ITER SITE PLAN AND TOKAMAK BUILDINGS

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ABSTRACT

This paper describes the ITER Site Plan and Tokamak Buildings design completed during the Engineering Design Activity (EDA). The Site Plan evolved from the development of the ITER Site Requirements and Design Assumptions which is one of the EDA deliverables. Additional features of the Site Plan were the result of building designs and the routing of services for the operation of the tokamak and its support systems. The focal point of the Site Plan is a cluster of buildings referred to as the Tokamak Buildings. At the center of this cluster is a deeply embedded cylindrical pit that contains the tokamak in a cryostat. The superstructure of the building is a large rectangular crane hall which is used to assemble the tokamak and some of the attached support equipment. The Tokamak Pit and superstructure are supported by, and structurally integrated with, the Tritium Building on the east and the Electrical Termination Building on the west.

INTRODUCTION

The International Thermonuclear Experimental Reactor, (ITER) is in the final year of the EDA. This six-year design project is an excellent example of how international cooperation can overcome technical and managerial challenges in a high technology environment. The EDA is significantly situated in the Pacific Rim with the location of two of its three design offices, San Diego, CA and Naka, Japan in this region. Furthermore, while the EDA is due to end in July 1998, negotiations are underway to extend the EDA for three years pending a site and construction agreement early in the 21st Century. If there is a decision to construct ITER early in the next century, if will have a strong Pacific Rim participation regardless of where it is sited.

One objective of the EDA was to establish a set of compulsory site requirements so that any parties wishing to offer a site could assure the proposed site was viable and attractive for ITER. These compulsory requirements were restricted to the minimum number that were necessary to meet the ITER mission and objectives. In 1996 key requirements concerning land area, geotechnical characteristics, electrical and water supplies, heat sink and transportation/shipping capabilities were issued in ITER EDA Documentation Series No. 9. This document also contains a set of assumptions about the site which were necessary for the design of buildings, power supplies and other site-sensitive features of the ITER Plant. These assumptions are not compulsory and were selected to be in the intermediate range of values, giving designers neither excessively harsh nor mild site design conditions. The designers were instructed to select designs that could be adapted to harsher or milder conditions at the actual ITER Site. As will be seen later, this was a major determining factor in the strategy for anti-seismic design of the Tokamak Buildings.

ITER SITE PLAN

The ITER Site Plan was developed as an iterative process, starting with the ITER Site Requirements and Design Assumptions and updating the plan as buildings and services became better defined. A set of layout criteria were used to optimize the location of buildings and services. The Tokamak Buildings were located close to the geographic center of the site to optimize the performance of the tall exhaust stack. All buildings and services that are predominately involved with water and other fluid systems were located to the east of the Tokamak Buildings. All buildings and services that are predominately electrical power systems were located to the west of the Tokamak Buildings. The area to the south of the Tokamak Buildings was dedicated to movement of people and non-radioactive material on and off the ITER Plant site. The area to the north was reserved for construction activities and radioactive shipments. As electrical and fluid services converge on the Tokamak Buildings it becomes increasing difficult to adhere to the layout criteria and some exceptions were allowed. However, the overall plant layout adheres to the layout criteria.

A number of other factors influenced the location and orientation of buildings outside the Tokamak Buildings. Interfacing systems and functions required some buildings to be located close to the Tokamak Buildings. The length and number of bends in RF waveguides for plasma heating systems are good examples. The uncertainty in the designs for some systems made it necessary to keep at least one side of some buildings unobstructed for future expansion, if required. Roadways and access space were inserted around buildings to ensure access for fire fighting vehicles, road cranes and other heavy equipment. Large roadways were placed at the north and south entrances to the Tokamak Crane Hall for initial assembly, decommissioning and dismantling activities. The Site Plan can be seen in Figure 1 below:

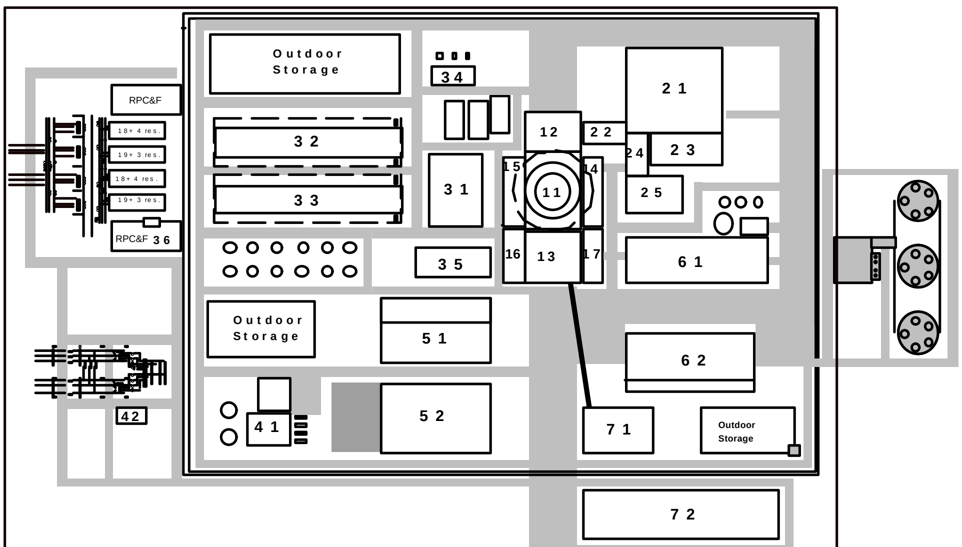

Figure 1

The land area within the outermost rectangle is about 70 hectares as defined in the Site Requirements. The cooling towers on the east side of the Plant are outside the compulsory site area because cooling towers are a design assumption and not a site requirement. Mechanical draft cooling towers were assumed because they provide a basis for cost estimates that should be adequate for most sites.

Table 1 The numbers on the building footprints in the Site Plan were assigned by region on the site. Some numbers have been reserved for new buildings that might be added later in the project or operating life of ITER. The numbers identify the buildings as follows:

Building No.	Building Name	Footprint Area (m2)
11	Tokamak Hall & Pit	5,630
12	Laydown Hall	2,690
13	Assembly Hall	3,580
14	Tritium Building	1,670
15	Electrical Termination Building	1,670
16	West Tokamak Services Building	1,220
17	East Tokamak Services Building	1,220
21	Hot Cell Building	8,430
22	Tokamak Access Control Building	1,300
23	Radwaste Building	1,440
24	Personnel Access Control Building	1,260
25	Personnel Building	2,400
31	Magnet Power Supply Switching Bldg.	4,440
32	North Magnet Power Conversion Bldg.	6,000
33	South Magnet Power Conversion Bldg.	6,000
34	NBI Power Supply Building	720
35	RF Heating Power Supply Building	2,500
36	Pulsed Power Switchyard Building	380
41	Emergency Power Supply Building	3,620
42	Steady State Power Switchyard Building	270
51	Cryoplant Cold Box/Dewar Building	8,030
52	Cryoplant Compressor Building	10,350
61	Site Services Building	8,300
62	PF Coil Fabrication Building	7,690
71	Control Building	2,880
72	Laboratory Office Building	5,500

TOKAMAK BUILDINGS

Buildings 11 through 15 form a structurally linked cluster of buildings called the Tokamak Buildings because these building are all directly involved in the assembly and operation of the tokamak. Buildings 11, 12, and 14 also have a public and worker radiological safety role. All of these buildings are cast-in-place, reinforced concrete structures with the ability to resist loads imposed by all assumed meteorological and seismic conditions.

The first function of the Tokamak Buildings is to provide space and permanently installed equipment for efficient assembly of the tokamak. Studies performed early in the EDA established the concept of a deeply embedded pit to contain the cryostat and tokamak with an elongated rectangular crane hall over the pit. This arrangement allows heavy components to enter the building from roadways at both ends of the crane hall. Sufficient space was provided adjacent to the pit to allow preassembly of sections of the machine after which they can be lifted and lowered into the pit. Two 750 t capacity bridge cranes travel the length of the crane hall. These cranes can be combined with a lifting fixture to lift up to 1500 t for the very heavy, preassembled parts of the tokamak. All the major dimensions of the building superstructure were set by these requirements.

During operation some of the Tokamak Buildings provide public and worker radiological protection through a combination of shielding for direct radiation and confinement of radioactivity by ventilation systems. Some of the rooms in the Tokamak Pit prevent the spread of radioactivity with containment structures during certain energetic events such as Loss of Coolant Accidents (LOCA). These rooms are isolated from other building ventilation systems and are able to resist over pressurization to a level defined by analysis of the events.

After a number of tokamak pulses using deuterium-tritium fuel mixtures, the internal components of the machine are expected to become activated to a level that conventional, hands-on maintenance will not be possible for some of the work. If it is necessary to remove plasma facing components (PFC), remote controlled handling and transport systems will be required. The Tokamak Pit must accommodate these systems and provide shielding for adjacent work areas because shielded transfer casks would be too heavy to be supported by the building floor slabs.

Some Tokamak components are very difficult to remove and replace if they fail. TF and PF coils, vacuum vessel segments and port extensions are examples of components that are not expected to fail during the operational life of ITER, but must be replaced if an unexpected failure occurs. The building design was evaluated and adjusted such that these difficult maintenance jobs could be performed without significantly altering the building structure.

Another requirement that greatly influenced the design of the buildings was the need to have certain tokamak support systems close to the machine. Primary heat transfer systems and magnet coil power feeds are two examples. Once the equipment was located, the fluid and electrical services had to be routed to the equipment from external sources. After the equipment space was allocated, heating, ventilation and air-conditioning (HVAC) ducts and air handler units had to be positioned within the remaining space.

As the buildings were analyzed for external events, it was clear that these loads would be bounded by the seismic events within the Site Design Assumptions. Furthermore, the design had to be able to accommodate more severe earthquakes if a site with high seismicity were selected. The public and worker safety functions could be accommodated by simply making the buildings stronger with better anchoring and bracing of critical components. However, analysis showed that the tokamak could not withstand high seismic forces and attempts to strengthen the tokamak were made difficult because of excessive heat transfer through support structures for the superconducting magnets at temperatures near 4.2 °K.

In order to protect the large investment in the tokamak, a detailed trade study (Dilling, et al., 1995) was conducted on various ways to implement seismic isolation, if required. The results of the study established a concept of partial seismic isolation for the pit portion of the building. Analysis showed that the tokamak and all directly attached equipment would be protected and no changes to the machine or equipment layout in the pit would be required. The building cost increase, while significant, is acceptable. The transition between isolated and unisolated portions of the Tokamak Buildings requires a gap of about 1 m between adjacent walls and slabs to allow differential motion and access for construction. Equipment and services crossing this gap would be subject to displacements proportional to the degree of seismic loading. A feasibility study was conducted on each type of equipment and service crossing the gap and it was concluded that a design to accommodate the displacements was possible.

Figure 2 shows the plan view of the Tokamak Buildings at grade and Figure 3 shows an east-west section through the vertical centerline of the pit. The major features and dimensions of the buildings can be seen. The seismically isolated alternative design is shown in Figure 4.

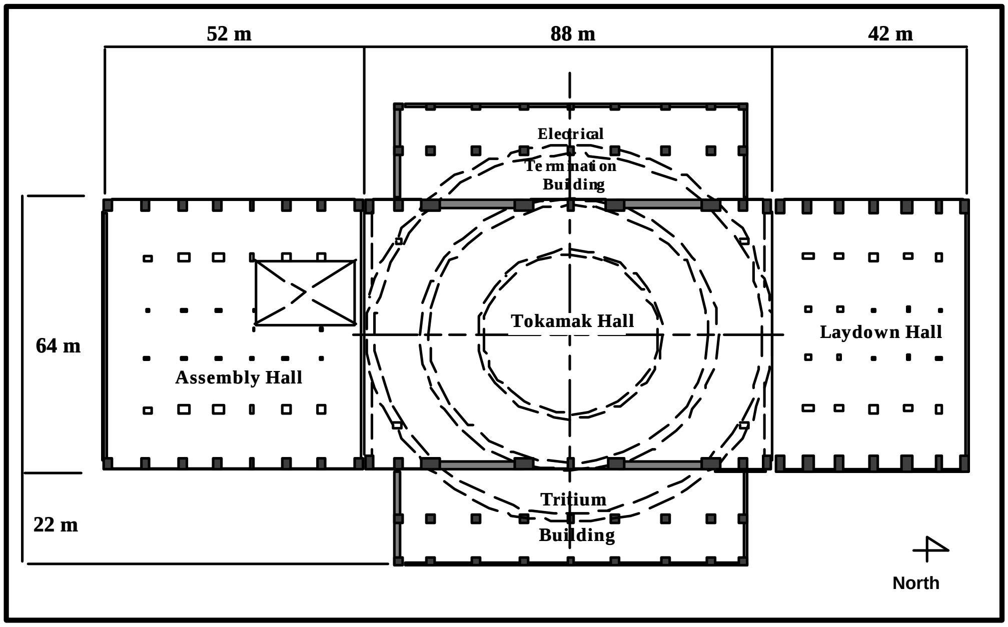

Figure 2

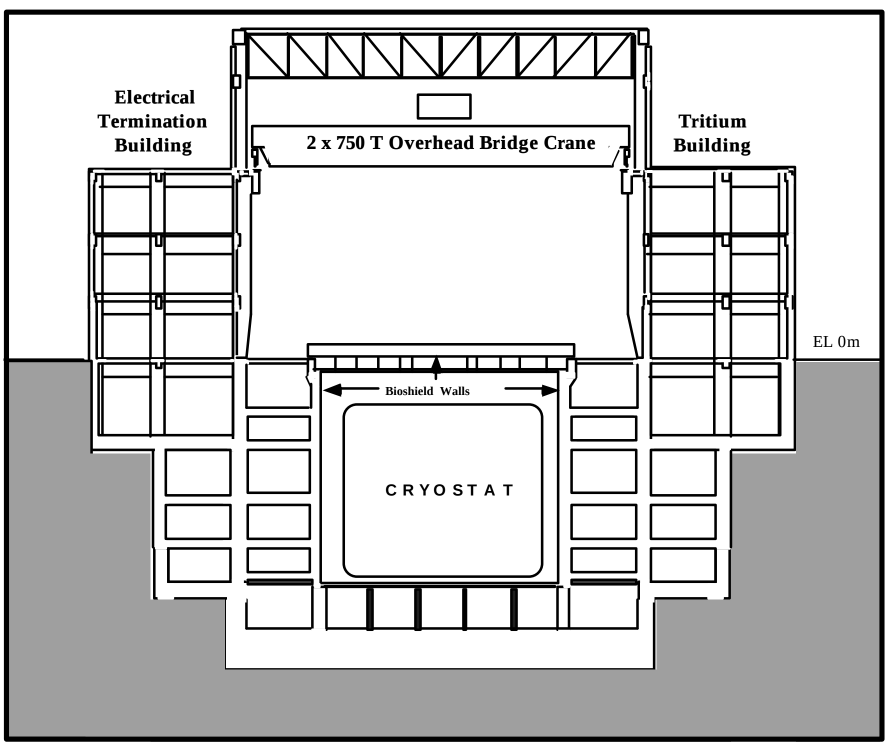

Figure 3

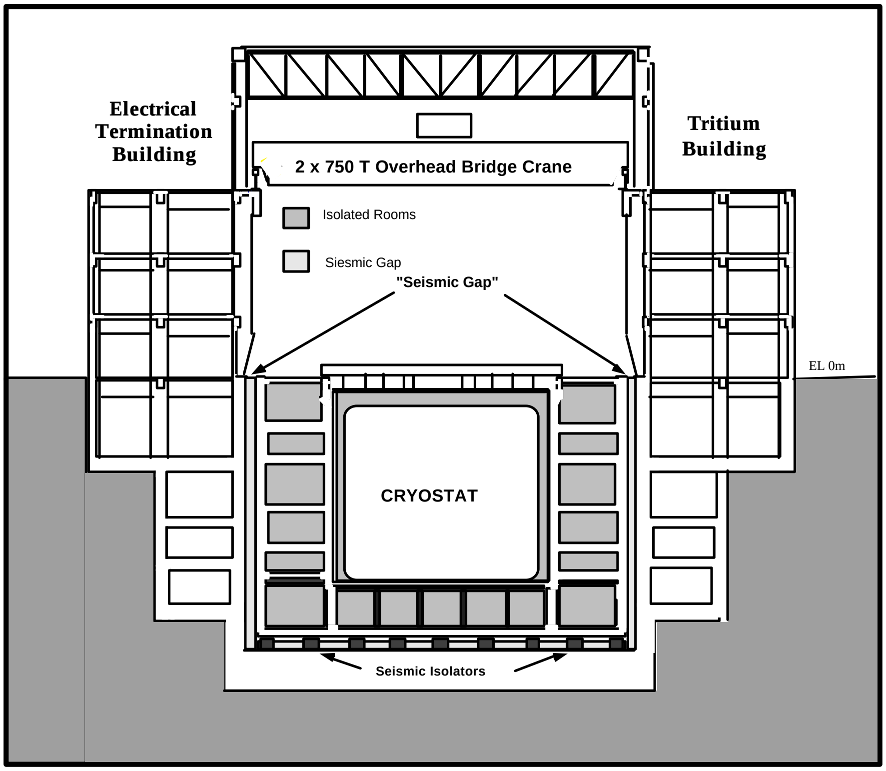

Figure 4

EQUIPMENT LAYOUT

The adequacy of the Tokamak Buildings to perform their functions could not be established with confidence until all major pieces of equipment and services were allocated space in the buildings and interferences were eliminated. Therefore a major collaborative effort amongst the ITER Joint Central Team (JCT) was undertaken in the last three years. The work was accomplished by starting with a three-dimensional CAD graphics model of the Tokamak Buildings rendered with the Catia (IBM Dassault) system. As equipment models were completed in this CAD system, they were merged into the building models such that interferences could be detected and eliminated. Similarly, services and HVAC were merged into the model. Early in the process, several adjustments were made to the buildings and the equipment and service layouts were iterated until a satisfactory solution was obtained. Minor changes continue to be made to the buildings, but at this point these adjustments do not change major dimensions or equipment layout.

The complexity and level of detail in the merged 3-D models makes it impossible to properly illustrate the equipment layout in 2-D figures. All layout work is done at workstations where engineers have the ability to view and adjust the models in 3-D. Recently it has become possible to simplify the 3-D models such that the work station operator can “navigate” through the building along desired pathways. By adjusting the viewpoint and recording these images to videotape, a “walk through” of the building with its equipment and services in place can be reviewed by a group of engineers and managers in a conference room. This capability has been very valuable in assessing the adequacy of the building and equipment layout with respect to initial tokamak assembly and maintenance of the major pieces of equipment. Maintenance scenarios have been modeled to the extent that models of workers and their tools and equipment can be included to verify maintenance accessibility.

3-D models have also been extremely valuable for locating stairwells, lifts and passages for workers and moveable equipment at all levels and areas in the buildings. For safety reasons, at least one and sometimes more alternative exits have been provided from each major equipment and work area.

Figure 5 is a partial section isometric view of the pit and gallery area of the Tokamak Buildings. Major pieces of equipment and large bore pipe are visible in the section view. Other services and small equipment are not visible when such large scale models are reduced to page size. Indeed, our ability to model structures and equipment, both large and small, has progressed to the point that they can only be viewed in detail with electronic media rather than paper. Discrete portions of the model can be extracted in 2-D form for paper prints that must be taken into the plant for maintenance or verification purposes.

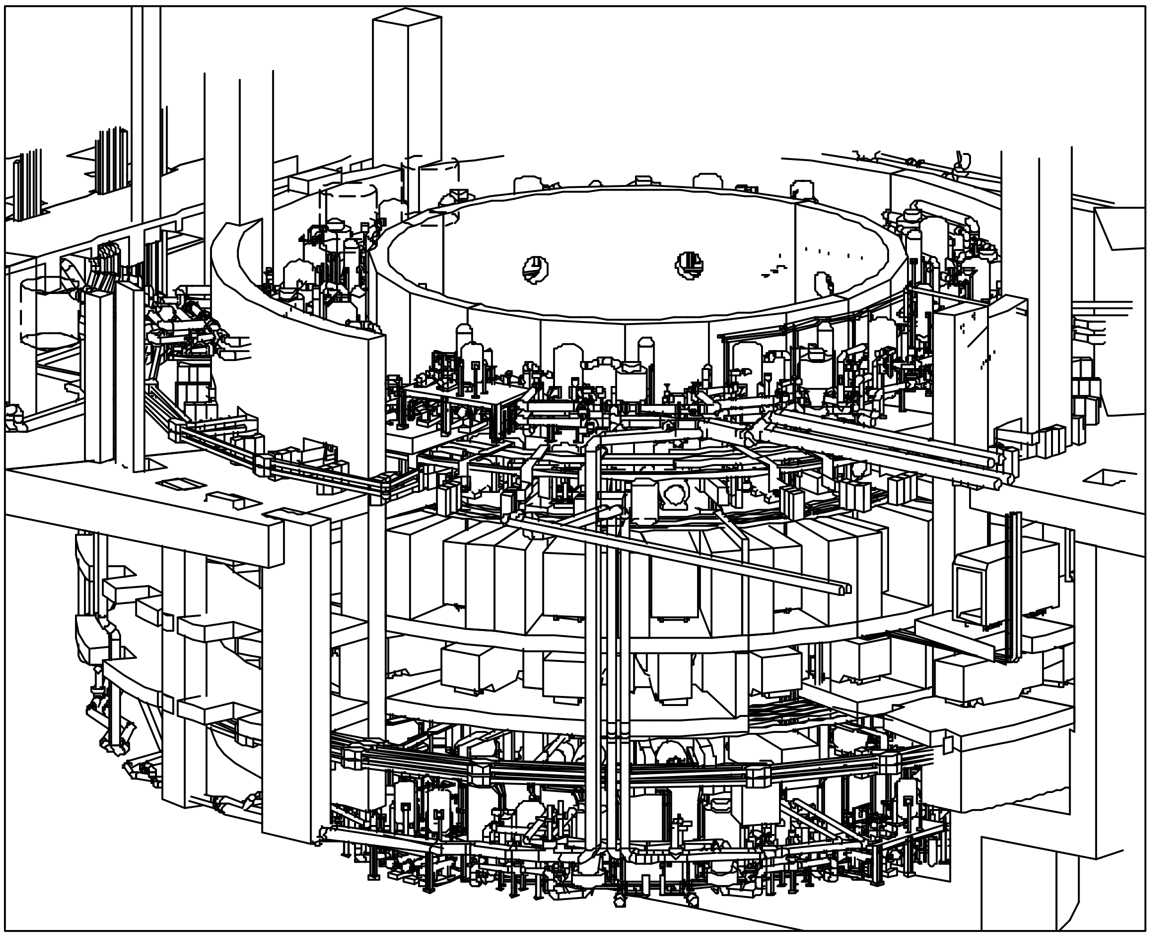

Figure 5

CONCLUSIONS

The ITER Site Plan and the related Site Requirements and Design Assumptions provide a set of useful references for any party wishing to offer a site for ITER. The Site Plan has established a layout of buildings and services that may be readily adapted to flat, unobstructed sites. Sites with a more difficult topography may require cuts and fills or rearrangement of some of the buildings, but significant segments of the site plan should be usable. The site plan also demonstrates that the Site Requirements have been reduced to reasonable levels while avoiding congestion and undesirable operating characteristics.

The Tokamak Buildings have been demonstrated to meet all functional requirements for all phases of the ITER project from tokamak assembly, commissioning and operation to final decommissioning and dismantling of the plant. The buildings have been analyzed sufficiently to establish their resistance to all internal and external loads identified in the EDA. The buildings have features which allow modifications to resist significantly higher seismic loads, without changing the general building geometry or equipment layout.

The adequacy of the size of the buildings has been confirmed by the 3-D modeling of equipment layout. The merged 3-D models have also built confidence that initial tokamak assembly and major maintenance can be accomplished with reasonable efficiency.

ACKNOWLEDGMENTS

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KEY WORDS

ITER, tokamak, site plan, site layout, Tokamak Buildings, equipment layout, CAD models**.**