ITER Generic Diagnostic Components and Arrangements

C.I. Walker[1], A.E.Costley[2], K. Itami[2], T.Kondoh[2], A.Malaquias[3], T.Sugie[2], G.Vayakis[2]

[1] *ITER International Team, Garching Joint Work Site, 85748 Garching, Germany*
[2] *ITER International team, Naka Joint Work Site, Ibaraki, 311-0193, Japan*
[3] *Instituto Superior Tecnico, EURATOM/IST, CFN, Lisboa, Portugal.*

Introduction

The ITER diagnostic system integrates 45 plasma parameter measurements from 40 diagnostic systems. Equipment for these diagnostics is integrated in 6 equatorial ports, 15 upper ports, 15 divertor cassettes and in all sectors of the vacuum vessel. Some standardization of the main engineering elements is required for R&D, design, fabrication, testing, handling services, maintenance. This is done for components and systems that are not dependent on particulars of the diagnostic, are repeated, specialist, or that have common interfaces with other Tokamak systems. To date, most of the reported diagnostic design has concentrated on achievement of acceptable diagnostic performance and establishing feasible integration concepts, within the constraint of the available space, environment etc. The engineering design of the generic systems has advanced along with this, where it has been necessary to establish feasibility, define spatial limits, generate cost estimates and schedule interfaces. So far approximately 15 generic engineering arrangements have been identified within the final design report (FDR) and procurement packages. Some of the engineering aspects are described here.

Generic Systems at Port Sites

Each equatorial and upper port incorporates a blanket shield module (BSM) and a port plug structure with an integral port seal (Figs 1 & 2). These are generic in nature and their design is common for all ports. Dedicated diagnostic-shielding modules are fitted into the plug structures within the primary vacuum. Interspace structures on plug flanges and biological shields are standardised as far as possible, but tend to reflect the specific needs of the diagnostics, as do the biological shield plug, with labyrinth channels.

At the divertor level, cassettes incorporate mirror mounts, sensors and waveguides. Diagnostic channels are sealed through shielding to the port and diagnostic racks are mounted in the port and structures on the port flanges.

At all three access levels to the torus a common approach is used for windows, feedthroughs and signal and service connections on the primary vacuum boundaries. These are chosen from a limited set of standard elements. A guard vacuum arrangement will be incorporated on windows for testing in situ.

Vacuum leak testing and surveying and remote maintenance will generate further standardized solutions with their own generic systems.

In most port cells, dedicated equipment is made removable by using a standard diagnostic cask. When removed, this allows access to the port. Ex-vessel services leave the cell with the diagnostic transmission lines through standard penetrations above the cell door, which is required as part of the release confinement approach.

Port Plug Design Features

Each port plug combines common, generic, structural elements with dedicated modules from several diagnostics. The engineering design considers the spatial combination of several diagnostic systems, and the applied environment of electromagnetic load, radiative heating, and arcing, erosion and deposition near the plasma. Nuclear radiation effects on electrical properties, neutron streaming, and activation, are important at all in-vessel locations. Manufacture, assembly, maintenance and regulatory safety considerations shape the final design solution. Specific technological issues for ITER are the provision of adequate neutron shielding and the removal of bulk gamma and neutron heat to ensure the thermal stability of near-plasma diagnostic equipment.

Port plugs are stainless steel welded fabrications, typically 120mm thick, drilled with water-cooling channels. This structure serves as a primary vacuum boundary, neutron shielding [1] of the port, as well as a stable support and a coolant manifold for the replaceable diagnostic-shielding modules. There are therefore common interfaces with the port flange seal, the blanket shield module, the diagnostic equipment, even where diagnostic elements differ geometrically (Fig a & b), and maintenance tooling.

The hydraulic design of the port plugs have been analysed (see Table 1). Inlet water at 100°C, 4 MPa, must be returned at ≤150°C, > 3MPa. The overall pressure drop in for the equatorial port plug, ~ 0.8 MPa, is dominated by the feed pipe impedance. Feed pipes 69mm bore (76mm OD) are chosen. The pressure drop in the BSM, with its 38 parallel paths, is only ~4% of the total. The individual differences of flow geometry, because of specific diagnostic apertures, is immaterial to the overall flow resistance. It is necessary to balance the flows in these paths, to avoid coolant starvation and possibly burn-out of individual BSM slices. The BSM flow design has been modified with the upper and lower halves split internally, irrespective of aperture requirements. This avoids the need for narrow flow restrictors with high local velocity and potential for blocking, has the advantage of reducing the e-m forces, minimizes the tendency for out-of-plane bowing and simplifies fabrication. The local velocity in the first wall channels is ~4.5 m/s , Re = ≈ 2.5×10^5. The heat transfer coefficient and consequently the BSM temperatures have still to be assessed.

The electromagnetic loads appearing on the BSM, and transferred to the plug structure, dominate structural design. Articulated supports allow expansion of the BSM without undue thermal stresses. The maximum loads seen for any ITER condition are given in Table 2.

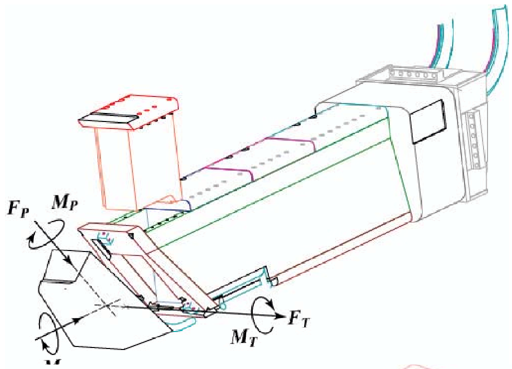

Figure 1 Upper Port Plug

Table 1 Port Plug Components and Hydraulics

	Vol	A) Mass	B) Neutron wall load	B) Heating	C) max specific heating	Total Flow
Upper Port Plug	1.14m (*pol*) x 1.15 (*tor*) x 5.9m *(rad)*					5.2
BSM (3 supports)	1.23 m (*pol*) x 0.53m (*tor max*) x 0.44 m *(rad)*					
	0.23	1.53	~ 0.56	1100	7500	5.2
Structure	1.86	12.1				
Module A	0.30	1.95		D) 7.6	400	E)
Module B	0.46	3.04		D) 1.0	0.38	E)
Module C	0.46	3.04		D) 0.1	0.10	E)
Plate D	0.07	0.46				
Plug beyond modules				0.06	0.04	
Rear Plug Walls & Flange				0.02	<0.01	
Equatorial Port Plug	2.1m (*h*) x 1.8m (*w*) x 3.5m (*l*)					20.2
BSM (4 supports)	2.01m (*pol*) x 1.74m (*tor*) max x 0.6 m *(rad)*					
	1.754	11.52	~ 0.8	4300	11000	20.2
Structure	2.88	18.9				
Module A	1.50	9.86		D) 30.0	600	E)
Module B	1.22	8.02		D) 4.0	0.6	E)
Module C	1.63	10.7		D) <.01	0.06	E)
Plug Flange				-	0.01	
	m^3	tonne	MW/m^2	kW	MW/m^3	kg/s

A) Nominal water filled weights: 80%steel: 20%
B) For Fusion Power 500 MW. Values x 1.4 for maximum fusion power of ~700 MW
C) Accounting for possible ~80mm wide vertical slot in the blanket
D) Including adjacent structure E) Variable, still to be defined

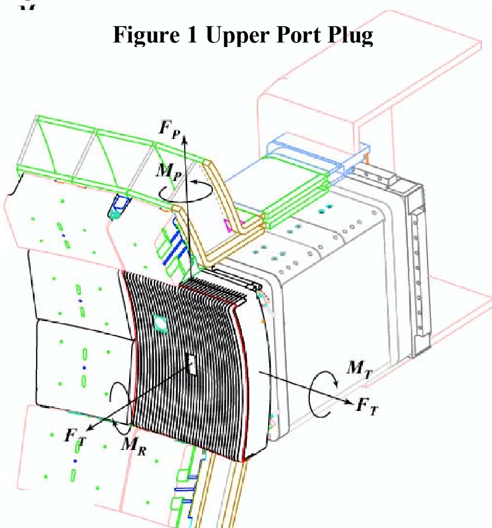

Figure 2 Equatorial Port Plug

Table 2 Blanket Shield Module e-m Loads

	Upper Port BSM	Equatorial Port BSM	
Eddy Current			
M_R	a) -102 kNm	c) -305 kNm	kNm
M_P	a) -286 kNm	b) -215 kNm	kNm
M_T	a) -55 kNm	c) -24 kNm	kNm
Halo Current			
F_P	a) 20 kN	no halo loads	kN
F_T	a) 3 kN		kNm

a) fast upward VDE, b) fast downward VDE, c) Major Disruption

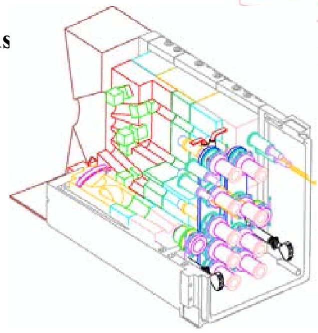

Figure 3 Details of Port Plug showing contents of modules and vacuum boundary elements

Generic Systems in the Divertor

On the divertor cassettes, and in the divertor-level ports, the diagnostic systems are more intricately combined with other machine systems. In the divertor ports, waveguides or optical elements utilize racks mounted on rails, and cabling from instrumentation on the cassettes is brought out to marshalling boards in the port cell.

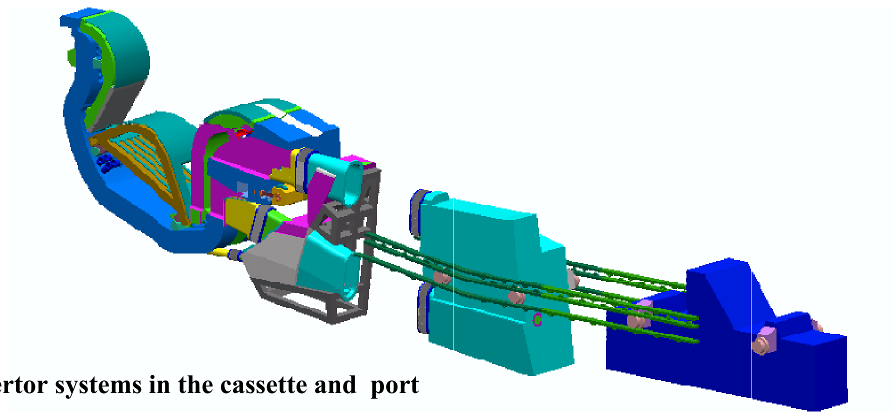

Figure 4 Divertor systems in the cassette and port

Systems on the Vacuum Vessel

On the vessel a full array of magnetic sensors is complemented by other diagnostic sensors and waveguides required to be close to the plasma or with a plasma view. Cabling and connections are common for many diagnostic sensors. The cables for all of these are rigidly mounted to the vacuum vessel to provide good thermal and mechanical anchors. They are brought out of the upper ports with mineral insulated feedthroughs.

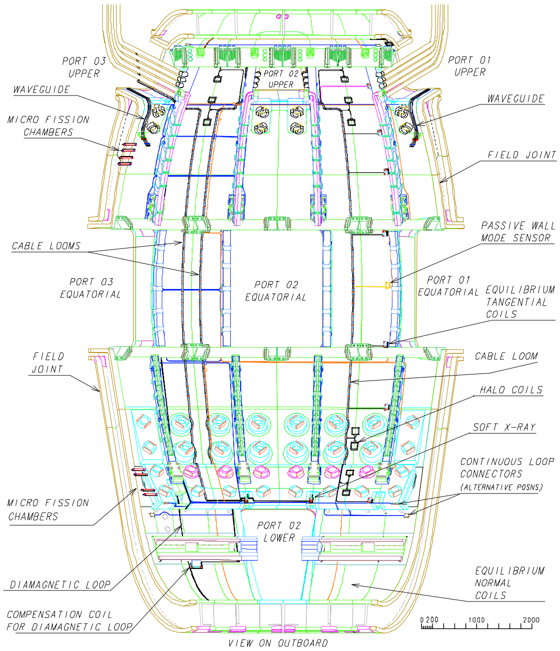

Figure 4 Diagnostic In-Vessel Cabling

Outside the Torus Hall

The test assembly at the hot cell maintenance area is a large, multi-purpose facility, used for acceptability and functional testing of diagnostic components before installation in the torus. Equipment of a generic nature, such as cubicles and cabling, is also found in the diagnostic area adjacent to the torus hall.

Conclusions

Elements of the diagnostic equipment reach into all parts of the tokamak. At each of these, they must follow the local design rules, and meet the demands of the particular environment there, independent of the diagnostic's own requirements. Design, procurement, safety, conformity, QA, configuration, RH tooling, waste disposal, testing, etc. of all equipment in any port cell will require a standardised approach, assisted by as much generic activity as possible. The identification of certain generic components and systems allows there to be a degree of sharing in the design, procurement and organisational tasks. Of course each area's system will be reviewed from the point of view of the actual elements there, a combination of these generic elements and many diagnostic components.

Acknowledgement

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References

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