

Attachment 4 Target Measurement Specification (ITER-FEAT) (as published in the Final Design Report)

MEASUREMENT	PARAMETER	CONDITION	RANGE or COVERAGE	RESOLUTION		ACCURACY
				Time or Freq.	Spatial or Wave No.	
1. Plasma Current	I_p	Default	0 – 1 MA	1 ms	Integral	10 kA
			1 – 17.5 MA	1 ms	Integral	1 %
		I_p Quench	20 – 0 MA	0.1 ms	Integral	30 % + 10 kA
2. Plasma Position and Shape	Main plasma gaps, Δ_{sep}	$I_p > 2$ MA, full bore	-	10 ms	-	1 cm
		I_p Quench	-	10 ms	-	2 cm
	Divertor channel location (r dir.)	Default	-	10 ms	-	1 cm
		I_p Quench	-	10 ms	-	2 cm
dZ/dt of current centroid	Default	0 – 5 m/s	1 ms	-	0.05 m/s (noise) + TBD % (absolute)	
3. Loop Voltage	V_{loop}	Default	0 – 30 V	1 ms	4 locations	5 mV
		I_p Quench	0 – 500 V	1 ms	4 locations	10 % + 5 mV
4. Plasma Energy	β_p	Default	0.01 – 3	1 ms	Integral	5 % at $\beta_p=1$
		I_p Quench	0.01 – 3	1 ms	Integral	~ 30%
5. Radiated Power	Main Plasma P_{rad}	Default	TBD – 0.3 GW	10 ms	Integral	10 %
	X-point / MARFE region P_{rad}	Default	TBD – 0.3 GW	10 ms	Integral	10 %
	Divertor P_{rad}	Default	TBD – 0.3 GW	10 ms	Integral	10 %
	Total P_{rad}	Disruption	TBD – 50 GW	3 ms	Integral	20 %
6. Line-Averaged Electron Density	$\int n_e dl / \int dl$	Default	$1 \cdot 10^{18} - 4 \cdot 10^{20} / m^3$	1 ms	Integral	1 %
		After killer pellet	$8 \cdot 10^{20} - 2 \cdot 10^{22} / m^3$	1 ms	Integral	100 %
7. Neutron Flux and Emissivity	Total neutron flux		$1 \cdot 10^{14} - 5 \cdot 10^{20} n/s$	1 ms	Integral	10 %
	Neutron / α source		$1 \cdot 10^{14} - 4 \cdot 10^{18} n/m^3/s$	1 ms	a/10	10 %
	Fusion power		TBD – 1 GW	1 ms	Integral	10 %
	Fusion power density		TBD – 10 MW/m ³	1 ms	a/10	10 %
8. Locked Modes	Br(mode)/Bp		$10^{-4} - 10^{-2}$	1 ms	(m,n) = (2,1)	30 %
9. Low (m,n) MHD Modes, Sawteeth, Disruption Precursors	Mode complex amplitude at wall		TBD	DC – 3 kHz	(0,0) < (m,n) < (10,2)	10 %
	Mode – induced temperature fluctuation		TBD	DC – 3 kHz	(0,0) < (m,n) < (10,2) $\Delta r = a/30$	10 %
	Other mode parameters TBD					
10. Plasma Rotation	VTOR		1 – 200 km/s	10 ms	a/30	30 %
	VPOL		1 – 50 km/s	10 ms	a/30	30 %
11. Fuel Ratio in Plasma Core	nT/nD	r/a < 0.9	0.1 – 10	100 ms	a / 10	20 %

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12. Impurity Species Monitoring	Be, C rel. conc.		$1 \cdot 10^{-4} - 5 \cdot 10^{-2}$	10 ms	Integral	10 % (rel.)
	Be, C influx		$4 \cdot 10^{16} - 2 \cdot 10^{19}$ /s	10 ms	Integral	10 % (rel.)
	Cu rel. conc.		$1 \cdot 10^{-5} - 5 \cdot 10^{-3}$	10 ms	Integral	10 % (rel.)
	Cu influx		$4 \cdot 10^{15} - 2 \cdot 10^{18}$ /s	10 ms	Integral	10 % (rel.)
	W rel. conc.		$1 \cdot 10^{-6} - 5 \cdot 10^{-4}$	10 ms	Integral	10 % (rel.)
	W influx		$4 \cdot 10^{14} - 2 \cdot 10^{17}$ /s	10 ms	Integral	10 % (rel.)
	Extrinsic(Ne,Ar, Kr) rel. conc.		$1 \cdot 10^{-4} - 2 \cdot 10^{-2}$	10 ms	Integral	10 % (rel.)
	Extrinsic (Ne, Ar, Kr) influx		$4 \cdot 10^{16} - 8 \cdot 10^{18}$ /s	10 ms	Integral	10 % (rel.)
13. Zeff(Line-averaged)	Zeff		1 – 5	10 ms	Integral	20 %
14. H-mode: ELMs and L-H Transition Indicator	ELM D _α bursts	Main Plasma	–	0.1 ms	One site	–
	ELM density transient	r/a > 0.9	TBD	TBD	TBD	TBD
	ELM temperature transient	r/a > 0.9	TBD	TBD	TBD	TBD
	L-H D _α step	Main Plasma		0.1 ms	One site	–
	L-H Pedestal formation (ne, Te)	r/a > 0.9	–	0.1 ms	–	TBD
15. Runaway Electrons	E _{max}		1 – 100 MeV	10 ms	–	20 %
	I _{runaway}	After Thermal quench	$(0.05 - 0.7) \cdot I_p$	10 ms		30 % rel
16. Divertor Operational Parameters	Max. surface temperature		200 – 2500°C	2 ms	–	10 %
	Real-time net erosion		0 – 3 mm	1 s	1 cm	10 %
	Gas pressure		$1 \cdot 10^{-4} - 20$ Pa	50 ms	Several points	20 % during pulse
	Gas composition	A = 1-100 ΔA = 0.5	TBD	1 s	Several points	20 % during pulse
	Position of the ionisation front		0 – TBD m	1 ms	10 cm	–
17. First Wall (FW) Visible Image & Wall Temperature	FW image		TBD	100 ms	TBD	–
	FW surface temperature		200 – 1500°C	10 ms	TBD	20°C
18. Gas Pressure and Composition in Main Chamber	Gas pressure		$1 \cdot 10^{-4} - 20$ Pa	1 s	Several points	20 % during pulse
	Gas composition	A = 1-100 ΔA = 0.5	TBD	10 s	Several points	50 % during pulse
19. Gas Pressure and Gas Composition in Ducts	Gas pressure		< 7 kPa	100 ms	Several points	20 % during pulse
	Gas composition	A = 1-100 ΔA = 0.5	TBD	1 s	Several points	20 % during pulse
20. In-Vessel Inspection	Wall image		100 % coverage of FW and divertor	–	1 mm	
21. Halo Currents	Poloidal current	In disruption	$0 - 0.2 I_p$	1 ms	9 sectors	20 %
22. Toroidal Magnetic Field	B _T		2 – 5.5 T	1 s	2 locations x 2 methods	0.1 %
23. Electron Temperature Profile	Core T _e	r/a < 0.9	0.5 – 30 keV	10 ms	a/30	10 %
	Edge T _e	r/a > 0.9	0.05 – 10 keV	10 ms	0.5 cm	10 %

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24. Electron Density Profile	Core N_e	$r/a < 0.9$	$3 \cdot 10^{19} - 3 \cdot 10^{20} / m^3$	10 ms	a/30	5 %
	Edge N_e	$r/a > 0.9$	$5 \cdot 10^{18} - 3 \cdot 10^{20} / m^3$	10 ms	0.5 cm	5 %
25. Current Profile	q(r)	Physics study	0.5 - 5	10 ms	a/20	10 %
			5 - TBD	10 ms	a/20	0.5
	$r(q=1.5,2)/a$	NTM feed-back	0.3 - 0.9	10 ms	-	5 cm / a
	$r(q_{min})/a$	Reverse shear control	0.3 - 0.7	1 s	-	5 cm / a
26. Zeff Profile	Z_{eff}	Default	1-5	100 ms	a/10	10 %
		Transients	1-5	10 ms	a/10	20 %
27. High Frequency Macro Instabilities (Fishbones, TAEs)	Fishbone-induced perturbations in B,T,n		TBD	0.1 - 10 kHz	(m,n) =(1,1)	-
	TAE mode - induced perturbations in B,T,n		TBD	30 -300 kHz	n = 10 - 50	-
28. Ion Temperature Profile	Core T_i	$r/a < 0.9$	0.5 - 50 keV	100 ms	a/10	10 %
	Edge T_i	$r/a > 0.9$	0.05 - 10 keV	100 ms	TBD	10 %
29. Core He Density	n_{He}/n_e	$r/a < 0.9$	1 - 20 %	100 ms	a/10	10 %
30. Confined Alphas	Energy spectrum	Energy resolution TBD	(0.1 - 3.5) MeV	100 ms	a/10	20 %
	Density Profile		$(0.1 - 2) 10^{18}/m^3$	100 ms	a/10	20 %
31. Escaping Alphas	First wall flux	Default	TBD - 2 MW/m ²	100 ms	a/10 (along poloidal direction)	10 %
		Transients	TBD - 20 MW/m ²	10 ms	TBD	30 %
32. Impurity Density Profile	Fractional content, $Z \leq 10$	$r/a < 0.9$	0.5 - 20 %	100 ms	a/10	20 %
		$r/a > 0.9$	0.5 - 20 %	100 ms	5 cm	20 %
	Fractional content, $Z > 10$	$r/a < 0.9$	0.01 - 0.3 %	100 ms	a/10	20 %
		$r/a > 0.9$	0.01 - 0.3 %	100 ms	5 cm	20 %
33. Fuel Ratio in the Edge	n_T/n_D	$r/a > 0.9$	0.1 - 10	100 ms	Radial integral	20 %
	n_H/n_D	$r/a > 0.9$	0.01 - 0.1	100 ms	Radial integral	20 %
34. Neutron Fluence	First wall fluence		0.1 - 1 MWy / m ²	10 s	TBD	10 %
35. Impurity and D,T Influx in Divertor	$\Gamma_{Be}, \Gamma_C, \Gamma_W$		$10^{17} - 10^{22}$ at/s	1 ms	5 cm	30 %
	Γ_D, Γ_T		$10^{19} - 10^{25}$ at/s	1 ms	5 cm	30 %
36. Plasma Parameters at the Divertor Targets	Ion flux		$10^{19} - 10^{25}$ ions/s	1 ms	0.3 cm	30 %
	n_e		$10^{18} - 10^{22} / m^3$	1 ms	0.3 cm	30 %
	T_e		1 eV - 1 keV	1 ms	0.3 cm	30 %
37. Radiation Profile	Main plasma P_{rad}		0.01 - 1 MW/m ²	10 ms	a/15	20 %
	X-point/MARFE region P_{rad}		TBD - 300 MW/m ²	10 ms	a/15	20 %
	Divertor P_{rad}		TBD - 100 MW/m ²	10 ms	5 cm	30 %
38. Heat Loading Profile in Divertor	Surface temperature		200 - 2500°C	2 ms	3 mm	10 %
	Power load	Default	TBD - 25 MW/m ²	2 ms	3 mm	10 %
		Disruption	TBD - 5 GW/m ²	0.1 ms	TBD	20 %

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39. Divertor Helium Density	n_{He}		$10^{17} - 10^{21} /m^3$	1 ms	–	20 %
40. Fuel Ratio in the Divertor	n_T/n_D		0.1 – 10	100 ms	integral	20 %
	n_H/n_D		0.01 – 0.1	100 ms	integral	20 %
41. Divertor Electron Parameters	n_e		$10^{19} - 10^{22} /m^3$	1 ms	10 cm along leg, 3 mm across leg	20 %
	T_e		0.3 –200 eV	1 ms	10 cm along leg, 3 mm across leg	20 %
42. Ion Temperature in Divertor	T_i		0.3 –200 eV	1 ms	10 cm along leg, 3 mm across leg	20 %
43. Divertor Plasma Flow	V_p		TBD – 10^5 m/s	1 ms	10 cm along leg, 3 mm across leg	20 %
44. n_H/n_D Ratio in Plasma Core	n_H/n_D		0.01 – 0.1	100 ms	a/10	20 %
45. Neutral Density between Plasma and First Wall	D/T influx in main chamber		$10^{18} - 10^{20}$ at/m ² /s	100 ms	Several poloidal and toroidal locations	30 %

Attachment 6

Proposed Revised Requirements for Divertor Measurements in ITER

Changes with respect to the FDR (see Attachment 4) are indicated in red.

MEASUREMENT	PARAMETER	CONDITION	RANGE or COVERAGE	RESOLUTION		ACCURACY
				Time or Freq.	Spatial or Wave No.	
16. Divertor Operational Parameters	Max. surface temperature		200 – 2500°C	2 ms	–	10 %
	Erosion rate		1 - 10 µm/s	2 s	1 cm	30 %
	Net erosion		0 – 3 mm	Per pulse	1 cm	12 µm
	Gas pressure		1·10 ⁻⁴ – 20 Pa	50 ms	Several points	20 % during pulse
	Gas composition	A = 1-100 ΔA = 0.5	TBD	1 s	Several points	20 % during pulse
38. Heat Loading Profile in Divertor	Position of the ionisation front		0 – TBD m	1 ms	10 cm	–
		Surface temperature		200 – 1000°C	2 ms	3 mm
			1000 – 2500°C	20 µs	3 mm	10%
	Power load	Default	TBD – 25 MW/m ²	2 ms	3 mm	10 %
		Disruption	TBD – 5 GW/m ²	0.1 ms	TBD	20 %
41. Divertor Electron Parameters	n _e		10 ¹⁹ – 10 ²² /m ³	1 ms	5 cm along leg, 3 mm across leg	20 %
	T _e		0.3 – 200 eV	1 ms	5 cm along leg, 3 mm across leg	20 %
42. Ion Temperature in Divertor	T _i		0.3 – 200 eV	1 ms	5 cm along leg, 3 mm across leg	20 %