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SSME ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

DVS STATUS REPORT FOR HIGH-PRESSURE OXIDIZER TURBOPUMP

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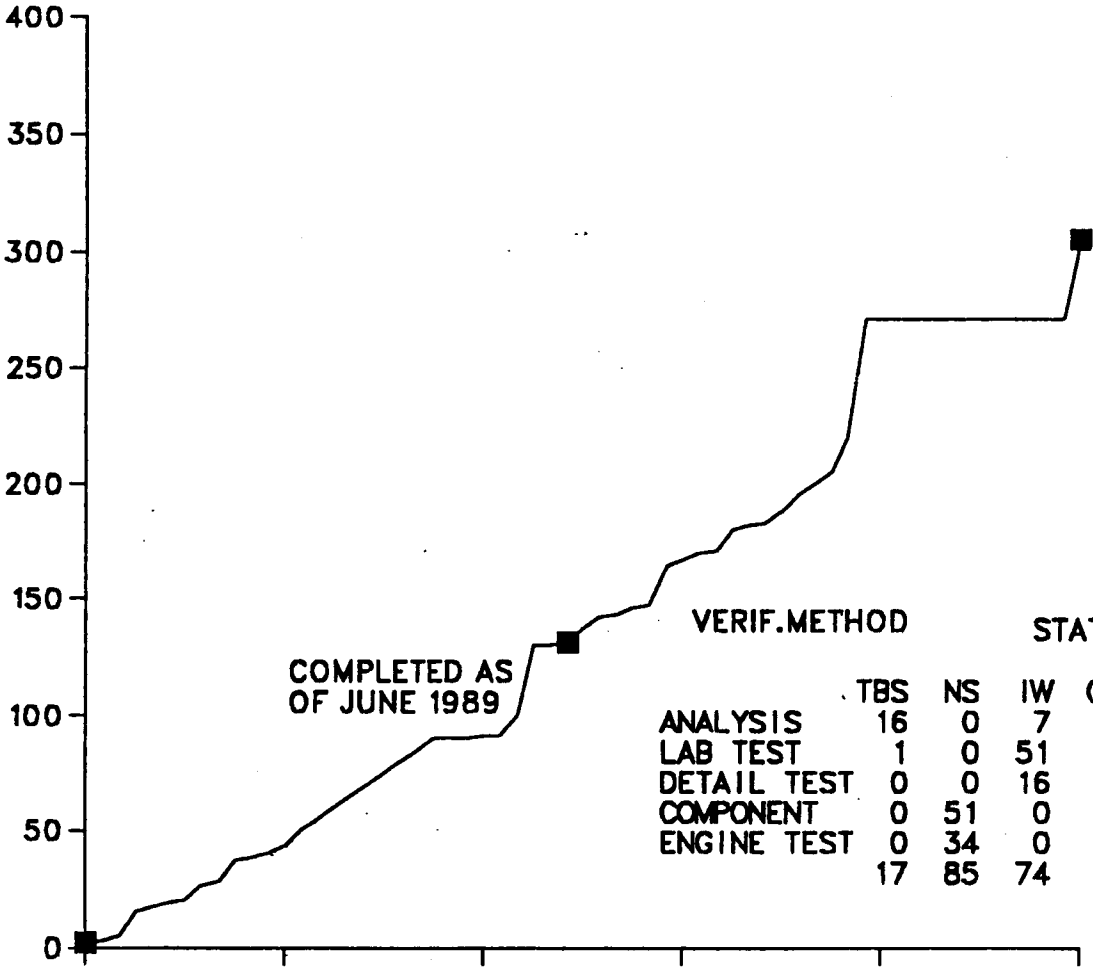
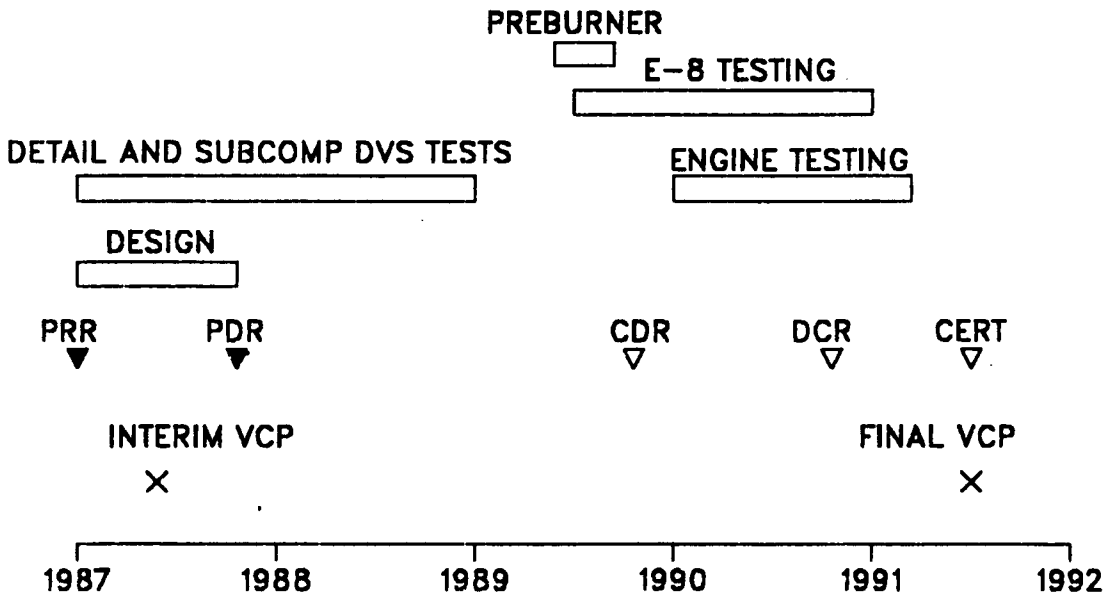
ATD DVS STATUS – HPOTP



VERIF.METHOD	STATUS				
	TBS	NS	IW	COMP	TOTAL
ANALYSIS	16	0	7	126	149
LAB TEST	1	0	51	3	55
DETAIL TEST	0	0	16	2	18
COMPONENT	0	51	0	0	51
ENGINE TEST	0	34	0	0	34
	17	85	74	131	307 TOTAL



Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
DESIGN REQ'MENTS	3.0	**In this and subsequent DVS Status Reports, an asterisk will designate an item that has been completed since the previous report.**			
Functional and Nonoperating Characteristics	3.1				
Functional Perf.	3.1.1				
Power Levels	3.1.1.1	Analysis to verify the pump meets the requirements of engine start mainstage throttling and S/D and to show that the pump is compatible with SSME phase II and II+ performance requirements and to minimize interface fluid requirements from the current SSME database, and to minimize controller gains to meet stability requirements.	4.1.2.1 a	2/87 comp	
Shutdown/ Throttling/ Step Change	3.1.1.2	Component testing (on E-8) to verify 1) Multiple mission capability 2) Provide a functional evaluation of the pump turbine, rotor support and rotor thrust control systems. 3) Evaluate the DTM and PBM computer models.	4.1.3.3 d 4.1.3.3.2 d	10/90 ns 10/90 ns	
		Turbopump testing at the NASA engine test facility to verify engine-component compatability (deemed acceptable if the PBM and DTM conditions as defined in the ICD and the health parameters in 4.1.3.4.2 are met).	4.1.3.4. e 4.1.3.4.1 e 4.1.3.4.2 e	12/91 ns 12/91 ns 12/91 ns	
Starts	3.1.1.3	The analytical portion of these requirements are to be verified by a combination of the SSME turbine stator meanline analysis and and cold flow testing and development of the PBM, DTM, and SVM. The models may be modified after testing (both E-8 and engine level at MSFC).	4.1.2.1 a 4.1.2.1 a 4.1.2.1 a 4.1.2.1 a 4.1.3.3.2 d 4.1.3.4.2 d	12/86 comp 12/86 comp 9/87 comp 9/87 comp 10/90 ns 12/91 ns	
RPL/MPL Duration	3.1.1.4	Engine level testing to demonstrate continuous operation between MPL and RPL for 823 seconds.	4.1.2.1 a 4.1.4.4.1.4 e	9/87 comp 12/91 ns	
FPL Duration	3.1.1.5	Engine level testing to verify continuous operation at FPL for 754 seconds.	4.1.2.1 a 4.1.4.4.1.4 e	9/87 comp 12/91 ns	
Propellant	3.1.1.6	Verify (by instrumented component and engine tests) that the turbopump pumps liquid oxygen as supplied by the low pressure pump per ICD spec CP 11371 and that the required PBM and DTM parameters specified in 4.1.3.3.2 and 4.1.3.4.2 are met.	4.1.3.3.2 d 4.1.3.4.2 e	10/90 ns 12/91 ns	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Leakage	3.1.1.7	Verify that pump leakage doesn't exceed 7 x 10 E-2 scc/sec helium by analysis, component and engine testing.	4.1.2.13 a 4.1.3.3.2 d 4.1.3.4.2 e 4.1.4.3.2.1 d	comp 10/90 ns 12/91 ns 10/90 ns	
Prelaunch Conditioning Duration	3.1.1.8	Demonstrate by an instrumented component test that the ICD head/ flow conditions for propellant delivery during prechill will condition turbomachinery within the 90 minute chilldown period.	4.1.3.3.6 d	10/90 ns	
Prelaunch Service Free Duration	3.1.1.9	Demonstrate by a component test that the pump will function at any time within 24 hours under propellant loaded conditions without ground servicing.	4.1.3.3.6 d	10/90 ns	
Turbopump Dynamic Transfer Character-istics	3.1.1.10	Ensure that the turbopump functions without coupled engine-vehicle oscillations and retains adequate stability margin as defined in ICD CP 11371 by analysis and instrumented component and engine tests.	4.1.2.1 a 4.1.3.3.2 d 4.1.3.4.2 e 4.1.4.4.1.2 e	9/87 comp 10/90 ns 12/91 ns 12/91 ns	
Low Freq. Oscillations	3.1.1.11	Verify that pump generated oscillations for the operating NPSP do not exceed the CEI specification by analysis, and instrumented component and engine tests.	4.1.2.1 a 4.1.3.3.2 d 4.1.3.4.2 e	9/87 comp 10/90 ns 12/91 ns	
Duty Cycle	3.1.1.12	Ensure that the turbopump meets the design requirements of operation (without overhaul) for 7.5 hours and 60 starts at associated mission profiles by analysis, component and engine testing.	4.1.2.1 a 4.1.3.3.2 d 4.1.4.4.1.4 e	9/87 comp 10/90 ns 12/91 ns	
Purges	3.1.1.13				
Operational	3.1.1.13.1	Verify pump's operational ability to purge without exceeding specified parameters by analysis, rig and component testing.	4.1.2.14 a 4.1.3.2.2.1 c 4.1.3.3.2 d	comp 12/89 iw 10/90 ns	
Drying Purge	3.1.1.13.2	Verify pump's capability to remove combustion products from the turbopump and show that the post shutdown drying purge doesn't introduce moisture into the oxidizer section of the HPOTP through the interpropellant seal. Verification is to be by analysis of IPS components, component and engine testing.	4.1.2.14 a 4.1.4.3.1.8 d 4.1.3.4.2 e	comp 10/90 ns 12/91 ns	
Breakaway Torque	3.1.1.14	Component and engine testing is to ensure that the breakaway torque doesn't exceed TBD amounts and a correlation will be made between ambient and cyrogenic conditions.	4.1.3.3.2 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Functional Interface	3.1.1.15	Verify that the turbopump performs within spec while being influenced by the in tolerance performance of interfacing components by analysis and engine test.	4.1.2.2 a 4.1.5.1 a 4.1.3.4.2 e	comp tbs 12/91 ns	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
HPOTP Hardware Character-istics	3.1.2				
Detail Parts	3.1.2.1				
Main Housings	3.1.2.1.1				
Membrane Stress	3.1.2.1.1.1	Housing membrane stress to be verified by 2 and 3-D finite element analysis (as required) and a strain gaged pressure test.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.1.1 b	9/87 comp 4/89 comp 4/90 iw	
Burst Rupture	3.1.2.1.1.2	Pressure test to 1.5 times design conditions.	4.1.2.9 a 4.1.4.1.1.1 b	8/89 iw 4/90 iw	
Resonant Vibration	3.1.2.1.1.3	Analytical verification to be accomplished with a NASTRAN analysis and instrumented (transducers) vibration tests and other non-destructive methods. Instrumented component and engine testing will also be done to verify pump response.	4.1.2.9 a 4.1.4.1.1.2 b 4.1.4.3.1.1 d 4.1.4.3.2.2 d 4.1.4.4.1.1 e	comp 4/90 iw 10/90 ns 10/90 ns 12/91 ns	
Fabrication	3.1.2.1.1.4	Verify that the main housing material surface finish capabilities are not affected by using ECM or EDM by lab specimen metalographic evaluation tests.	4.1.4.1.1.3 b 4.1.4.1.1.4 b	11/89 iw 11/89 iw	
Welded Sections	3.1.2.1.1.5	Verification of life capability shall be by analysis and laboratory weld sample testing.	4.1.2.9 a 4.1.4.1.1.3 b	iw 11/89 iw	
Preburner Impeller Housing	3.1.2.1.2				
Membrane Stress	3.1.2.1.2.1	Analytical prediction of stress levels is to be by 2 and 3 D finite element stress analysis followed by a strain gaged pressure test.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.1.1 b	9/87 comp 4/89 comp 4/90 iw	
Burst Rupture	3.1.2.1.2.2	Pressure test to 1.5 times design conditions.	4.1.2.9 a 4.1.4.1.1.1 b	4/90 iw 4/90 iw	
Resonant Vibration	3.1.2.1.2.3	Verification by a NASTRAN analysis and instrumented rig testing.	4.1.2.9 a 4.1.4.1.1.2 b	comp 4/90 iw	
Fabrication	3.1.2.1.2.4	Verify that the preburner impeller housing surface finish capabilities are not affected by using ECM or EDM by lab specimen material characterization tests.	4.1.4.1.1.3 b 4.1.4.1.1.4 b	11/89 iw 11/89 iw	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Pump Sect. Bearing	3.1.2.1.3				
B1 Life, Cool. Flow Load Cap.	3.1.2.1.3.1	Jones II and V Ball Bearing Analysis Shaberth Bearing Heat Analysis Pump and Turbine Sideload Analysis Rig testing	4.1.2.7 a 4.1.2.7 a 4.1.2.7 a 4.1.4.1.2.2 b 4.1.4.1.2.3 b	3/87 comp 3/87 comp 7/87 comp 1/90 iw 1/90 iw	FR-19847-1 19847-1
S.F. Lub. Trans. Eff.	3.1.2.1.3.2	Heat Transfer Analysis and instrumeted rig testing.	4.1.2.7 a 4.1.4.1.2.2 b 4.1.4.1.2.3 b	7/87 comp 1/90 iw 1/90 iw	
Heat Generation	3.1.2.1.3.3	Fit Analysis Cage Structural Analysis Rig testing at E-20/21 to demonstrate twice the operational life on four (4) bearings and gain an understanding of bearing operating parameters.	4.1.2.7 a 4.1.2.7 a 4.1.4.1.2.3 b 4.1.4.1.2.2 b	9/87 comp 5/88 comp 1/90 iw 1/90 iw	
Turb. Sect. Bearings	3.1.2.1.4				
B1 Life, (BB)	3.1.2.1.4.1	Jones II and V Ball Bearing Analysis Shaberth Bearing Analysis and rig testing.	4.1.2.7 a 4.1.2.7 a 4.1.4.1.2.2 b	3/87 comp 3/87 comp 1/90 iw	
B1 Life(RB) Load Cap.	3.1.2.1.4.2	Jones IV bearing analysis. Pump and turbine sideload analysis. Rig testing.	4.1.2.7 a 4.1.2.7 a 4.1.4.1.2.2 b	3/87 comp 7/87 comp 1/90 iw	19847-1
S.F. Lub. Trans. Eff.	3.1.2.1.4.3	Heat transfer analysis and rig testing.	4.1.2.7 a 4.1.4.1.2.2 b	7/87 comp 1/90 iw	
Heat Generation	3.1.2.1.4.4	Fit Analysis Cage Structural Analysis Bearing Environmental Test Rigs Show 2x operational life (120 cycles, 15 hours) on B.B. Show 2x operational life (120 cycles, 15 hours) on R.B.	4.1.2.7 a 4.1.2.7 a 4.1.4.1.2.2 b 4.1.4.1.2.4 b 4.1.4.1.2.5 b	9/87 comp 5/88 comp 1/90 iw 1/90 iw 1/90 iw	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
High Speed Inducer	3.1.2.1.5				
Plastic Deformation	3.1.2.1.5.1	2 and 3 D finite element analysis and deck 5138 analysis and rig testing will be used.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.4.1 b	comp 4/89 comp 1/90 iw	
Burst Speed	3.1.2.1.5.2	2 and 3 D finite element and hand analysis techniques and rig testing.	4.1.2.9 a 4.1.4.1.4.2 b	comp 1/90 iw	
Vibration	3.1.2.1.5.3	NASTRAN analysis with rig testing.	4.1.2.9 a 4.1.4.1.4.3 b	comp 11/89 iw	20730-3
Main Impeller	3.1.2.1.6				
Plastic Deformation	3.1.2.1.6.1	2 and 3 D finite element analysis and deck 5138 and rig testing.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.3.2 b	comp 4/89 comp 1/90 iw	
Burst Speed	3.1.2.1.6.2	2 and 3 D finite element and hand analysis techniques with rig testing.	4.1.2.9 a 4.1.4.1.3.2 b	comp 1/90 iw	
Vibration	3.1.2.1.6.3	NASTRAN analysis and rig testing.	4.1.2.9 a 4.1.4.1.3.3 b	comp 11/89 iw	20730-1
Fabrication	3.1.2.1.6.4	Verify that the main impeller material surface finish capabilities are not affected by using ECM or EDM by lab metalographic evaluation.	4.1.4.1.3.5 b	11/89 iw	
Unbalance	3.1.2.1.6.5	Forced response analysis using the A346 code with component testing.	4.1.2.10 a 4.1.4.3.1.1 d	comp 10/90 ns	
Preburner Impeller	3.1.2.1.7				
Plastic Deformation	3.1.2.1.7.1	2 and 3 D finite element analysis with deck 5138 and rig testing.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.3.2 b	comp 4/89 comp 1/90 iw	
Burst Speed	3.1.2.1.7.2	2 and 3 D finite element analysis and hand analysis techniques and rig testing.	4.1.2.9 a 4.1.4.1.3.2 b	comp 1/90 iw	
Vibration	3.1.2.1.7.3	NASTRAN analysis with rig testing.	4.1.2.9 a 4.1.4.1.3.3 b	comp 11/89 iw	20730-2
Fabrication	3.1.2.1.7.4	Verify that the preburner impeller material surface finish capabilities are not affected by using ECM or EDM by lab specimen material characterization tests.	4.1.4.1.3.5 b 4.1.5.2 a	11/89 iw tbs	
Unbalance	3.1.2.1.7.5	Forced response analysis using the A346 code	4.1.2.10 a	comp	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Turbine Disk/Shaft	3.1.2.1.8				
Plastic Deformation	3.1.2.1.8.1	2 and 3 D finite element analysis and deck 5138 with rig testing.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.7.3 b	comp 4/89 comp 1/90 iw	
Burst Speed	3.1.2.1.8.2	2 and 3 D finite element analysis with hand calculations and rig testing.	4.1.2.9 a 4.1.2.10 a 4.1.4.1.7.3 b	9/88 comp comp 1/90 iw	
Vibration	3.1.2.1.8.3	NASTRAN analysis and rig, component, and engine testing.	4.1.2.9 a 4.1.4.1.7.4 b 4.1.4.3.1.1 d 4.1.4.4.1.1 e	comp 11/89 iw 10/90 ns 12/91 ns	
Fatigue Life	3.1.2.1.8.4	Analysis utilizing the stress analysis results and the material characterization and property studies and component and engine testing.	4.1.2.9 a 4.1.4.3.1.2 d 4.1.4.4.1.5 e	comp 10/90 ns 12/91 ns	
Unbalance	3.1.2.1.8.5	Forced response analysis using ARDS or A346 code.	4.1.2.10 a	comp	
Turbine Blades	3.1.2.1.9				
Vibration	3.1.2.1.9.1	NASTRAN analysis with detailed part, subassembly and component and engine testing. SPATE, Modal, and Holography testing. HCF and spin vibration.	4.1.2.9 a 4.1.4.1.8.2 b 4.1.4.1.8.2 b 4.1.4.2.4.1 c 4.1.4.3.1.1 d 4.1.4.4.1.1 e	comp 6/89 comp* 11/89 iw 1/90 iw 10/90 ns 12/91 ns	
Fatigue Life	3.1.2.1.9.2	Analysis using the stress analysis and material characterization testing results and rig tests.	4.1.2.5 a 4.1.2.9 a 4.1.4.1.8.3 b 4.1.4.1.8.1 b	8/87 comp comp 11/89 iw comp	
Turbine Vanes	3.1.2.1.10				
Vane Vibration	3.1.2.1.10.1	NASTRAN analysis with all levels of testing.	4.1.2.9 a 4.1.4.1.9.1 b 4.1.4.2.5.1 c 4.1.4.3.1.1 d 4.1.4.4.1.1 e	comp 12/89 iw 4/90 iw 10/90 ns 12/91 ns	
Platform Vibration	3.1.2.1.10.2	NASTRAN analysis and all levels of testing.	4.1.2.9 a 4.1.4.1.9.1 b 4.1.4.2.5.1 c 4.1.4.3.1.1 d 4.1.4.4.1.1 e	comp 12/89 iw 4/90 iw 10/90 ns 12/91 ns	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Fatigue Life	3.1.2.1.10.3	2 and 3 D (as required) finite element analysis and material property data. (Codes M571/F589) with rig testing and component and engine verification.	4.1.2.5 a 4.1.2.9 a 4.1.4.1.9.2 b 4.1.4.3.1.2 d 4.1.4.4.1.5 e	8/87 comp comp 11/89 iw 10/90 ns 12/91 ns	
Turbine Inlet Duct	3.1.2.1.11				
Membrane Stresses	3.1.2.1.11.1	2 and 3 D finite element analysis and rig testing.	4.1.2.9 a (2D) 4.1.2.9 a (3D) 4.1.4.1.5.1 b	9/87 comp 4/89 comp 4/90 iw	
Burst Rupture	3.1.2.1.11.2	2 and 3 D finite element and thermal shock analysis and rig testing.	4.1.2.9 a 4.1.4.1.5.1 b	iw 4/90 iw	
Vibration	3.1.2.1.11.3	NASTRAN analysis with all levels of testing.	4.1.2.9 a 4.1.4.1.5.2 b 4.1.4.2.5.1 c 4.1.4.3.2.2 d 4.1.4.4.1.1 e	comp 4/90 iw 4/90 iw 10/90 ns 12/91 ns	
Fatigue Life	3.1.2.1.11.4	Input from the 2 and 3 D finite element analysis and the material characterization studies and component, engine testing.	4.1.2.9 a 4.1.4.3.1.2 d 4.1.4.4.1.5 e	4/89 comp 10/90 ns 12/91 ns	
Turbine Turnaround Duct	3.1.2.1.12				
Membrane Stress	3.1.2.1.12.1	Finite element analysis (3D) and rig testing.	4.1.2.9 a 4.1.4.1.6.1 b	4/89 comp 4/90 iw	
Burst Rupture	3.1.2.1.12.2	Thermal shock analysis with input from the finite element analysis and rig testing.	4.1.2.9 a 4.1.4.1.6.1 b	4/90 iw 4/90 iw	
Vibration	3.1.2.1.12.3	NASTRAN analysis with all levels of testing.	4.1.2.9 a 4.1.4.1.6.2 b 4.1.4.21.6.1 c 4.1.4.3.2.2 d 4.1.4.4.1.1 e	comp 4/90 iw 4/90 iw 10/90 ns 12/91 ns	
Fatigue Life	3.1.2.1.12.4	Input from the finite element analysis and the material characterization studies with component and engine testing.	4.1.2.9 a 4.1.4.3.1.2 d 4.1.4.4.1.5 e	4/89 comp 10/90 ns 12/91 ns	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Subassembly	3.1.2.2				
Ball Bearing Support Syst	3.1.2.2.1				
Springrate	3.1.2.2.1.1	Verify that the Ball Bearing support system has the required springrate by analysis, rig and component testing.	4.1.2.7 a 4.1.2.10 a 4.1.4.2.1.1 c 4.1.4.3.1.4 d	comp comp 4/90 iw 10/90 ns	
Turbine Bearings Support Sys.	3.1.2.2.2				
Spring Rate	3.1.2.2.2.1	Verify that the turbine bearing support system has the required springrate by analysis, and rig testing.	4.1.2.10 a 4.1.4.2.2.1 c	comp 4/90 iw	
Interpropellant Seal Package	3.1.2.2.3				
Positive Propellant Separation	3.1.2.2.3.1	Analytical verification is to be performed by various in house computer models with rig verification of ability to meet required parameters.	4.1.2.14 a 4.1.3.2.2.1 c 4.1.4.3.1.5 d 4.1.4.3.1.8 d	comp 8/89 iw 10/90 ns 10/90 ns	
Seal Package Life	3.1.2.2.3.2	Perform structural analyses of seal life and verify with rig testing.	4.1.2.14 a 4.1.3.2.2.2 c 4.1.4.3.1.2 d	comp iw 10/90 ns	
Flow Limits	3.1.2.2.3.3	ICD limits will be verified by analysis and rig and component testing.	4.1.2.14 a 4.1.3.2.2.1 c 4.1.4.3.1.5 d	comp 8/89 iw 10/90 ns	
HPOTP Rotor Assembly	3.1.2.2.4				
Rotor Dynamic Stability	3.1.2.2.4.1	Ensure that the pump exhibits no fundamental bending modes in the operating range by a combination of analysis, rig and component testing.	4.1.2.10 a 4.1.4.2.3.1 c 4.1.3.3 d	comp 4/90 iw 10/90 ns	20730-10

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Turbine Gas Path	3.1.2.2.5				
Flow Discrepancies	3.1.2.2.5.1	Ensure that no flow discrepancies (which will impact performance) exist by analysis and detail part and rig testing.	4.1.2.4 a 4.1.2.11 a 4.1.3.1.1 b 4.1.3.2.4.1 c 4.1.3.2.4.2 c 4.1.3.2.4.3 c 4.1.3.2.4.4 c	comp comp 12/89 iw comp comp 10/89 iw 10/89 iw	19847-1 & 20724-1 to 6 20833
Foreign Object Damage	3.1.2.2.5.2	Ensure that the turbine airfoils are resistant to FOD by analysis.	4.1.2.12 a	comp	
Inducer/ Impeller Inlet Flowpath	3.1.2.2.6				
Flow Discrepancies	3.1.2.2.6.1	Analysis with the TMLD (code p774) and subassembly testing.	4.1.2.3 a 4.1.3.2.1.1 b	4/87 comp comp	19847-1 19847-3
Turbine Inlet Bellows Shield and Bellows Assy	3.1.2.2.7				
Vibration	3.1.2.2.7.1	Analysis will be used to verify that the TIBS and BA have no resonant responses within 10 % of any critical excitations. Component and engine testing will also be used.	4.1.2.9 a 4.1.3.3 d 4.1.4.4 e	comp 10/90 ns 12/91 ns	
Damper Seal	3.1.2.2.8				
Functional Performance	3.1.2.2.8.1	Verify that the damper seal provides optimum damping effectiveness by analysis and subassembly testing.	4.1.2.8 a 4.1.2.10 a 4.1.3.2.3.1 c	comp comp iw	
Component	3.1.2.3				
Pump Performance	3.1.2.3.1	Compare the DTM, PBM, SVM simulations to instrumented component and subassembly tests.	4.1.2.3 a 4.1.3.2.1 c 4.1.3.3.2 d	comp 1/90 iw 10/90 ns	
Cavitation Power Level	3.1.2.3.1.1	Verify that the pump operates with less than a 3 % loss in head rise and delivers oxygen per ICD requirements by analysis and component testing.	4.1.2.3 a 4.1.3.3.3 d	comp 10/90 ns	
Cavitation Engine Cut-Off	3.1.2.3.1.2	Verify that the pump resists cavitation at MECO by analysis and component testing.	4.1.2.3 a 4.1.3.4.2 d	comp 10/90 ns	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Bistable Operation	3.1.2.3.1.3	Analytical verification by the DTM, PBM, etc that the pump doesn't exhibit bistable operation.	4.1.2.3 a	comp	
Turbopump Rotor Dynamic Stability	3.1.2.3.2				
Nonsychronous Rotor Whirl	3.1.2.3.2.1	Verify that the pump operates without occurrence of discrete nonsynchronous rotor whirl.	4.1.2.10 a 4.1.4.3.1.1 d 4.1.4.4.1.1 e	comp 10/90 ns 12/91 ns	20730-10
Rotor Vibration	3.1.2.3.2.2	Verify that the pump operates without the occurrence of detrimental rotor vibratory modes by analysis and component and engine testing.	4.1.2.10 a 4.1.3.3.2 d 4.1.4.4.1.1 e	comp 10/90 ns 12/91 ns	20730-10
Housing Relative Motion	3.1.2.3.2.3	Ensure that the rotor housing's relative motion does not exceed clearances over the entire operating range by analysis and component testing.	4.1.2.10 a 4.1.4.3.1.1 d	comp 10/90 ns	20730-10
Turbopump Axial Thrust Balance	3.1.2.3.3				
Rotor Axial Thrust Balance	3.1.2.3.3.1	Verify that the pump provides adequate internal rotor axial thrust balance to preclude degradation of the bearings and other components by analysis and component tests.	4.1.2.6 a 4.1.2.7 a 4.1.3.3.7 d	comp comp 10/90 ns	
Turbopump Side Loads	3.1.2.3.4				
Hydrodynamic and Aerodynamic Side Loads	3.1.2.3.4.1	Verify that the pump side loads are minimized by analysis and component testing.	4.1.2.6 a 4.1.2.7 a 4.1.4.3.1.4 d	comp comp 10/90 ns	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Maintainability Reliability Safety and Quality	3.2				
Maintainability	3.2.1	Verify that the HPOTP meets the CEI spec by submittal of a Maintainability Program Plan.	4.1.5 a	3/87 comp	
Interchange-ability and Replace-ability	3.2.1.1				
Physical Interchange-ability	3.2.1.1.1	Verify physical interchangeability by demonstrating on a mockup replaceability as an LRU.	4.1.5.1 a 4.1.2.2 a	comp 3/88 comp	
Functional Interchange-ability	3.2.1.1.2	Verify by ensuring that the pump performs within spec by analysis and ensuring that the pump meets the requirements of section 2.	4.1.5.1 a 4.1.2.2 a 4.1.8.1 a	comp comp comp	
Manufacturing Processes	3.2.1.1.3	Verify by the adherence and establishment of a Quality Assurance system and fabrication / assembly procedures.	4.1.5.2 a	2/87 comp	19634-2
Identification and Marking	3.2.1.2				
Turbopump	3.2.1.2.1	The pump shall be marked per CEI spec 11369 which is also the VCP for this requirement.	4.1.5.3 a	5/87 comp	
Marking of Connections	3.2.1.2.2	The pump shall be permanently marked per MIL-STD 1247.	4.1.5.3 a	comp	
Packaging	3.2.1.2.3	Verify that packing, packaging, etc is done in accordance with NHB 6000.1 .	4.1.5.6 a	tbs	
Reliability	3.2.2	Verify that the design has minimized failure modes that can adversely affect crew, vehicle or mission by a FMECA .	4.1.5.4 a	3/87 comp	
Safety	3.2.3	The HPOTP shall be designed to meet the Safety Program Plan.	4.1.5.5 a	3/87 comp	19720-1

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Quality Assurance	3.2.4	Ensure that the design provides appropriate control of material, fabrication, cleaning, and testing by submittal of a QAP(DR RA-09).	4.1.5.6 a	3/87 comp	
Physical Characteristics	3.2.5	Verify that the pump meets the requirements of CP 11371 by analysis and physical measurement of detail parts and the assembled pump.	4.1.9.1 a 4.1.9.1 b 4.1.9.1 d	comp 3/90 iw 10/90 ns	
Inspection	3.2.6	Demonstrate visual inspectability for external damage and leakage and by internal borescoping of the turbine, pump and bearings.	4.1.5.7.1 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Checkout and Monitor	3.2.7	Verify that no special automatic checkout provisions are required in the design by component and engine evaluation.	4.1.5.7.2 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Service	3.2.8	No special service requirements are permitted in the pumps' design over its useful life.	4.1.5.7.3 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Access	3.2.9	Verify that the design does not restrict access to hardware attach points demonstrating on an engine and component tests.	4.1.5.7.4 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Handling	3.2.10	Verify that the pump design includes attach points for handling of the turbopump by a component and engine evaluation.	4.1.5.7.5 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Repair	3.2.11	Demonstrate a 60 start capability without any repair activity.	4.1.5.7.6 d 4.1.3.4.2 e	10/90 ns 12/91 ns	
Environment	3.3				
Ambient, Storage and Exposure	3.3.1	Verification by analysis.	4.1.6.1 a 4.1.6.2 a 4.1.6.3 a	tbs tbs tbs	
Acceleration and Ground Handling	3.3.2	Verify that the pump can withstand the environmental loads specified without detrimental deformation, structural failure or degradation of reliability.	4.1.6.1 a 4.1.6.4 a	tbs tbs	
Vibration, Shock and Acoustic	3.3.3	Verify that the pump can withstand the vibration, acoustic and shock requirements specified in the CEI spec by analysis.	4.1.6.4 a	tbs	
Corrosion	3.3.4	Verify that the design conforms to the listed specs by analysis and component testing.	4.1.6.2 a 4.1.4.3.1.7 d	tbs 10/90 ns	
Contamination	3.3.5	Verify by submittal of a Contamination Control Plan.	4.1.6.5 a	9/88 comp	19836

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Moisture	3.3.6	Verify that moisture will be prevented from existing in the IPS prior to propellant entry by analysis.	4.1.6.6 a	comp	
Fungus Resistance	3.3.7	Analysis to verify that no fungus nutrient materials are used.	4.1.6.7 a	comp	
Design Criteria	3.4				
Structural Criteria	3.4.1	Verification is to be by the establishment of design criteria manual.	4.1.7.1 a	comp	
Safety Factor Criteria	3.4.1.1				
Pressure Vessel Struct-ural Criteria	3.4.1.2				
Limit Load Conditions	3.4.1.2.1	Verify that the limit Pressure values have been established by an analysis which considers the worst operational values.	4.1.7.3 a	comp	
Pressure Vessel Proof Criteria	3.4.1.2.2	Verify that the proof pressures have been specified in accordance with section 3.	4.1.7.4 a	comp	
Pressure Vessel Burst Criteria	3.4.1.2.3	Verify that the proper burst pressure has been chosen.	4.1.7.4 a	comp	
Fatigue Criteria	3.4.1.3	Verify that the fatigue criteria is satisfied for all components.	4.1.7.5 a	comp	
Fracture Control Criteria	3.4.1.4	The pump's fracture control criteria is defined in FR 19793-1 and all ATD components shall conform to the FCP.	4.1.2.9 a	comp	19793-1,2

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
P&W Mil Specs and Standards	3.5				
P&W Mil Specs and Standards	3.5.1	Verify that the section 2 listed documents are used, when applicable by analysis.	4.1.8.1 a	comp	
Standards	3.5.2	Verify the turbopump design by reviewing the engineering drawings and specs, and ensuring all requirements have been followed.	4.1.8.1 a	comp	
Parts	3.5.2.1	Ensure that MC, MS, AN or MIL standard parts are used whenever they are suitable and identified by standard part numbers.	4.1.8.1 a	comp	
Design	3.5.2.2	Ensure that MC, MS, NAS design standards are used whenever possible.	4.1.8.1 a	comp	
Threads	3.5.2.3	Ensure threads conform to the requirements of MIL-S-8879 class 3A or 3B.	4.1.8.1 a	tbs	
Parts List	3.5.2.4	Verify that the pump parts list reflects the part numbers called out by the drawings that sucessfully completes preliminary or final flt cert.	4.1.8.1 a	tbs	
Dimensional Units	3.5.2.5	Unless otherwise specified, all units shall be in the English system.	4.1.8.1 a	comp	
Material Properties	3.5.2.6	Verify that the pump conforms to the Materials Control Plan by ensuring that the drawings use approved design properties.	4.1.8.1 a	comp	19673-2
Materials	3.5.2.7	Submittal of a Materials Control Plan (FR 19673-2) shall be used to verify this requirement.	4.1.8.1 a	comp	19673-2
Processes	3.5.2.8	Verify that the processes used conform to the MCP and the Manufacturing Plan.	4.1.8.1 a	comp	19673-2 19685-2
Welding Processes	3.5.2.9	Verify that welds are made in accordance with PWA 16, MSFC-SPEC 560 and MSFC-STD-655 by incorporating and implementing these specs	4.1.8.1 a	comp	
Parts and Materials Pgm.	3.5.2.10	Verify that the design uses parts that have been qualified as meeting the the performance, reliability, and quality requirements.	4.1.8.1 a	tbs	
Flammability LOX/GOX and Propellant Compatability	3.5.2.11	Ensure conformance to NHB 8060.1B ("... Test Procedures for Materials That Support Combustion") and NAS 1113 ("Requirements for Materials Exposed to High Pressure LOX/GOX").	4.1.8.1 a	tbs	

Design Req'ments	DR #	Verification Method (V.M.)	Sect.	Status	VCR #
Material Selection List	3.5.2.12	Verify by submission of a MSL and MUA.	4.1.8.1 a	tbs	
Hydrogen Embrittlement	3.5.2.13	Verify that materials exposed to hydrogen which are not rated "A" as defined in MSFC-HDBK-527 are submitted to NASA via an MUA.	4.1.8.1 a 4.1.8.1 b	tbs tbs	
Braze Proc.	3.5.2.14	Verify that braze processes meet the requirements of the ATD Materials Control plan by reviewing drawings, prints, ect.	4.1.8.1 a	comp	
Failure, Mode Effect and Criticality Analysis	3.6				
Failure, Mode Effect and Criticality Analysis	3.6.1	Verification is to be by submittal of a FMEA and a CIL.	4.1.5.7.8 a	comp	
Safety	3.6.2	Verify that the pump is designed to minimize hazards that could result in injury or damage by performing a hazard analysis.	4.1.5.5 a	3/90 iw	
Failsafe Design	3.6.3	Ensure that in the event of a single failure in any external functional component, that the pump is capable of safely shutting down by performing a hazard analysis.	4.1.5.5 a	3/90 iw	
System and Design Analysis Results	3.7				
Design Verification Test Plan	3.7.1	Verification test plans for the bearing and IPS rigs, E-8 and TTB and NSTL testing shall be submitted per SE-07.	4.0 a	as required	
DVS Status Report	3.7.2	A report (monthly) of the status of progress shall be provided in accordance with SE-11.	4.5 a	as required	
Verification Complete Package	3.7.3	Submit VCP's (as required) per SE-12.	4.6 a	as required	