



Design and technical requirements of the Thermal Shield System for the DTT facility



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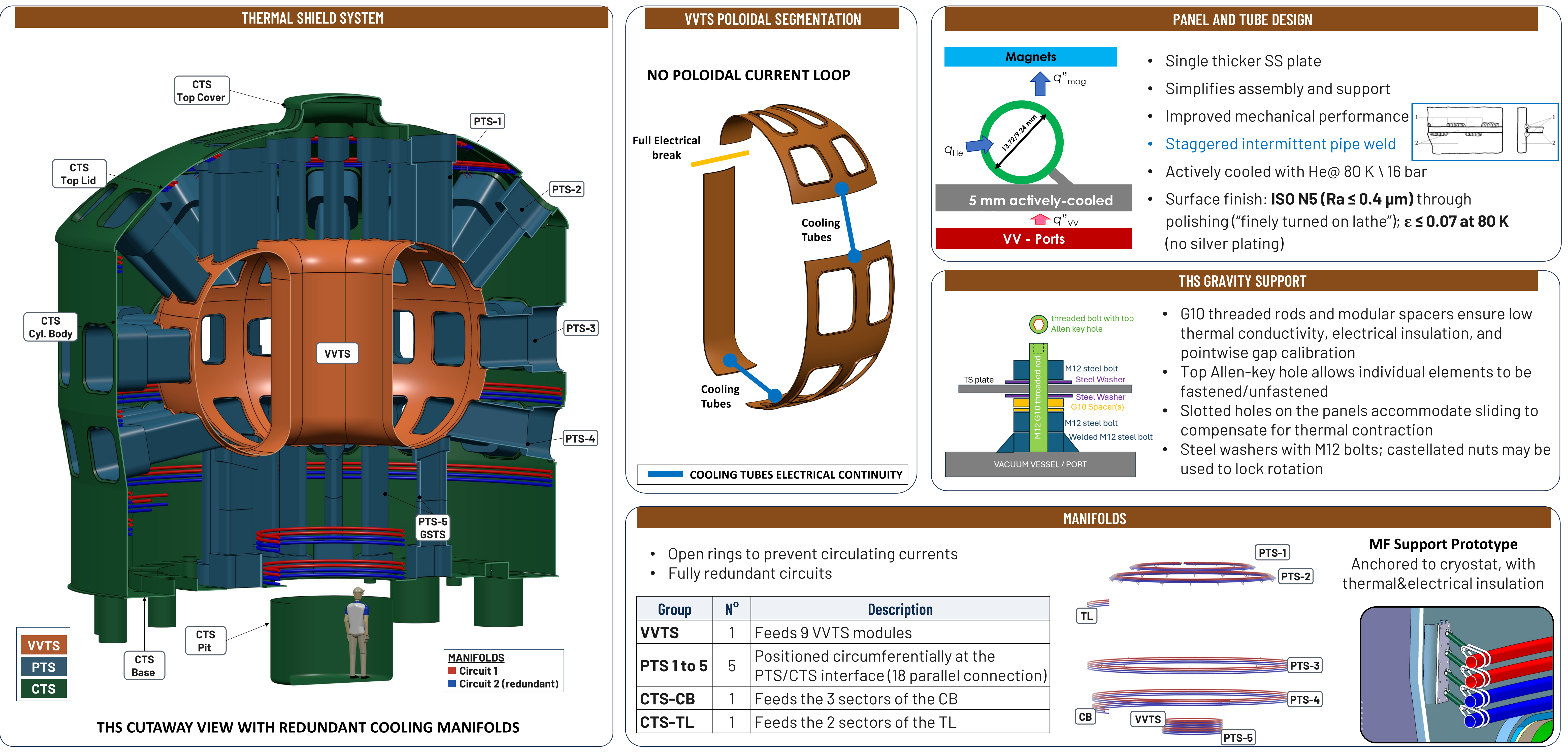
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ABSTRACT: The Divertor Tokamak Test (DTT) facility, currently under construction at ENEA Frascati, includes a Thermal Shield System (THS) designed to protect the superconducting magnets from radiative heat loads coming from warmer surrounding components. The THS comprises three modular, helium-cooled sub-systems – the Vacuum Vessel Thermal Shield (VVTS), the Port Thermal Shield (PTS) and the Cryostat Thermal Shield (CTS) – all manufactured from AISI 316L stainless steel with restricted content of high-activation impurities (Co, Ta, Nb). VVTS and PTS adopt a single-shell, actively cooled 5 mm panel, while the CTS uses a single 3 mm cooled shell fitted with Multi-Layer Insulation (MLI) on the cryostat side. The cooling system relies on fully redundant, continuous seamless 1/4" STD pipes, intermittently welded to the panels and operated with gaseous helium at 16 bar / 80 K (inlet); PTS 1-5 each have dedicated parallel paths, the VVTS follows a toroidal sector-based periodicity with its own dedicated manifold, and the CTS is fed by separate manifolds for its cylindrical body (3 sectors) and top lid (2 sectors) – all configured to maximize surface coverage. The THS is anchored to warm components (Vacuum Vessel, Ports, Cryostat) via gravity supports rated for plasma operation and baking up to 300 K, using G-10 epoxy for thermo-electrical insulation and slotted holes to accommodate thermal contraction. A full-scale VVTS prototype validates welding, distortion management, surface finishing and gravity-support performance under representative loads, de-risking series manufacturing ahead of the procurement campaign for VVTS, PTS and CTS.

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SYSTEM DESIGN



SCOPE OF SUPPLY					
HARDWARE					
Sub-system	Module	Units	Toroidal ext.	Surface (m²)	Mass (kg)
VVTS*	Regular	18 (3x6)	40°	115	4 500
	Wide	6 (3x2)	50°		
	Closing	3 (3x1)	20°		
PTS*	PTS 1	18	—	565	22 000
	PTS 2	18	—		
	PTS 3	17	—		
	PTS 4	18	—		
	PTS 5	11	—		
	VVGS shield	6	—		
CTS**	Cylin. body	3	120°	420	9 850
	Top lid	2	180°		
	Top cover	1	360°		
	Base	Segmented	—		
	Pit	1	360°		
				1100	36 350

* Panel thick.: 5 mm. ** Panel thick.: 3 mm (with MLI on the cryostat side)

INSTRUMENTATION				
Sensor type	VVTS	Port	Cryostat	Total
TC (point)	60	90	30	180
DFOS (distributed Temp)	Continuous fibre along representative cooling circuits			multi-point
Strain gauges (point) + DFOS	Critical welds, gravity supports and manifold anchors			multi-point
Displacement (ITER-type)	Support interfaces and key relative-motion points			multi-point

ADDITIONAL SUPPLY ACTIVITIES	
Beyond the hardware and instrumentation above, the scope of supply includes: all design activities up to completion of the manufacturing design; supervision of Site Acceptance Tests; logistics (packaging, transport, delivery on site, as a single shipment); and design of dedicated supporting/transport frames for the VVTS modules and CTS cylindrical body, ensuring safe dimensional inspection and transportation.	

MANUFACTURING & QUALITY		
REQUIRED TESTS & FAT		
Test	Standard / Criterion	Stage
Gravity support mechanical test	RT.01	Prototype only
Pipe omega mechanical test	RT.02	Prototype only
Visual inspection	ISO 20890-4	FAT.01 + prototype
Weld inspection	VT (EN ISO 17637) · PT (ISO 3452)	FAT.02 + prototype
Magnetic permeability	EN 60404-15 · ≤ 1.05 / ≤ 1.1 welds	FAT.03 + prototype
Surface roughness	ISO 25178 · 30% of surface	FAT.04 + prototype
Total hemispherical emissivity	RT.03	Prototype (for information)
Dimensional inspection	ISO/TS 21749 · ISO 14253-1	FAT.05 + prototype
Pneumatic cyclic pressure	18 bar	FAT.06 + prototype
Helium leak test	≤ 1·10 ⁻⁹ Pa·m³/s	FAT.07 + prototype
Flow verification	every redundant circuit	FAT.08 + prototype
THS instrumentation test	—	FAT.09
Site Acceptance Test (SAT)	representative test subset	On site

MANUFACTURING & FINISH		MATERIALS	
Parameter	Requirement	Item	Property
Surf. roughness Ra	≤ 0.4 μm (VVTS/PTS); ≤ 0.8 μm (CTS)	AISI 316L (EN 1.4404)	Y ≥ 310 MPa; UTS ≥ 1235 MPa @ 77 K
Magn. Permeability	≤ 1.05 (≤ 1.1 in welds)	G-10 / FR-4 supports	Flexural ≥ 465 MPa · ρ ≥ 1x10 ⁸ Ω·cm
Assembly environ.	Segregated, oil-free, ISO 8 clean area	CTS MLI blanket	Heat flux < 2.5 W/m² (300→80 K)

PROTOTYPE	
A full-scale prototype of a regular 40° VVTS outboard sector – matching the final product's material, pipe routing, welding and surface treatment – provides the final qualification evidence for the manufacturing process, building on earlier intermediate prototypes and mock-ups. It validates:	
• Pipe welding process and optimal weld-bead length, Manufacturing geometrical and dimensional tolerances	
• Distortion management plan, Surface finishing process	
• Gravity-support mechanical resistance under specified loads	
• Pipe-omega elastic performance at panel-to-panel interfaces	
De-risking series manufacturing ahead of the VVTS, PTS and CTS procurement campaign	