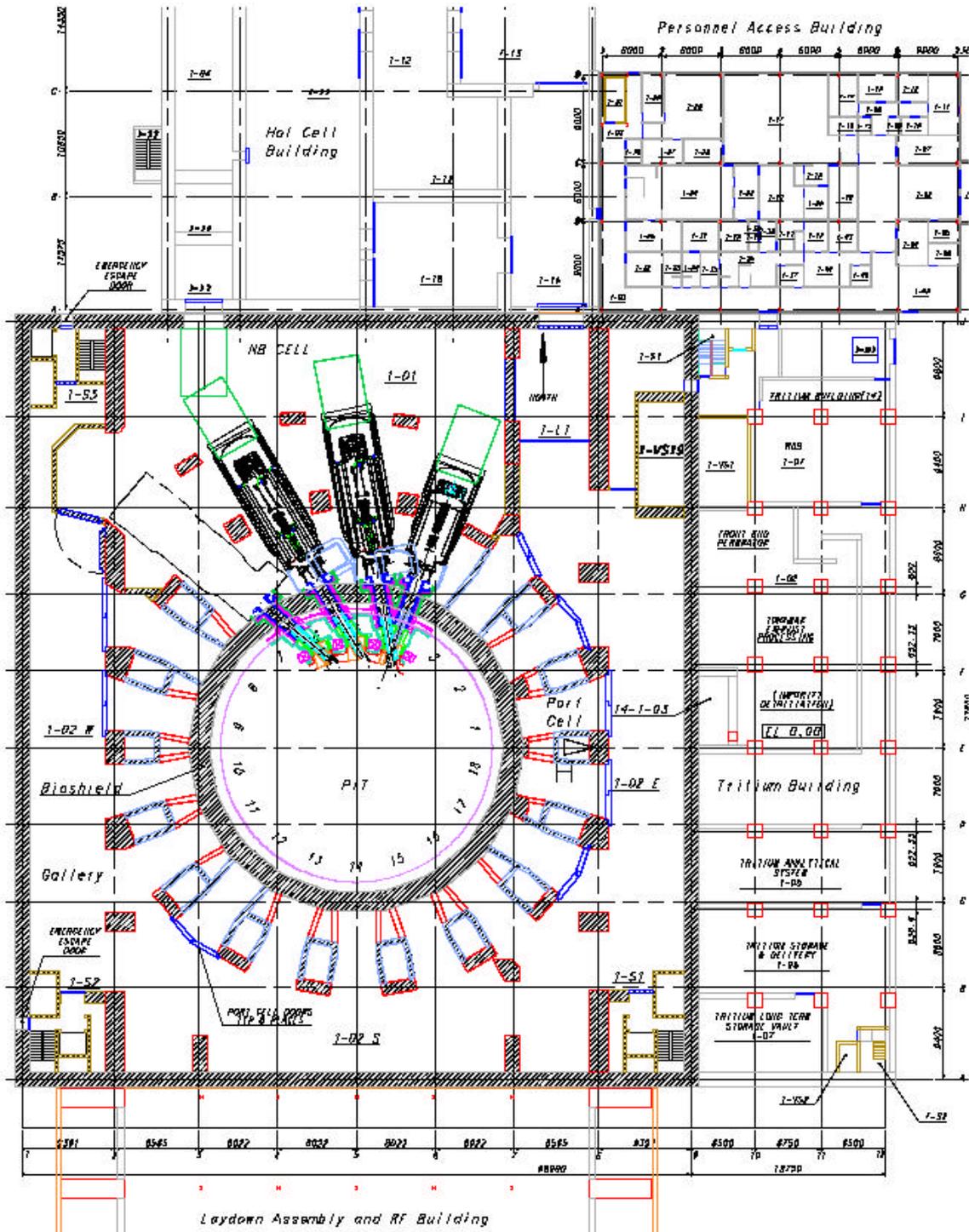
The tokamak pit is that volume surrounded by the cylindrical bioshield wall, that houses the cryostat, the vacuum vessel, the magnets, and all the other in-cryostat and in-vessel components. The tokamak pit is configured to permit the replacement of the central solenoid, the replacement or in-situ repair of any PF coil, and any 40° machine sector (which consists of a 40° VV sector, associated thermal shields, and 2 TF coils), without dismantling the other TF coils, cutting cables or pipes belonging to other TF coils or machine sectors. The cryostat in turn is supported on the tokamak building basemat. There is sufficient access through the bioshield at the basemat level, via temporary removable blocks, so that the in-situ rewinding of a faulted lower PF coil (PF5 or PF6) is possible if required.

The rooms and access areas under the crane hall floor and outside the bioshield, plus the TCWS vault and the VV pressure suppression tank vault, are organised in several levels (see Figure 3.6.4-2):

- basement level;
- divertor level;
- equatorial level;
- upper port level;
- upper magnet or CVCS level;
- crane hall and TCWS vault level.

At the divertor, equatorial, and upper port levels, the areas are divided into port cells and galleries. A port cell is defined as the volume from the bioshield wall out to the end of the vertical pipe shaft alongside each port. Typical locations of pipe shafts are shown in Figures 3.6.4-1, -2, and -4. The gallery is the space outside the port cells and connects all the port cells circumferentially around the tokamak. If the port cell is used for class 1 remote handling, it will be closed by a sliding full shielding leak-tight door across two adjacent vertical pipe shaft end walls (see Figure 3.6.4-1). This allows personnel access and parallel

maintenance activities in the galleries and nearby port cells after a cask has been placed inside the port cell. For ports requiring class 2 or 3 RH operations, shielding for parallel maintenance is to be decided on a case-by-case evaluation.



**Figure 3.6.4-1 Tokamak Building – Plan View of the Equatorial Level**

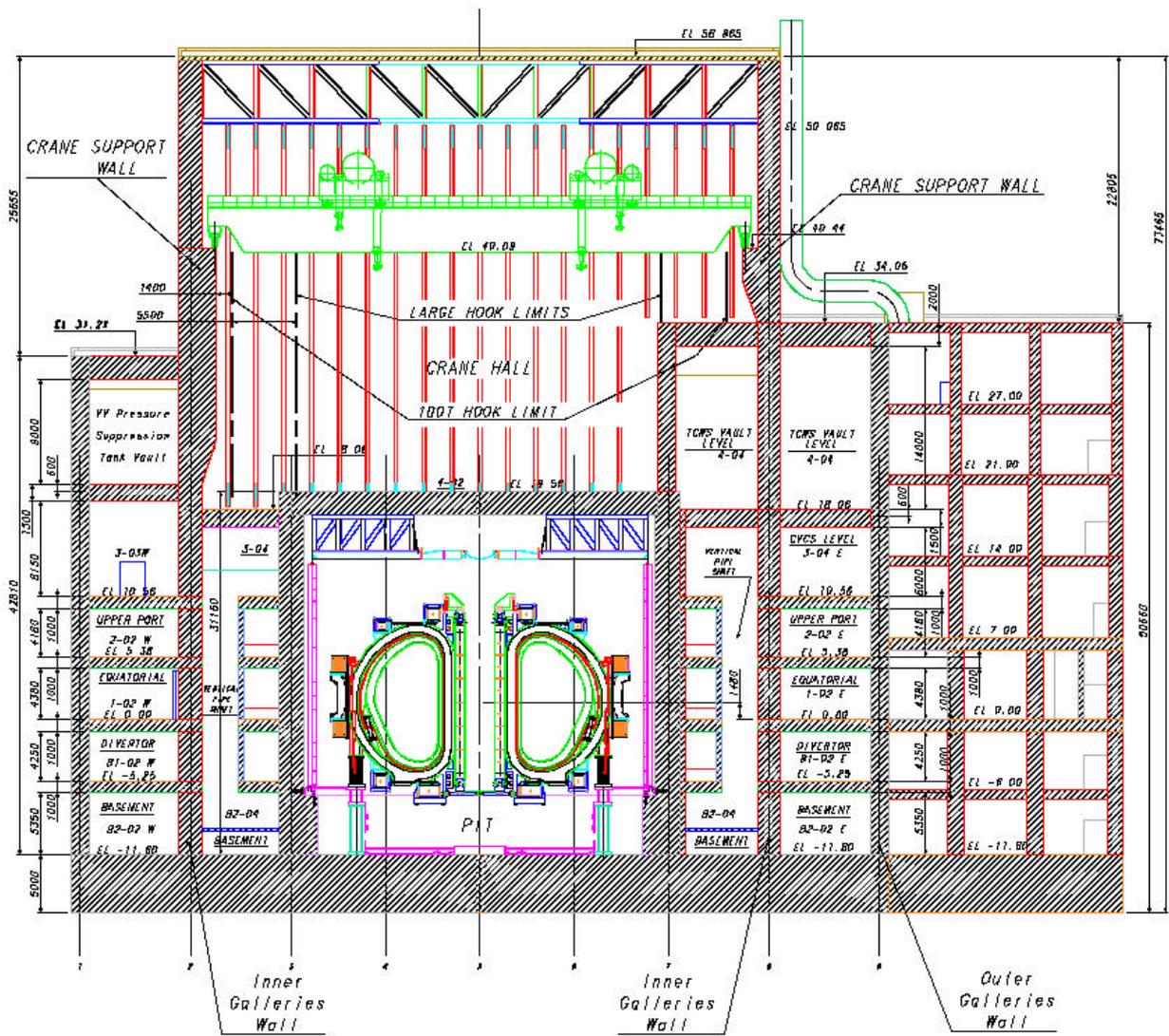


Figure 3.6.4-2 Tokamak Building Elevation (E-W Section)

The tokamak crane hall is connected to the laydown, assembly and RF heating building to form a contiguous crane hall, about 175 m in length, with the crane rails being approximately 47 m apart. This south end of the crane hall, the laydown, assembly and RF heating building, will initially have no internal structure, as it will be used to assemble the tokamak and other components.

The architecture and dimensions of the tokamak building, shown in Figures 3.6.4-1 and -2, are determined through a complex trade-off between various functional and structural constraints:

- equipment sizes;
- service routing;
- internal transport;
- shielding and structural elements;
- initial assembly and maintenance requirements.

The room heights at the port levels are dictated by the height available or necessary for the ports. The room heights at the other floor levels are determined by the equipment that is located on those floors:

The building size is influenced in the vertical and horizontal planes as described below.

#### *Tokamak building vertical layout*

The tokamak building height (Figure 3.6.4-2) is determined by two factors:

- the height of the pit below the bioshield top, which is dependent upon the machine port arrangement and the equipment on the tokamak gallery floors that, in turn, set the floor slab heights;
- the height of the hall above the bioshield, which is dependent upon the maximum crane lift for the largest machine component during the assembly process.

In the tokamak galleries, the size and position of the port extensions limits the available locations for slab elements. However, the building design must accommodate clear spans on the order of 10 m and maintenance loads on the order of 100 t and it is not practicable to size slab elements generally less than about 1 m thick. As a consequence the residual clearance between the bottom of the slabs and the top of the remote handling casks is on the order of 0.5 m. This height must be sufficient for installing, at the roof of each level, all the services connecting to the ports or the port area and, in particular, the coolant pipes for in-vessel component cooling. In order to connect the coolant pipes to the ports without crossing the gallery and thereby blocking the movement of remote handling vehicles, they go in vertical pipe shafts between the ports. The toroidal connections and routing of the coolant pipes is made in two annular pipe chases located at the CVCS level and at the basement level.

The NB injectors require a clear space about 6.4 m high, more than the space between the equatorial level floor and ceiling slabs. Consequently, the upper port level floor slab in the area of the NB cell is replaced by a metallic mezzanine floor.

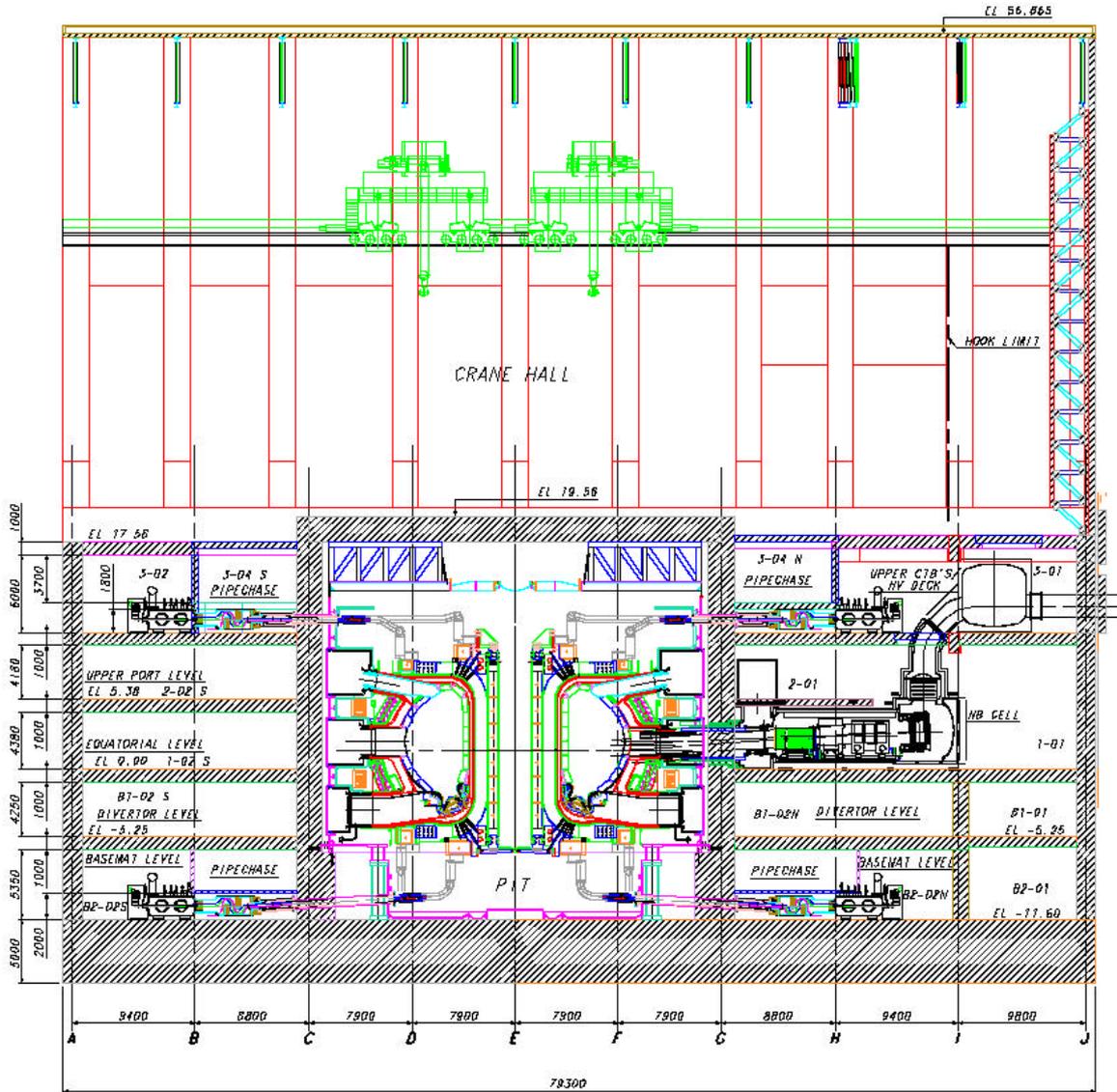
This mezzanine floor can be more easily integrated with the injector structures and provides limited access to the upper horizontal ports above the NB injector locations.

The toroidal field coil terminal boxes (CTBs), and those for the lower poloidal field coils and lower half of the central solenoid, are located in the basement level below the divertor port level. The upper poloidal field coils, the upper half of central solenoid coil modules, and upper correction coils, are served by CTBs located at the CVCS level, either above the NB cell or on the west side of the tokamak building.

The bioshield roof design is a 2 m thick concrete shield with steel lattice girder supports, with the dual purpose of providing reinforcement to the cryostat head, and access to the upper cryostat area for maintenance.

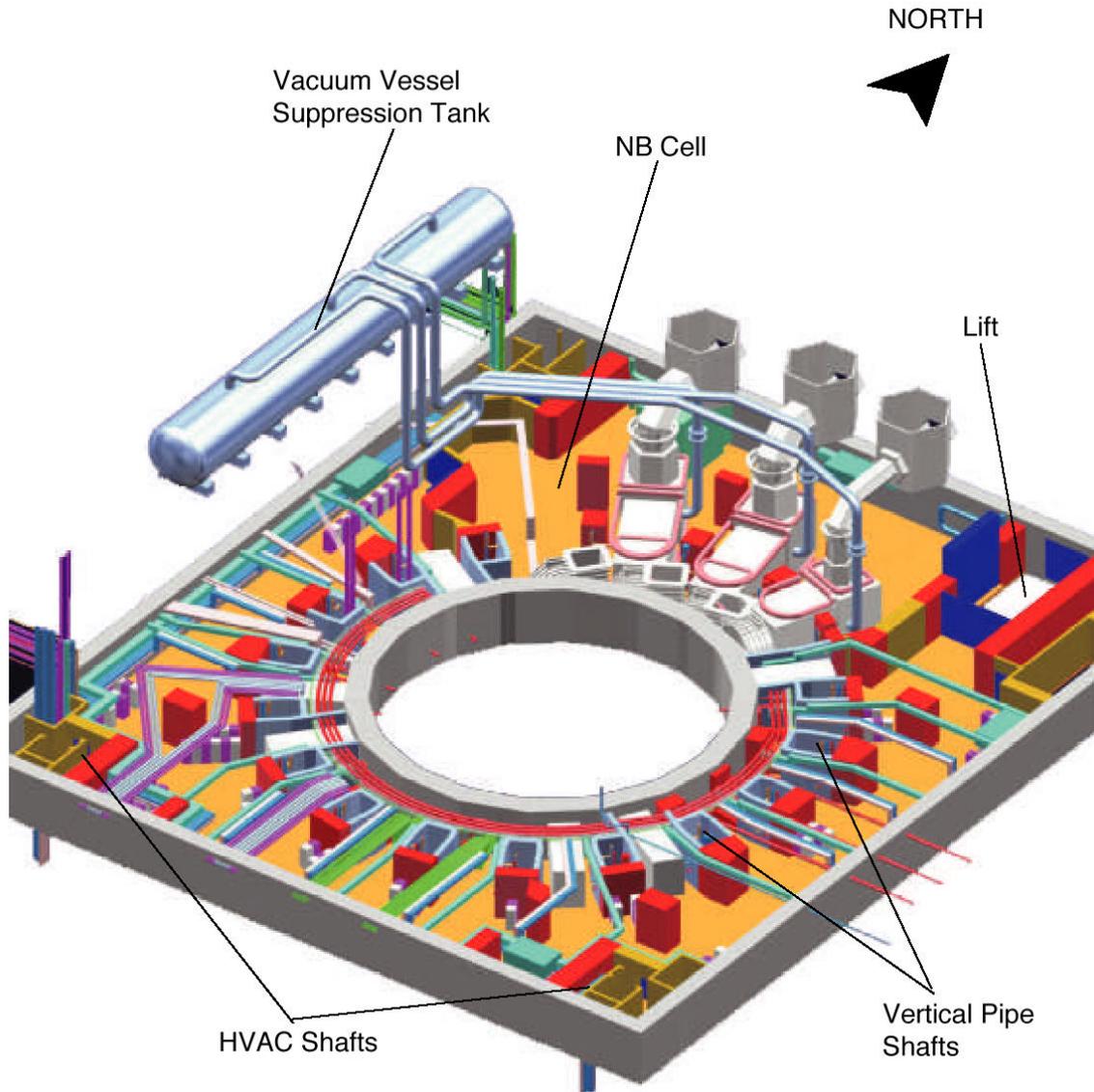
The tokamak crane hall height is set by the tallest component lift. The height of a 40° sector is approximately 18.5 m, the specific lifting tool is 1 m deep, plus a manoeuvring height of 0.5 m ground clearance. Hence, the overall height is approximately 20 m. The lifting beam arrangement for the crane requires an additional vertical space, estimated at 3 m, but this has been partly accommodated by incorporating a removable section in the bioshield wall. This feature will save 2 m from the crane clearance height.

There will be two, independent, identical 750 t capacity bridge cranes. Each crane will be equipped with 2 trolleys. Each trolley has a 375 t capacity main hoist and a 100 t auxiliary hoist. The rail-to-rail spacing of the crane rails is 44.82 m. By synchronising the operation of the four main hoists, loads up to 1,500 t can be raised (including jigs). The rail height has been set at EL + 40.595 m. In addition, it is anticipated that the crane lifting beam could be designed to allow the lift to rise between the 2 cranes, saving a further 3 m in building height. This latter option, however, would be a trade-off between cost reductions from lowering the building height by 3 m, against the cost of procuring the special crane lifting tools.



Level	Room no.	Room Designation	Level	Room no.	Room Designation
Basemat	B2-01	TCWS Drain Tanks	Magnet & CVCS	3-01	HV Deck & CTB Area North
	B2-02	Basemat Galleries		3-02	CTB Area South
	B2-L1	Elevator (Lift) Area		3-03	Cryodistribution Area
	B2-VS19	HVAC Shaft		3-04	CVCS Area East
	B2-SU1	Sump		3-L1	Elevator (Lift) Area
	B2-04	Lower Pipe Chase		3-04	Upper Pipe Chase
	B2-04	Upper Level			
Divertor	B1-01	TCWS Drain Tanks	Crane Hall & TCWS Vault	4-01	Crane Hall
	B1-02	Divertor Galleries		4-02	Top of Bioshield
	B1-L1	Elevator (Lift) Area		4-03	VV Suppression Tank
B1-VS19	HVAC Shaft	4-04		TCWS Equipment	
Equatorial	1-01	NB Cell	4-L1	Elevator (Lift) Area	
	1-02	Equatorial Galleries			
	1-L1	Elevator (Lift) Area			
	1-VS19	HVAC Shaft			
Upper Port	2-01	NB Cell Mazzanine	West Roof	VV PHTS Air Heat Exchanger	
	2-02	Equatorial Galleries	Main Roof	Plant Exhaust Duct (el 60.000)	
	2-L1	Elevator (Lift) Area	East Roof	VV PHTS Air Heat Exchanger	
	2-VS19	HVAC Shaft			

**Figure 3.6.4-3 Tokamak Building Elevation (N-S Section)**



**Figure 3.6.4-4 Tokamak Building – Isometric View of the Equatorial Level**

*Tokamak building plan layout*

The plan layout (Figure 3.6.4-1) is primarily defined by the space requirements for the cryostat which define the inner diameter of the biological shield wall. The thickness of the biological shield (2 m) wall is then defined, providing both the necessary structural strength and the radiation shielding for the port cells.

The level of embedment of the tokamak building into the ground is defined by choosing as reference grade the equatorial level. This choice is favourable for two reasons. Primarily the access from other buildings into the tokamak building is easier than a deeper embedment and a rectangular layout has been designed, with a better location of plant components, and other services not directly connected to bioshield penetrations. Ground water is assumed at 10 m below nominal grade. This assumption may require engineered ground water control during the construction of the tokamak building.

The floor space required by the additional heating system is then allocated. In particular the volume for the NB cell, the secondary confinement for that H&CD system, occupies part of the north side of the equatorial level and of the upper port level. The floor space is defined by the need to integrate in the NB cell up to three NB injectors plus one smaller diagnostic neutral beam. The location on the north side is defined by the proximity of the NB power supply switch-yard.

The heat transfer equipment is located above grade on the east side of the tokamak building in a single TCWS vault. From the TCWS vault, cooling water is distributed to the blanket modules, divertor cassettes, and vacuum vessel at every sector.

This level of embedment, making the building rectangular, and locating the heat transfer equipment into a single vault, produces some options for placement of the crane support structures. Several options were considered for the structural support wall for the crane rail. On the west side of the building, the crane support wall is located over the inner gallery wall, based on input from the assembly process, to maximise the utility of the assembly hall and to offer full crane cover over the tokamak pit. On the east side of the building, the crane support wall interacts with the TCWS vault by means of pillars through the vault and suitable penetrations to accommodate the TCWS equipment and piping layout. The crane beam overhangs the bioshield, resulting in a distance between the crane rails of approximately 47 m. The operating scope of the crane is maximized, including all of the area inside the bioshield.

Remote handling cask access to each of the ports is required, with the exception of the equatorial ports 4, 5 and 6, allocated to the NB injectors. Cask envelope dimensions are specified by the port size and design of on-board tooling. Casks of 8.5 m long have been assumed as the standard length for analyzing cask access routes. Kinematic analyses of remote handling vehicle motion have been performed to set wall and column positions so that all available ports are accessible. Current analysis shows that casks of this size can be accommodated on the three port levels. All ports allocated for remote handling can be accessed by casks which are able to manoeuvre via the galleries to the building-high 100 t capacity lift in the north east corner of the building. The only exception is for the ports to be accessed from the mezzanine above the NB injectors. At this level, the mezzanine is restricted by the diagnostic neutral beam injector. This issue is under study.

The location for the remote handling lift is on the east crane wall. The lift opens into the passageways to the hot cell building at the equatorial level, for the hot cell processing, and to the RH test stand areas in the hot cell building at elevations + 10.56 m and at + 15.81 m.

Provision has also been made for cask rescue, in the event of breakdown, by an alternative route to the lift on both the equatorial and divertor levels of the building. At the equatorial level the NB cell includes a corridor on the north side that provides a route for the NB maintenance casks to exit to the main equipment lift on the east side. This corridor also provides an alternative access route for the remote handling casks if the gallery is obstructed by a temporarily disabled transport vehicle. The corridor is connected to the gallery by an airtight door. The alternative path for cask rescue is not available on the upper port level due to the additional height requirement of the NB cell. This issue is under study.

### *Additional space requirement*

A preliminary layout and evaluation of space availability has been conducted for:

- HVAC ducts;
- cable trays;
- cubicles.

The arrangement of the HVAC system at the basement, three port levels and magnet levels has been developed using ring ducts (750 mm x 650 mm cross section) fixed to the outer gallery walls. At each floor level, these ring ducts have four air handling chiller units symmetrically distributed around the gallery perimeter. The intake air from the cooler end is redistributed by the ring duct through outlets around the perimeter of the outer gallery wall. A similar arrangement is used to allocate HVAC duct space at the basement and magnet levels. Each port cell is closed by either a shielding door or a closing membrane that seals against the wall, thus separating the port area from the gallery area. During normal operation, air is extracted from each port cell area and processed through a vent detritiation system prior to external release through the plant exhaust system. This creates a differential pressure of -1 mbar between the port cell inside and the gallery atmosphere.

When the shielding doors or membranes need to be opened for cask or personnel access, the depression is temporarily lost. During this period, no operations are permitted within the port cell that could release any tritium or activated products.

A preliminary conceptual design has been decided for the routing of cable trays. Space has been allocated for a minimum of 2 separate cable trays; one for interlock/signals and one for power cables, for each port cell area, excluding the RH cells. These two trays feed into two rings of cable trays situated just inside the outer gallery wall. These two rings feed into the two vertical shafts on the south-west and south-east corners of the building behind the lift shafts. From there, they feed between floors or out of the building, to their respective sources and destinations.

Specific cubicle requirements have not yet been defined. Early estimates indicate a need for about 355 cubicles in the gallery area and another 400 in the diagnostic hall. Over 660 standard sized cubicles (800 mm x 800 mm x 2,000 mm high) have been placed in the 3D model of the tokamak building, throughout the galleries, as follows:

- upper port level           ~ 200
- equatorial port level     ~ 260
- divertor port level        ~ 200

Cubicles for the magnet current and cryogenic feeders in the basement and the magnet levels have also been located.

The estimated heat load from these cubicles in the tokamak building is about 500 kW, and may need to be cooled by a chilled water system rather than by the building HVAC system, thus minimizing the number of local gallery air conditioning units

### 3.6.4.2 Laydown, Assembly, and RF Heating Building (13)

This is a large, rectangular, reinforced concrete building that is the southward extension of the tokamak crane hall, and houses several vital functions.

During the machine assembly phase, the building will be used for the assembly of the ITER machine. At this time, the building will consist only of the shell: the walls, the roof, the interface with the adjacent tokamak building, and the south wall with a 30 m wide door. The floor at grade-level allows easy access of material and components into the area, enabling the pre-assembly of the 2 TF coils with a 40° vacuum vessel sector and its thermal shields, using the large pre-assembly tools necessary for handling these heavy and large components. The 1,500 t main cranes will be used extensively during this period, and the crane rails are designed to allow smooth transition from the tokamak building to the laydown, assembly, and RF heating building. Preliminary design studies of the main crane and its support structure under design-basis earthquake conditions indicate that adequate safe performance would be sustained.

Assembly will take about 39 months (to month 84). However, as the workload in the assembly hall diminishes towards month 66, the conversion of the assembly area to incorporate the RF heating can begin in time for completion and commissioning by month 96. In order to make this viable, a temporary screen would have to be installed between the RF heating construction and installation area and the still busy assembly area. Commissioning of the RF heating equipment could be delayed to a later stage of the commissioning of the tokamak without seriously affecting the schedule of tokamak activities.

### 3.6.4.3 Tritium, Vacuum, Fuelling, and Services Building (14)

This building, more simply called the tritium building, is located immediately adjacent to the tokamak building to minimise the length of vacuum and tritium process lines. It is built on the same basemat as the tokamak building, and is 21 m in the east-west direction, and about 79 m in the north-south direction. The bottom floor of the tritium building is at elevation - 11.6 m, and has six additional floors at elevations up to 27 m. The roof is contiguous with the east side of the tokamak building roof, at elevation + 34 m.

The tritium building is structured to house the major systems and components on the various floor elevations as shown in Figure 3.6.4-5 and 3.6.4-6.

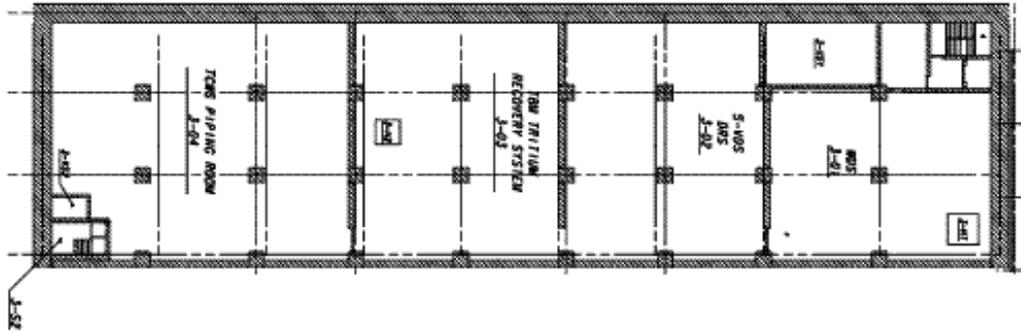
The room heights at the 7 floor levels are determined by equipment located on those floors:

- 11.6 m level:	4.600 m
- 6 m level:	5.000 m
+ 0 m level:	6.000 m
+ 7 m level:	6.000 m
+ 14 m level:	6.000 m
+ 21 m level:	6.000 m
+ 27 m level:	6.060 m

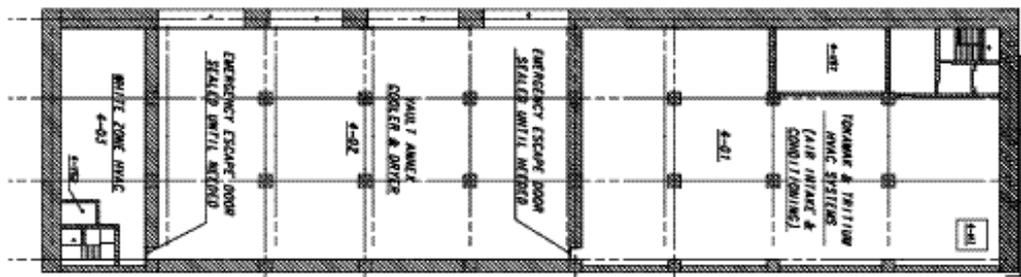


Figure 3.6.4-5 Tritium, Vacuum, Fuelling, and Services Building Plan View at Elevations: - 11.6 m , - 7.0 m, 0.0 m and + 7.0 m

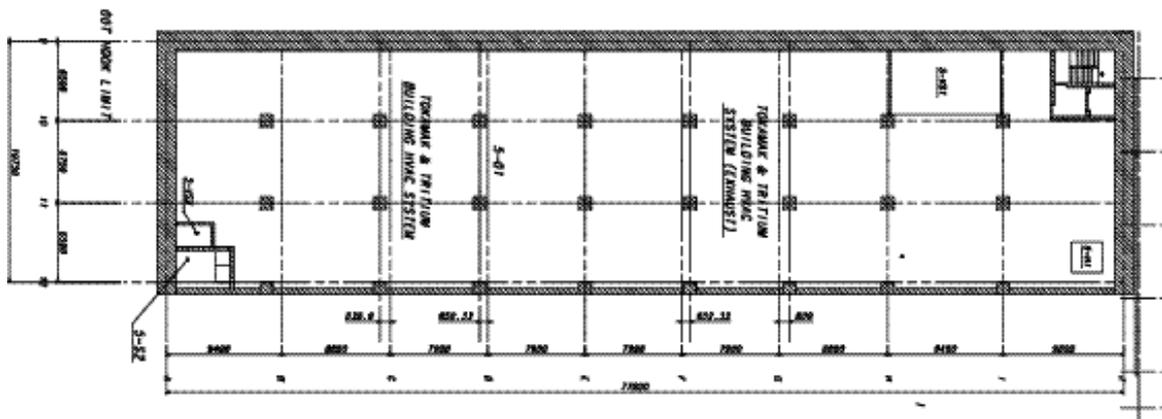
TRITIUM BUILDING PLAN VIEW AT ELEV. : +14.000



TRITIUM BUILDING PLAN VIEW AT ELEV. : +21.000



TRITIUM BUILDING PLAN VIEW AT ELEV. : +27.000



**Figure 3.6.4-6 Tritium, Vacuum, Fuelling, and Services Building  
Plan View at Elevations: + 14.0 m , + 21.0 m, + 27 m**

The building drawings have been prepared to show these minimal dimensions, which results in column spans and room heights in non-standard distances. A final site-specific design would incorporate some standardisation in these areas, where possible.

#### 3.6.4.4 Diagnostic and TF Coil Fast Discharge Resistors and Capacitors Building (74)

This building is a reinforced concrete building with four stories above grade and one below, containing the following diagnostic systems and equipment:

- shielded neutron test area;
- cubicles;
- spectrometers;
- reflectrometry;
- toroidal interferometer and polarimeter;
- LIDAR.

In addition, the building houses the TF coil fast discharge resistors and capacitors, and the busbars supplying DC power to the magnet coils. The number of floors, their heights, and equipment layout are determined by the space requirements for the diagnostic cables or waveguides. The TF coil fast discharge resistors are located on the third floor. Also on the third floor, at the north and south ends of the building, is space for routing the busbars between the tokamak complex and the magnet power supply switching network (31).

### 3.6.5 **Hot Cell and Radwaste Complex**

#### 3.6.5.1 Hot Cell Building (21)

The hot cell building is located close to the tokamak building to facilitate the transportation of objects removed from the tokamak.

The hot cell building is a rectangular reinforced concrete building with a 53.7 x 44.5 m footprint. It is organised on two main levels (see 2.9). Ground level functions include in-vessel component docking, dust cleaning, storage, repair/testing, remote handling (RH) tools exchange and maintenance, waste processing and waste storage and shipping, and new parts and components receiving and storage. Upper level (+ 10.56 m and +15.81 m) functions include RH equipment test, transfer casks and RH equipment storage, atmosphere confinement control and atmosphere detritiation equipment.

The rationale for the hot cell building layout and size is determined in the first instance by the maintenance requirements, and secondly by a few main design features which have evolved from a number of studies and reviews which particularly aimed at simplification of the remote handling processes. The main features and requirements for space are given below:

- a) hot cell arrangement on one (ground) level;
- b) in-line repair and refurbishment concept (assumption for the present layout);
- c) common in-vessel component refurbishment area is used instead of dedicated hot cells;
- d) common in-vessel component receiving/dust cleaning and storage cell with two docking ports that, together with current dimensions of transfer casks, determine the size of the hot cell transportation/docking area;
- e) common radioactive waste processing and storage area is used instead of dedicated cells;
- f) common repair/test area for all diagnostic, test blanket modules (TBMs) and RF heating port plugs including interspace blocks;
- g) equipment and RH tool exchange holding and repair/storage area;
- h) new parts and components receiving and storage area;
- i) cranes/manipulators and transportation devices retraction/maintenance space;

- j) RH equipment test stand and transfer cask and RH equipment storage area on top of the hot cell building;
- k) space for atmosphere detritiation system (ADS), the vent detritiation system (VDS), and HVAC;
- l) biological shielding, air locks, access and escape routes for personnel.

Figure 3.6.5-1 shows the hot cell building layout on grade level and its proximity to the adjoining personnel, radwaste, tokamak, and tritium buildings.

The sizing of the hot cell receiving room, processing room and storage space is based on meeting the requirements for the maximum allowable maintenance durations, together with the above design features and assumptions.

The sizing of the hot cell receiving/dust cleaning and in-vessel component storage cell is based on unloading and loading of two casks during the same shift and required storage space for the simultaneous storage of 4 blanket modules, 16 divertor cassettes, 4 equatorial port plugs and up to 4 upper port plugs or, instead of the upper port plugs, 3 diagnostic racks (structures for diagnostics at equatorial and upper port plugs).

The process cell size is based on simultaneous refurbishment of two divertor cassettes and one blanket module. In parallel, port plugs can be refurbished and tested by insertion in special port interfaces (test tanks).

The current hot cell building size is defined to satisfy the minimum requirements of all hot cell facility users. However, the detailed refurbishment procedures and the necessary RH equipment are still under detailed study. It may therefore be expected that further design optimisation will be possible at a future date.

Most of the other room sizes are a logical consequence of their functional requirements, i.e., space needed for casks to manoeuvre, space for equipment, e.g., HVAC, etc.

The hot cell building is available during the initial installation phase of the tokamak in-vessel components to provide a pre-assembly, Be-controlled area and a facility for loading components into transfer casks.

The hot cell building is designed such that it can be expanded to meet future, increased processing capacity needs, e.g., for the decommissioning phase of ITER.

To minimise the amount of tritiated water generated because of air inleakage, the leak-tightness of the building must be verified by detailed design, and the same attention to penetrations must be made as is required for the containment volume.

There is still the issue of mixed wastes arising because of the possibility of generating waste materials that contain both toxic Be and radioactive materials. This is an issue that will have to be dealt with in the host country licensing discussions.

Finally, the hot cell building will be built early in the schedule, and will be available for the temporary storage of RH equipment used for in-vessel assembly, as well as the storage and assembly of some of the in-vessel assembly components. This will obviate the need for a temporary facility to serve these functions.

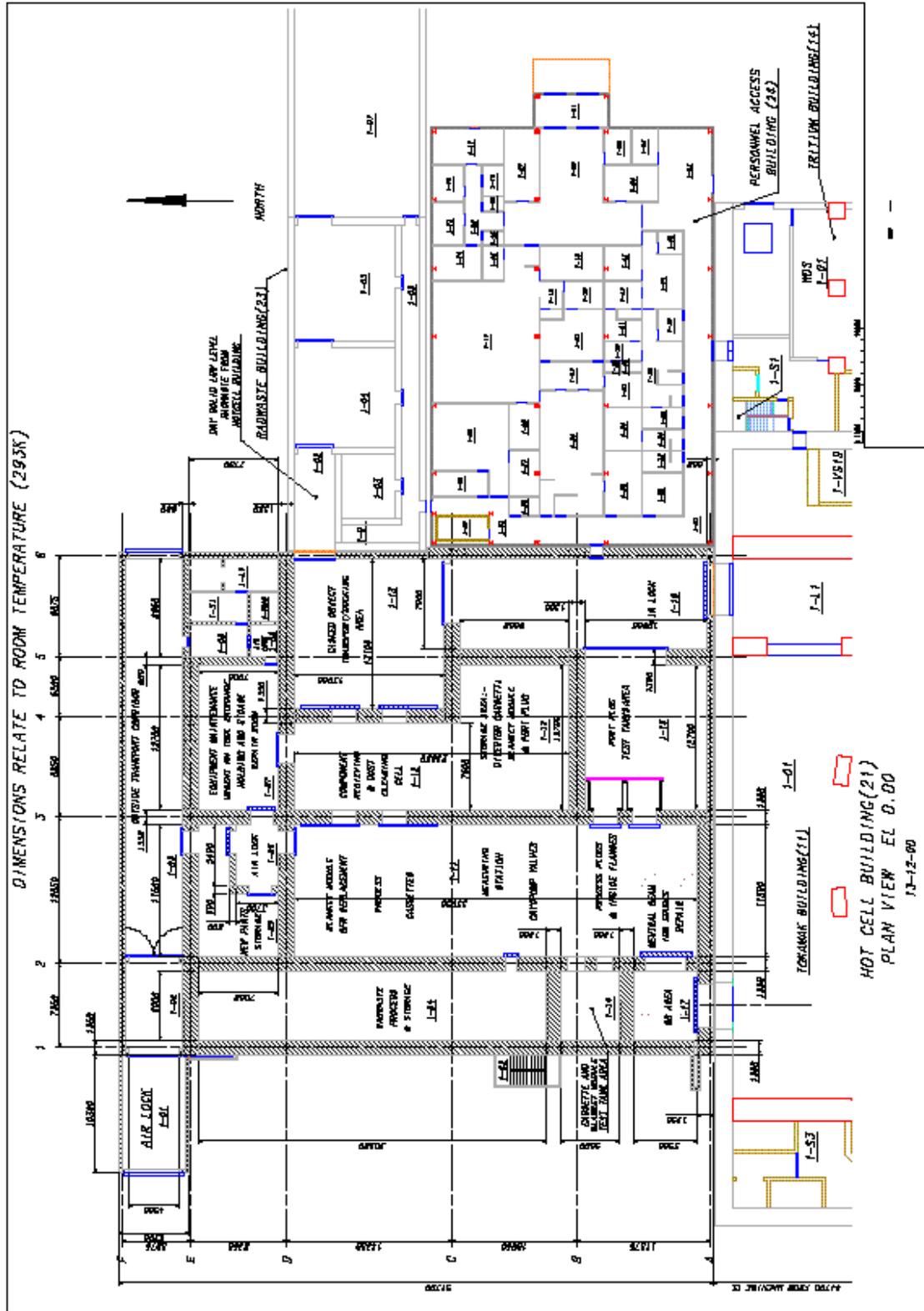


Figure 3.6.5-1 Hot Cell, Low Level Radwaste, and Personnel Access Control Buildings (plan view at grade level)

### 3.6.5.2 Low Level Radwaste Building (23) and Personnel Access Control Building (24)

As seen in Figure 3.6.6-1, these building are located close to the tokamak, the tritium, and the hot cell buildings to facilitate the management of personnel exposure and health physics, and to minimise the length of radioactive waste treatment connections.

The low-level radwaste building provides space for systems which process mildly contaminated water. Floor drainage from radiologically controlled buildings, active laboratories, tokamak cooling water system equipment drains, and shower and laundry drains, are treated here. Paper, plastic, and other dry solid material are collected and stored for appropriate packaging. The low-level radwaste building is configured to facilitate the handling of loaded filter and demineralizer beds. Filters and demineralizers are designed so that the beds can be sealed in a disposable liner and handled as wet solid waste. A de-watering step may be necessary before these materials can be transferred for disposal, and a connection to the hot cells provides for a common exit for this transfer. Materials are sealed in containers for off-site disposal by the host country. It is intended that the radwaste facility will be able to package materials so that they do not require any further processing prior to disposal by the host. The low-level radwaste building will be constructed using cast-in-place reinforced concrete.

Primary coolant will be continuously cleaned by the CVCSs to remove particulate and ionic material, some of which may have become activated. When the CVCSs filters and demineralizer beds reach their end-of-service life, the filter medium or demineralizer resin bed will be replaced. The spent filters and demineralizer beds may be treated as wet solid radioactive waste and packaged for disposal. Alternatively, ITER may have features which would allow backwashing of filters or regeneration of CVCS demineralizer beds thereby reducing the waste volume.

When primary coolant is intentionally removed from the system, it will be collected in drain tanks. Normally, primary coolant systems will be refilled from these tanks to resume operation.

Occasionally, it will be necessary to remove primary coolant to the waste systems. Primary coolant, water which is spilled onto the floor and collected in drains within the radiologically controlled areas, fluid from active laboratory drains, and decontamination fluid, will be collected in tanks in the radwaste building and treated in a dedicated waste process stream. Fluid will be sampled before and after processing. This process stream will include oil separators, filters, and demineralizers. If the product water meets the specifications for primary coolant, but exceeds the allowable tritium content for release to the environment, it will be sent to a water detritiation system where tritium will be extracted and detritiated water can be discharged. If the water does not meet primary coolant specifications, it must be recycled until additional particulate and ionic activity have been removed. The filter beds and demineralizer resins from this stream will also be treated as waste and handled in a manner similar to the primary coolant CVCS filters and demineralizers.

As with the hot cell, the low level radwaste building has been reduced to the minimum, because rather than designing and installing a comprehensive radwaste processing facility, the use of contractors for further waste processing is foreseen.

There is still the issue of mixed wastes arising because of the possibility of generating waste materials that contain both toxic Be and radioactive materials, an issue that will have to be dealt with the host country licensing regulations.

The personnel access control building is a rectangular steel frame building on a slab at ground level in plan 36.0 m x 24.0 m, with a height of 7.4 m. This building is on two floors and located so that it is contiguous with the tokamak building, the tritium building, the hot cell building and the low level radwaste building. The above-grade structures use structural steel framing. The building has floor levels at grade (0.00 m) and at + 3.60 m, and a roof at + 7.40 m, and is divided into white and green zones, based on their potential contamination. There are separate HVAC ducts to separate the rooms with different degrees of airborne and surface contamination. This building provides the single, controlled pathway for personnel access to the potentially contaminated zones in the connected buildings.

### **3.6.6 Pulsed Power Supply Complex**

#### **3.6.6.1 Magnet Power Supply Switching Network Building (31)**

The main function of the MPSSN building is to house the busbar connections for incoming DC electric power from the magnet power conversion buildings (32 and 33), plus the magnet power switching network, poloidal field (PF) circuit protective equipment, and dump resistors. Included is an instrumentation room, personnel support facilities, as well as general services such as HVAC, lighting, power, drainage, fluids, and lifting capability. A compressed air system and water cooling supply system are located at grade.

The MPSSN building is a rectangular steel frame structure, with dimensions 46 m wide by 70 m long by 14 m high, running north and south. The structure is set on a cast-in-place reinforced concrete slab, with two floor levels at grade 0.00 m, + 7.00 m and a roof level at + 14.00 m. The foundation of the building is set below grade by 0.2 m so that the finished floor level matches grade level. It is located inside the ITER high security fence on the west side of the tokamak building, in order to minimize the length of magnet power busbars.

#### **3.6.6.2 North and South Magnet Power Conversion Buildings (32 and 33)**

The two magnet power conversion buildings are two-level structures arranged as relatively long and thin structures to provide adequate indoor space for rectifier sets and related equipment, while also providing large exterior walls for connections to transformers. The steel frame buildings are each set on a reinforced concrete foundation. Rectifiers and power conditioning equipment are floor-supported, along the edge of each building. Power supply circuit transformers are located outdoors on foundation structures, including blast/fire walls to protect equipment inside. Busbars are routed vertically from the rectifier sets to an upper level. Large doors, at grade level and at +10 m on an intermediate floor, allow the installation and removal of equipment using portable equipment. The roof level (+16 m), is structurally flat, with only HVAC equipment located there.

High current power supply output is collected in air-cooled busbars, located on a second level above the converter sets in each building. The building provides general services such as HVAC, lighting, power, drainage, fluids, and lifting capability, as well as personnel support areas, including an office.

### 3.6.6.3 NB Power Supply Building (34)

The NBPS building provides space for neutral beam injection converters, inverters and control cubicles for delivering 33 MW to the plasma. The building includes a control room, facilities for personnel support, and general services such as HVAC, lighting, power, drainage, fluids, and lifting capability. It is located inside of the ITER high security fence on the north side of the tokamak building, adjacent to the NB power supply area, that contains the power supply units for the NB and DNB injectors.

The NBPS building is structural steel, column and beam frame, 15 m wide by 45 m long and 11 m high, with two floor levels at grade 0.00 m, + 6.00 m and a roof level at + 11.00 m.

The structure is set on a cast-in-place reinforced concrete slab foundation, 0.2 m below grade so that the finished floor level matches grade level. The second level contains power conditioning equipment and the control room, while the HVAC is located on the flat roof.

### 3.6.6.4 Pulsed Power HV Substation Area (35)

This pulsed power area is an outdoor switchyard and serves the magnet and plasma heating systems. The site infrastructure includes cast-in-place equipment foundations for transformers, circuit breakers, pylons, switchgear and other switchyard equipment. No building structure is required to protect this equipment.

### 3.6.6.5 NB Power Supply Area (37)

The power supply units for the NB injectors and DNB will be placed in the NB power supply area at the north side of the MPSSNB and near the hot cell building. This NB power supply area has the size of about 100 m x 80 m and it includes one building (the NB power supply building), which houses the static converters and inverters of the power supplies for both the NB and DNB injectors. All step-down and isolating transformers, as well as the HV rectifiers for the acceleration power supplies, are placed outdoors, around the building. Moreover, space is reserved for a NB power supply test facility, and for future extension (power supplies for a possible 3rd NB injector).

Power for the NB acceleration is taken from the pulsed power HV substation to the west. The output power is delivered to the NB sources located in the NB cells (tokamak building) via HV transmission lines which cross the hot cell building to the HV deck in the gallery of the tokamak building.

The site infrastructure includes concrete firewalls for the large transformers, and cast-in-place equipment foundations for transformers and rectifiers, etc.

## 3.6.7 **Steady-State Power Supply Complex**

### 3.6.7.1 Emergency Power Supply Building (41)

The EPS building is a rectangular reinforced concrete three-level structure, 36 m by 42.7 m by 14.4 m high, located at the west end of the high security area, next to the steady-state power supply switchyard. It houses two diesel electric generator sets, each rated at 6.3 MW<sub>e</sub>, plus control and switchgear equipment, to supply plant power in case of emergency.

The generators are set on separate foundations, to isolate their vibration. Diesel engine exhaust muffler, stack and heat rejection systems are located on the roof. Diesel fuel is stored in nearby underground tanks.

#### 3.6.7.2 Steady – State Power HV Substation Area

This steady-state power area is an outdoor switchyard and serves “house” loads, including the cryoplant, cooling systems, hot cell systems, HVAC, etc. The site infrastructure includes cast-in-place equipment foundations for transformers, circuit breakers, pylons, switchgear, and other switchyard equipment. No building structure is required to protect this equipment.

#### 3.6.7.3 Alternating Current Distribution Building (36)

The AC distribution building is a reinforced concrete, two-level structure. Reinforced concrete is used because the DC battery room requires the strength of massive and strong walls to resist a potential hydrogen explosion. Heavy equipment is located at grade.

#### 3.6.7.4 3.3 kV Power Supply Structures (44)

Two independent 3.3 kV power supply (PS) structures (44-1 and 44-2) are dedicated to motor loads up to 400 kW. PS 44-1 is just west of the cryoplant compressor building (52), and PS 44-2 is located south of the diagnostic building (74) between the cryoplant coldbox (51) and the tokamak assembly hall (13).

Each of the 3.3 kV power supply structures is a single-level, rectangular structural steel, column and beam configuration unit, set on a concrete slab at grade, with a roof level at + 4.70 m.

Siding is architectural metal with integral insulation, supported on horizontal stringers. Non-structural concrete walls separate the transformers and switchgear along building walls. Two power transformers for each structure, are located outdoors on concrete foundations, which incorporate oil catch basins and fire/blast separation walls. Roofing is structurally flat with built-up insulation to provide slopes to drainage points. Each structure provides general services such as ventilation, lighting, power, fire protection, fluids and drainage.

There are no operator support facilities.

#### 3.6.7.5 Electrical Load Centres

LCs are located throughout the site to efficiently consolidate the electric power requirements for a particular area, building, or a group of buildings. Currently, ten load centres are served by tunnels from the main power supply areas, feeding the end users in the vicinity.

### **3.6.8 Cryoplant Complex**

#### 3.6.8.1 Cryoplant Coldbox Building (and PF Coil Fabrication Building 1 (51))

As with the cryoplant coldbox building, the cryoplant compressor building is built in the early stages of construction, and used initially for PF coil fabrication. It is configured in the same manner as the PF coil fabrication building 2, below, and will be used to simultaneously

fabricate coils PF3 and 4. After the coil fabrication campaign, the building will be converted to the cryoplant coldbox building.

The cryoplant coldbox building is a single-level structure with clear span. The building provides space for process equipment and is serviced by an overhead main 50 t bridge crane and by a 5 t bridge sub-crane, suitable for servicing and assembly and disassembly of the helium coldboxes. The general configuration of the building is the same as for the cryoplant compressor building. The cold process boxes contain series of counter-flow regenerative heat exchangers, cold turbines and valves. The streams of compressed helium and nitrogen are supplied to these cold boxes from the cryoplant compressor building. The space for mechanical and electrical services, parts storage, and personnel areas such as local control room, offices, lavatories, and other worker support functions will be provided at the east end of building. Additional cryoplant equipment, including gaseous helium storage tanks, and LHe and LN<sub>2</sub> tanks, are located outdoors.

### 3.6.8.2 Cryoplant Compressor Building (and PF Coil Fabrication Building 2 (52))

The cryoplant compressor building is built in the early stages of construction, and used initially for PF coil fabrication. It is a single-level steel frame structure with a space for mechanical and electrical services. The building footprint is sufficient to provide for simultaneous fabrication of coils PF1, 2, 5, and 6. Each coil type, i.e. 1 and 6 or 2 and 5, will occupy 5 equivalent coil diameters, plus space for conductor laydown and spooling for a two-in-hand winding operation. The height of the building is controlled by the height of the winding operation plus room for pancake and module handling tools, crane, and roof truss depth.

The tools, jigs, and winding fixtures needed for the largest coil determine the space requirements for the building. The heaviest module determines the crane capacity. The manufacturing process involves the application of epoxy insulating and bonding materials, vacuum impregnation steps, and preparation of conductor joints. The process requires cleanliness, lighting, and environmental control, which are similar to modern aircraft manufacture.

The building includes space for an electrical load distribution centre, which is part of the plant steady-state electrical power distribution system. Personnel areas such as offices, lavatories, change facilities, and other worker support functions, will be provided using temporary buildings.

After the coil fabrication campaign, the PF coil fabrication building 2 will be converted to the cryoplant compressor building.

The cryoplant compressor building is a single-level structure with clear span. The building provides space for process equipment and is serviced by an overhead main 40 t bridge crane as well as by a 5 t bridge sub-crane, suitable for servicing and assembly and disassembly of the compressors. To maintain stability, the crane columns are built up with an effective width of 2.5 m, resulting in 40 m between crane rails. The maximum hook height for the crane is 18 m. The north aisle is used for interior truck access and routing of services, both overhead and in a below-grade utility trench. Large doors are provided at the east end of the building. The spaces for mechanical and electrical services, parts storage, and other worker support

functions are provided at the west end of the building. Additional cryoplant equipment, and helium gas heaters for the final stage of warm-up, are located outdoors.

### 3.6.8.3 Cryoplant Storage Tanks

Three warm and one 80K helium tanks, all rated at 1.8 MPa, a low pressure He balloon, and liquid nitrogen tanks, are located in an outside area, adjacent to the cryoplant coldbox building. The site infrastructure includes cast-in-place tank foundations.

## 3.6.9 **Laboratory Support Complex**

### 3.6.9.1 Site Services Building (61)

The site services building provides space for industrial support systems including compressed and breathing air, miscellaneous gas distribution, chilled water, demineralized water, potable and hot water treatment, auxiliary steam for space heating, and electrical power distribution. It contains space dedicated to non-radioactive waste handling, the non-active chemical laboratory, spare parts warehousing, machine shops, and offices.

The building has two parts: the main building and a small auxiliary boiler annex.

The main building is a single-level structure, 75 m long x 40 m wide and 12.5 m high, internally divided into three bays. Two 17 m wide bays, at each side of the building, provide space for process equipment and are serviced by overhead bridge cranes 20 t and 5 t. The centre bay, 6 m wide, is used for interior truck access and routing of services, both overhead and in a below-grade utility trench. Large doors at several locations provide access to interior equipment during operation. The roof is structurally flat.

The separate auxiliary steam boiler annex is 16 m x 15 m x 7.3 m high, set on a concrete slab at ground level.

### 3.6.9.2 Gas Storage Area

This area is allocated for the storage of hydrogen, deuterium and possibly nitrogen.

### 3.6.9.3 Hot Basin and Cooling Towers (67)

The ITER cooling system is based on generic site conditions, which include the use of mechanical draft cooling towers. Since the power production is not steady state, the cooling system is optimized by providing separate hot and cold water basins. The cooling towers are set on a foundation built as part of the cold water basin.

The cooling water for the tokamak systems is drawn from the cooling tower cold basin, extracts heat throughout the tokamak systems, and is returned to the hot basin. The flow rates between the basins and through the cooling towers are used to control the water temperature in the two basins. A spillway allows excess hot basin water to overflow into the cold basin.

The volume of the hot basin is 12,000 m<sup>3</sup> while that of the cold basin is 20,000 m<sup>3</sup>. Make-up water pumps beside the cooling towers have a foundation which is 10 m x 8 m. The main pumps feeding the cooling towers are on the hot basin.

#### 3.6.9.4 Cooling Water Pumping Station (68)

The main cooling water pumping station is located east of the tritium building to minimise the distance that the cooling water needs to be pumped. It is connected to the cold basin via a utility tunnel. The structure for the pumping station is 18 m (EW) x 50 m (NS) x 14 m (height) with walls, a simple roof, and natural ventilation, housing ten (10) pumps and two safety-related chiller cooling towers, one at each end. Power for lighting and small power users, and a welding outlet, are provided. There is no crane, as pump maintenance will use temporary lifting devices.

### 3.6.10 **Control Complex**

#### 3.6.10.1 Control Building (71)

The control building is located south and east of the tokamak complex, within the high security fence boundary. It houses:

- basement level: machinery room, load centre, cable room, transformer room, library, meeting room, storage, offices
- ground level: control room, computer room, change area, visitors' rooms, offices, incident response area (with vehicle)

The control building is designed so that essential systems can be operated after a seismic event, and has the following size and characteristics.

- building dimension : 40.4 m (E-W) x 70.4 m (N-S) x 7.2 m (from grade)
- depth of basemat bottom: 8.8 m
- footprint: 2,844 m<sup>2</sup>
- total floor area: 5,688 m<sup>2</sup> (2,844 m<sup>2</sup> above ground, 2,844 m<sup>2</sup> below ground)

#### 3.6.10.2 Laboratory/Office Building (72)

The ITER office building, located outside the ITER high security fence, is a five-level rectangular structure with an appendage to house an auditorium. HVAC and elevator equipment are located on the roof. The building provides some general services such as lighting, power, HVAC, fluids and is linked to other parts of the ITER site through communications networks.

It is a structural steel framed building which has floor levels at grade 0.0 m, + 3.60 m, + 7.20 m, + 10.80 m, + 14.40 m, and a roof level at + 18.00 m. Ground floor building amenities include a lobby and display area at the building entrance, cafeteria and kitchen facilities, locker and exercise area, computer room, library, conference rooms, auditorium, and various areas to house building support personnel and equipment. Floors 2 through 4 provide staff offices, workstations (cubicles), and meeting or conference rooms.

Two roof structures are provided to house HVAC and elevator equipment.

#### 3.6.10.3 Personnel and Vehicle Access Control Gatehouse

The gatehouse is located just west of, and connected at grade level to, the laboratory/office building on the south, and to the control building on the north. The gatehouse provides access control to the high security area, such that all personnel and vehicle access is granted through this building. All personnel proceeding through on foot to the control building or other areas within the high security fence pass through this gatehouse.

### **3.6.11 Utility Tunnels and Service Structures, and Site Improvements**

#### **3.6.11.1 Utility Tunnels**

Underground tunnels between buildings provide a protected route for cooling water piping, cryoline piping, electric power, communication services, instrumentation and control wiring, fibre-optic cables, and general services such as lighting, power, and fluids. The tunnels form a network around the site, with combination tunnels being internally segregated for protection of the services from each other.

The major use of the tunnels is for the ITER cooling system piping, going from the cooling tower basin to the tokamak building via a pumping distribution station, located just north of the site services building, and east of the tokamak complex. These pipe tunnels are equipped with sumps and sump pumps to collect rainwater and leakage, and to pump the water collected to the site storm drain system. For areas of the tunnels containing potentially contaminated water, any collected leakage is first sent to the radwaste building for confirmation of the acceptability of discharging the water.

The next major use is for electrical power. These tunnels link both the steady-state electrical power switchyard and the pulsed power switchyard on the west side of the site with the various buildings and electrical load distribution centres throughout the plant.

#### **3.6.11.2 Service Structures**

Electrical load centres are located inside or adjacent to buildings. Those adjacent to buildings require only a minimum structure to protect the equipment from the elements, and to provide an area for inspection and maintenance. Similar protection is required for the 3.3 kV power supply structures, and for the AC distribution building. In some cases, electrical power is transferred on bridge structures where the required access to a building is above grade.

Other systems require foundations for equipment or tanks, and, in some cases, include the concrete storage tanks themselves. Such service structures include:

- foundation pads for large helium storage tanks used by the cryoplant, for fuel tanks used by the auxiliary boiler, for fuel tanks associated with the emergency power supply, and for water tanks associated with the demineralised and potable water systems;
- a reinforced concrete potable water basin sized to provide for 3 days of makeup for demineralised water and potable water storage systems including fire-water reserve;
- a large holdup basin available for temporary storage of industrial sewage so that, if the sewage streams become contaminated, the industrial sewage can be held while corrective action and procedures for processing are established.

### **3.6.12 Specific Areas and Site Improvements**

Each of the ITER buildings includes appropriate outdoor lighting. In addition, the site infrastructure includes outdoor overhead lights. Lighting covers the switchyards, cooling towers, security fence, perimeter road, personnel and vehicle gate areas, and parking areas.

The assembly of the ITER tokamak involves the receipt and on-site handling of numerous large heavy objects. Site-fabricated PF coils, off-site shop-fabricated TF coils, vacuum vessel segments, and other tokamak parts, must be delivered to the tokamak buildings. For such purposes, there are wide paved areas to the south of the tokamak building. There is also a wide, heavy duty transport path able to move the site-fabricated coils from the east end of the coil fabrication buildings to the south entrance of the tokamak hall. The pathway is smooth enough for heavy haul vehicles, and has sufficient surface drainage. Also, there is a temporary building to the south, designed for the fabrication of the cryostat sections.

### **3.6.13 Internal Communications**

A site-wide internal communication system is provided in most buildings, including telephone connections, public address system, and appropriate warning systems for plant emergency, crane movement, fire, radiation monitoring, access control, etc. In addition there will be dedicated intercommunication systems between the control room and important plant locations and access control points.

### **3.6.14 Fire Protection**

The fire protection strategy at ITER is that the building materials and installed components make extensive use of non-flammable or low-flammable materials, such as concrete, steel, and fire retardant cable insulation, etc. Nonetheless, the buildings and structures provide fire detection, alarm, and mitigation systems commensurate with the occupancy and fire risk loading. There will be an on-site incident response team which will be able to carry out fire-fighting duties. This team will be supplemented by off-site emergency services as required.

### **3.6.15 Assessment of Design**

The design of the ITER site and buildings has progressed in a varied manner across the site. Those buildings that are involved with the tokamak machine, that house the systems and the components that interact directly with the machine, that are required for close support of the tokamak machine, have received the greatest degree of attention. These buildings, in order of highest degree of design completion to lowest, are the:

- tokamak building;
- tritium, vacuum, fuelling and services building;
- hot cell building;
- low level radwaste building;
- personnel access control building.

Other buildings which are also associated with the above, have received preliminary and detailed design attention, but will need to be studied further, include:

- laydown, assembly, and RF heating building;
- diagnostic building.

The rest of the buildings have received only preliminary design attention.

The site and building structures, except for the nuclear-related buildings, are relatively conventional in design and construction technology for industrial buildings. There are no site or building problems with these buildings that require extraordinary efforts.

### 3.6.15.1 Tokamak Building

#### *General Layout*

The tokamak building provides a minimum size layout for the contained systems and equipment. This results in column spans and room heights in non-standard dimensions. A final site-specific design might well incorporate some standardisation in these areas, where possible.

In addition, some size constraints may be relieved by adopting special forms of concrete: in areas where shielding thicknesses govern the building size. Floor thicknesses could be reduced by the use of high density concrete (with a density of  $3.5 \text{ t/m}^3$ ), rather than normal density concrete ( $2.5 \text{ t/m}^3$ ), thus allowing an increase in room height of approximately 285 mm. This extra space could be taken up, if necessary, for fitting extra services, especially the HVAC ducting and any required cable trays, in the space above the cask travel paths. However, the present layout, which does not use heavy concrete, is found to provide sufficient space for all services and utilities within the building.

#### *Structural – Seismic Verifications*

In areas where special strength properties are required, high performance concrete or the use of a larger fraction of steel might still allow for some relaxation of column, beam, floor or wall thickness. With the present thickness and design, walls and floors are generally close to the allowable stresses, especially for the design basis earthquake.

The tokamak complex has been analysed by the JA HT, and the study concludes that the combined tokamak and tritium building will behave satisfactorily during the design basis seismic event. The evaluation showed:

- the maximum response shear stress at the shear wall is within the allowable value;
- the maximum response axial stress at the wall is  $4.0 \text{ kg/cm}^2$  (EL- 5.25m), and the building has enough strength to resist this;
- even when vertical seismic motion is considered, the contact pressure is 100% at the NS-direction and the EW-direction;
- the maximum contact pressure at the bottom of the foundation is  $90.4 \text{ t/m}^2$  (NS-direction) and  $80.5 \text{ t/m}^2$  (EW-direction), and is well within the short-term allowable bearing capacity,  $130 \text{ t/m}^2$  (which comes from twice the maximum soil bearing capacity for the generic site).

If it proves necessary to protect the tokamak complex from large seismic forces, the building will be placed on seismic isolation bearings.

#### *Structural – Containment Volume Overpressure Verifications*

Current calculations, using self weight and component weight, combined with the load imposed by an internal overpressure of 0.1 MPa as loading conditions, predict that surface cracks will appear at certain sections of the concrete structure. The main cracking occurs at corners and in the middle of side walls (predominantly TCWS vault, vertical pipe shafts and slabs of NB cell). These cracks are caused by tensile stresses due to bending, and hence occur mainly at the external surfaces of the walls and slabs loaded by the internal pressure. Additionally, cracking is likely at the internal surfaces at or near corners where walls meet floors, ceilings or intermediate floors and where pillars interface with slabs. The crack depth

remains small relative to the slab thickness, and therefore the predicted surface cracking has no consequences for the structural integrity and acceptance of the building design. It may only matter for licensing the vault as a containment volume, which must therefore have a high degree of leak tightness.

For CANDU reactors, pre-stressed concrete vacuum buildings are designed and constructed to contain steam pressures arising from a postulated LOCA event. Their design is based on limiting surface cracking during the LOCA to such values that the internal liner can “bridge” the cracks and maintain a seal against leaks. The combination of a glass fibre and epoxy liner was developed for this purpose restricting the crack width to 0.2mm. In the ITER case, the calculation predicts cracks up to 0.5mm in width for concrete with rebar.

There are a number of possible measures under consideration to decrease or eliminate the possibility of concrete cracks or effects of cracks due to low-probability accidental events, as indicated below. A decision on their possible use can be expected as part of site licensing considerations, when more detailed analysis will be available on crack occurrence and characteristics.

#### Reinforced Corners

External or internal reinforcement or a combination of both may be applicable to reduce the stress concentration at corners. External reinforcement is easily achieved by increasing the corner radii, or increasing (locally) the slab and wall thickness. Reinforcement internal to the concrete is possible using special structures connected firmly by welding or other means to the rebar structures in slabs and side walls. Such measures are neither expected to cause feasibility problems nor add substantial cost.

#### Prestressed Concrete

This method uses special cables and ducts embedded in the concrete, with large tensioning bolts/nuts at one or both ends to apply additional compressive stresses to the concrete structure, thereby reducing or eliminating the tension stress and as a result eliminating the predicted concrete cracking.

Due to the complexity of the current structures, it may be difficult to incorporate this method of construction. However, by concentrating on certain connections between the TCWS Wall and the various floors, and allocating sufficient space for the tensioning cables and end-point mechanisms, the strength of the concrete structures in these areas is expected to be able to be increased sufficiently to eliminate the cracking.

#### Special Concrete Mixes with Rebar, Fibre and Cement

Certain matrix combinations of short fibres (e.g. graphite, aramid, vinylon, or steel), concrete and rebars are possible in tokamak building structures to provide strength to weight ratios greater than current concrete mixes. In addition, the fibres make the cracks small but numerous. An R& D program would be needed to further investigate suitable mixtures and resulting behaviour under postulated stress conditions.

### Multiple Surface Layers of Epoxy Liner + Flexible Coatings

This approach would use the current concrete mixtures but apply a viscous, semi-plastic, deformable layer of appropriate organic substances, on top of concrete, then cover it with fiberglass-epoxy liner. Even if cracks were to occur in the surface, they would be covered over, or “healed” with the deformable layer. An R& D program would be required, to investigate feasibility, costs, and schedules.

### Steel liner

Applying and attaching a flexible thin steel liner to the inside of the confinement volume concrete would prevent leakage into and through any postulated cracks in the concrete. Considerable design changes would be required, both for attaching the liner, as well as construction sequencing, and subsequent testing. This method would be expensive.

#### 3.6.15.2 Tritium, Vacuum, Fuelling, and Services Building

The tritium plant building and its equipment is being designed by home team effort, using a conventional two-dimensional approach, and has not yet been incorporated into the ITER standard building 3-dimensional models. Likewise, the other equipment, such as the vacuum pumping systems, the fuelling systems, and HVAC, have not been modelled in 3-D space, which is planned for the next phase of work.

The building drawings have been prepared to show these minimal dimensions, which results in column spans and room heights in non-standard distances. A final site-specific design might well incorporate some standardisation in these areas, where possible.

#### 3.6.15.3 Laydown, Assembly and RF Heating Building

The detailed analysis for this building is yet to be done, but initial indications are that the building supports appear to be suitable for these loads.

The tokamak assembly has imposed stringent requirements on maintenance of temperature within  $\pm 2^{\circ}\text{C}$  in the areas where the large components are to be assembled, and in the tokamak pit as well. A conceptual HVAC design meeting this requirement has been completed.

Once the tokamak assembly has been completed, the RF power supplies will be installed on the basemat, and a non-magnetic mezzanine will be installed to support the RF H&CD generators. A preliminary layout of the RF H&CD equipment has been prepared, with detailed design of the internal structure to be done in the next phase.

#### 3.6.15.4 Hot Cell Building

The hot cell building has been reduced to the minimum possible size, dictated by the necessary RH operations that are required to be performed in the building, according to the maintenance requirements. Further, to minimise the amount of tritiated water generated because of air leakage, the leak-tightness of the building must be verified by detailed design, with the same attention to penetrations as is required for the containment volume.

#### 3.6.15.5 Personnel Access Control Building

The personnel access control building has been reduced to the minimum, with minimum-sized laundry facilities, relying instead on external laundry contractors. Such a plan may be problematic because of the potential for Be contamination, so further investigations are required.