

**QPS Fabrication Project
Work Breakdown Structure (WBS) Dictionary
Auxiliary Systems (WBS 2)**

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QPS WBS Dictionary

Auxiliary Systems (WBS 2)

WBS Element: 2		WBS Level: 2
WBS Title:	Auxiliary Systems	
Description:	<p>The Auxiliary Systems scope includes several subsystems that are critical to plasma performance. The QPS Fabrication Project includes gas fueling, torus vacuum pumping, and electron-cyclotron heating (ECH) subsystems. Future upgrades that can be accommodated include glow discharge cleaning, pellet injection, boronization, and radio frequency wave heating systems, as well as increases in ECH power at 28 GHz and/or 53 GHz.</p> <p>Included in the Fabrication Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Fabrication Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing. Integrated systems testing of the entire QPS device is covered in Integrated Systems Testing (WBS 73).</p> <p>Auxiliary Systems include all the systems and related elements that directly provide fueling, vacuum pumping, and heating to the plasma and plasma chamber. Auxiliary Systems include:</p> <ul style="list-style-type: none"> • Gas and Pellet Injection Fueling (WBS 21); • Vacuum Pumping (WBS 22); • Wall Conditioning Systems (WBS 23); • RF Heating (WBS 24). 	

WBS Element: 21		WBS Level: 3
WBS Title:	Gas and Pellet Injection Fueling	
Description:	<p>This WBS element consists of all the effort and systems to provide operational gas and pellet injection fueling systems for the QPS device. Included are: the Gas Fueling Systems (WBS 211) and Pellet Injector Fueling Systems (WBS 212)</p>	
WBS Element: 211		WBS Level: 4
WBS Title:	Gas Fueling	
Description:	<p>The QPS Fueling System will consist of two gas injectors located at the vacuum vessel and two injection lines located at divertor locations. Each will be capable of providing approximately 100 Torr-L/s of H₂, D₂, or He fueling. The configuration will have the flexibility to allow the easy changing of gas species and gas plenum volumes.</p> <p>The hardware for the Gas Fueling System consists of fast pulsed valves, control valves, instrumentation, gas lines and manifolds, and vacuum hardware. The controls will consist of a PLC which will also control the torus vacuum system the glow discharge cleaning (GDC) system, and (as a future upgrade) the boronization system.</p> <p>Vacuum vessel and plasma line-of-sight will allow future upgrades for pellet fueling.</p>	
WBS Element: 212		WBS Level: 4
WBS Title:	Pellet Injection	
Description:	<p>QPS will be designed to accommodate a pellet injector as a future upgrade. Guide tubes can be installed to facilitate pellet launch from the inboard (high field) side of the plasma.</p> <p>The only effort in this area for the QPS Fabrication Project will be to identify where the pellet injector will go, its space requirements, and the placement of guide tubes inside the vessel for pellet injection.</p>	

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WBS Element: 22		WBS Level: 3
WBS Title:	Vacuum Pumping	
Description:	<p>QPS requires a Torus Vacuum Pumping system in order to achieve the base pressure requirements. The vacuum system consists of a basic turbo-molecular Torus Pumping System and, if needed as a future upgrade, large titanium appendage pumps and/or liquid nitrogen cooled panels which can increase the pumping speed transiently by an order of magnitude.</p> <p><i>Note: for first plasma, baking will not be available and the vacuum vessel will only be treated with extensive wall conditioning (cf. below) which has been demonstrated to be sufficient for first plasma.</i></p> <p>The Torus Pumping System will be assembled and tested off-line prior to first operation on QPS. Based on experience with past fusion devices at ORNL, the Torus Pumping System should operate reliably and be readily maintainable.</p> <p>The Torus Vacuum Pumping System will be connected to building venting system for venting to the outside environment.</p> <p>Included are: High Vacuum Pumping (WBS 221), Roughing and Backing Vacuum System (WBS 222), Pumping Ducts/Valves (WBS 223), Leak Detection (WBS 224), Titanium Gettering (WBS225), LN2 Panels (WBS 226), and Local I&C (WBS 227).</p>	
WBS Element: 221		WBS Level: 4
WBS Title:	High Vacuum Pumping	
Description	Included are two, 2000 L/s turbo molecular pumps.	
WBS Element: 222		WBS Level: 4
WBS Title:	Roughing and Backing Vacuum System	
Description	This WBS element provides the design, procurement and installation of the roughing and backing system components, including foreline, foreline trap, foreline valve, and rotary vane roughing and backing pumps. The discharge line to the atmosphere is not included, but is part of the facility move project.	
WBS Element: 223		WBS Level: 4
WBS Title:	Pumping Ducts/Valves	
Description	Included are the valves and ducts necessary to connect and effectively operate the pumping system. Connections from the QPS vacuum vessel to the turbo pumps, from the turbo pumps to the backing/roughing pumps, and from the backing/roughing pumps to the building vent are included.	
WBS Element: 224		WBS Level: 4
WBS Title:	Leak Detection	
Description	The design of the QPS vacuum system shall be consistent with efficient leak detection procedures. This work is contained within the affected WBS element. The leak detection equipment from previous Fusion Energy Division facilities will be employed on QPS.	
WBS Element: 225		WBS Level: 4
WBS Title:	Titanium Gettering	
Description	The use of titanium getters in the large ducts that connect the QPS external vacuum vessel to the turbo molecular pumps is possible as a future upgrade.	
WBS Element: 226		WBS Level: 4
WBS Title:	LN2 Panels	
Description	The use of liquid nitrogen cooled getters in the large ducts that connect the QPS external vacuum vessel to the turbo molecular pumps is possible as a future upgrade.	
WBS Element: 227		WBS Level: 4
WBS Title:	Vacuum pumping local I&C	
Description	This WBS element provides the design, procurement, and installation of the ion gages, forepump gages, PLC controller and other controls and instrumentation for the vacuum pumping system.	

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WBS Element: 23		WBS Level: 3
WBS Title:	Wall Conditioning Systems	
Description:	<p>This WBS element consists of the effort and systems to provide wall conditioning and impurity control. <i>Boronization is a future upgrade.</i></p> <p>Included are: the Glow Discharge Cleaning System (WBS 231) and the Boronization Startup and Testing System (WBS 232).</p>	
WBS Element: 231		WBS Level: 4
WBS Title:	Glow Discharge Cleaning System	
Description:	<p>QPS is required to have a Glow Discharge Cleaning (GDC) System for wall conditioning (removal of adsorbed gaseous impurities and hydrogen) during bake-out and between shots as required by the experimental program. The system capabilities will include GDC with hydrogen, deuterium, helium, and other gases as needed. The GDC system will consist of one fixed wall anode and one pre-ionization filament unit installed in each of the 2 QPS sectors.</p>	
WBS Element: 232		WBS Level: 4
WBS Title:	Boronization Startup and Testing System	
Description:	<p>As a future upgrade, QPS is required to accommodate a system to boronize all surfaces with line-of-sight to the plasma. The present plan is to use a trimethylboron (TMB) system as presently used on NSTX and planned as an upgrade for NCSX. The boronization system will make use of the existing Fueling-, GDC-, and Torus Vacuum Pumping Systems. <i>For the QPS Fabrication Project, this WBS element consists of the design effort to assure that a boronization system can be accommodated on QPS as a future upgrade.</i></p>	

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WBS Element: 24		WBS Level: 3
WBS Title:	RF Heating	
Description:	Radio frequency (RF) heating will be the primary means for creating energetic plasmas for the QPS research program. An initial capability of 200 kW of 28 GHz microwaves for Electron Cyclotron Heating (ECH) is planned to upgrade up to total of 1 MW of 28 GHz power and 1 MW of 53 GHz power. Included are: ICRF (WBS 241), Electron Cyclotron Heating Systems—28 GHz (WBS 242), Electron Cyclotron Heating Systems—28 GHz Upgrade (WBS 243), and Electron Cyclotron Heating Systems—53 GHz (WBS 224).	
WBS Element: 241		WBS Level: 4
WBS Title:	ICRF	
Description	The addition of up to 3.5 MW of ICRF (ion cyclotron range of frequency) heating may be required as a future upgrade. For the QPS Fabrication Project, the effort is limited to only the necessary design effort to assure that an ICRH system can be accommodate at a later time. The design effort shall include developing a design concept, locating the equipment, and defining space requirements and will be costed in the WBS elements of the affected components. Included are coaxial lines, antennas, and controls. The high-frequency power supplies are being moved from Y12 as part of the Fusion Energy Division's relocation project.	
WBS Element: 242		WBS Level: 4
WBS Title:	ECH—28 GHz	
Description	Electron cyclotron heating (ECH) power at 200 kW at a frequency of 28 GHz will be utilized by the QPS project for initial plasma research. Included are the necessary waveguide components, controls, and launcher. The 28 GHz tube, socket, and power supply are being moved from Y12 as part of the Fusion Energy Division's relocation project.	
WBS Element: 243		WBS Level: 4
WBS Title:	ECH—28 GHz Upgrade	
Description	ECH power at 900 kW at a frequency of 28 GHz will be utilized by the QPS project for later phases plasma research program as a future upgrade. Included are the necessary waveguide components, controls, and launcher. The 28 GHz tubes, sockets, and power supplies are being moved from Y12 as part of the Fusion Energy Division's relocation project.	
WBS Element: 244		WBS Level: 4
WBS Title:	ECH—53 GHz	
Description	ECH power at up to 1 MW at a frequency of 53 GHz will be utilized by the QPS project for later phases of the research program as a future upgrade. Included are the necessary waveguide components, controls, and launcher. The 53 GHz tubes, sockets, and power supplies are being moved from Y12 as part of the Fusion Energy Division's relocation project.	