National Aeronautics and
Space Administration

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ATTACHMENT B
PERFORMANCE SPECIFICATION
FOR
TVC TURBINE PUMP ASSEMBLY

RFP NNC06ZDD033R
(Revision A)

Approved for Public Release; Distribution is Unlimited

DOCUMENT HISTORY LOG

REVISION LETTER	DESCRIPTION OF CHANGE	DATE	APPROVED
Initial	Initial Release of Specification		
Revision A	Section 3.2.1.4—Change of propellant consumption rates from 0.056 and 0.026 lbm/sec to TBD lbm/sec.	12/20/06	Tony Shook/ Tony Nerone

TVC Turbine Pump Assembly (TPA) Performance Specification

1. Background

This specification establishes the performance, design, development, and test requirements for the Thrust Vector Control (TVC) Turbine Pump Assembly (TPA) used for primary hydraulic power supply on the Upper Stage of Ares I (also known as the Crew Launch Vehicle). The purpose of this document is to provide potential proposers with a snapshot of the requirements as they currently stand; however, the exact values are subject to change as the vehicle configuration and/or mission evolves. These requirements may also be changed based on input from the Turbine Pump Assembly Contractor or other Ares I Contractors.

Classification

This specification applies to Engineering Model hardware and Flight Production hardware. If there are differences between the Engineering Model and Flight Production specifications, they will be noted.

1.1. Mission Profile

Typical mission profiles for Ares I are provided in Figures 1 and 2.

Mission Profile – Lunar Mission (24 Aug 06)

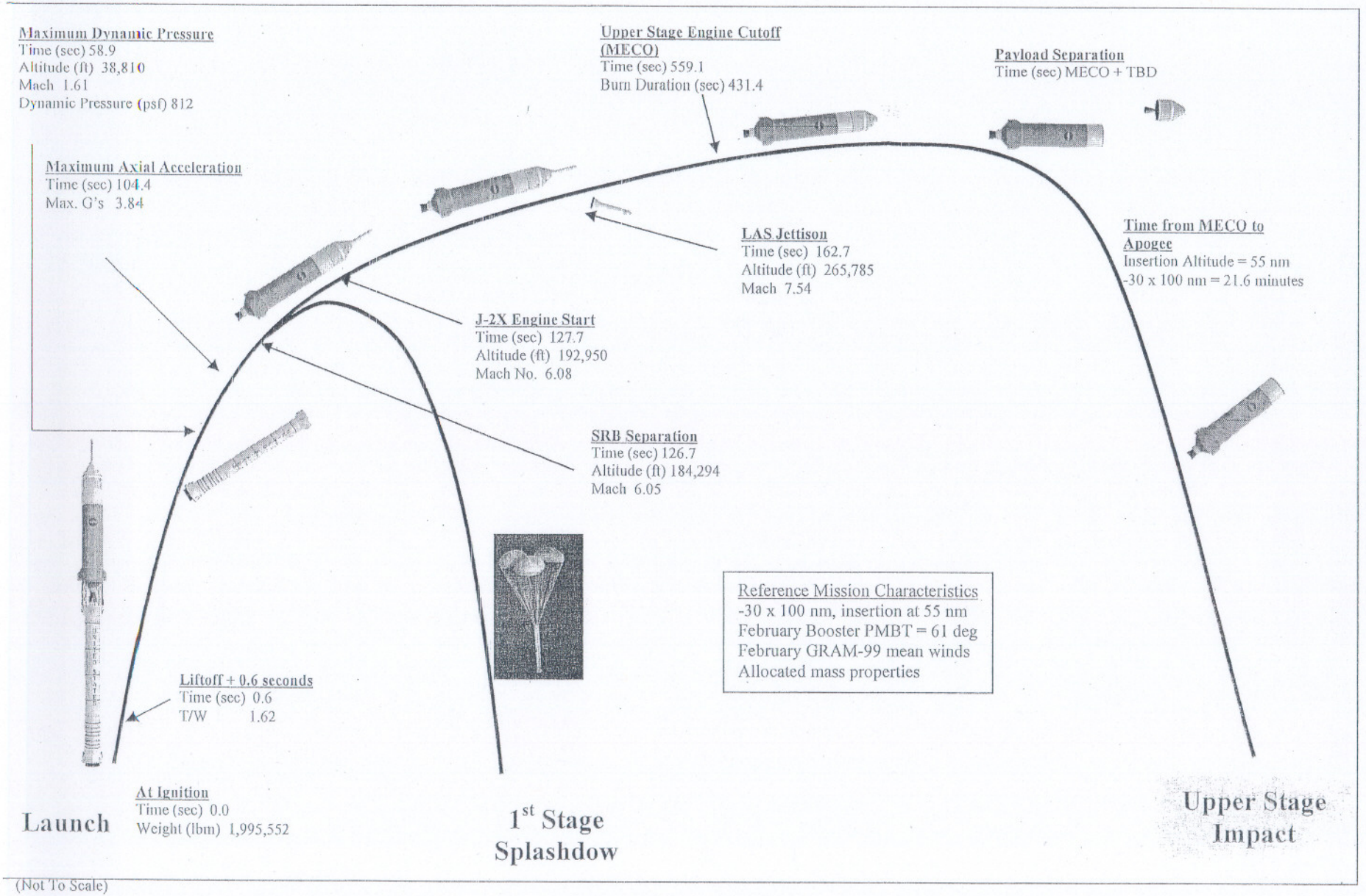

Figure 1. Ares I Lunar Mission Profile

Mission Profile – ISS Mission (24 Aug 06)

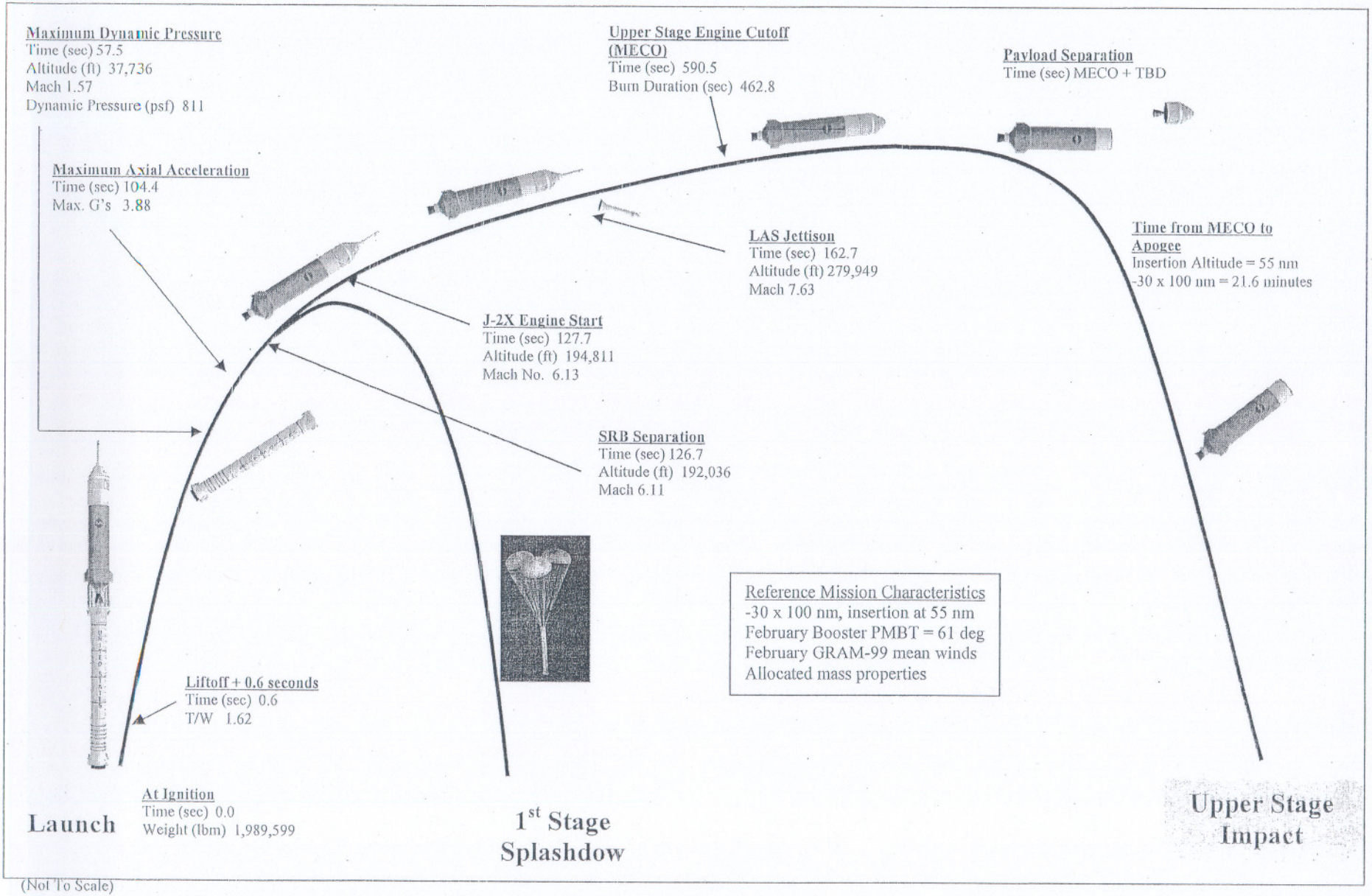

Figure 2. Ares I ISS Mission Profile

2. Applicable Documents

2.1. Government Documents

The following documents (of the exact issue shown) form a part of this specification to the extent referenced herein. In the event of a conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

STANDARDS

TBD

Table 1. Reference Documents TBD

3. Technical Requirements

3.0 Item Definition

The Turbine Pump Assembly will provide the primary hydraulic power to the hydraulic actuator to gimbal the J-2X engine of the Ares I upper stage. The assembly includes:

1. Turbine Assembly
2. Nozzle and Exhaust Housings
3. Propellant Control Valve (interface with GN&C)
4. Mechanical Speed Control (integral with TPA)
5. Hydraulic Pump (variable positive displacement with pressure compensation)
6. Gearbox/Governor (if required)

3.1. Physical Requirements

3.1.1. Interface Definition

The Turbine Pump Assembly has interfaces with: 1) the Upper Stage Main Propulsion System (MPS), 2) other Upper Stage subsystems such as power, command and data, and 3) other Thrust Vector Control assemblies

3.1.1.1 Vehicle Interfaces

The TPA shall interface with the Ares I upper stage thrust cone for mounting. Propellant will be supplied via an interface with the upper stage main propulsion system.

3.1.1.1.1 TPA Mounting Provisions

TPA to vehicle mounting provisions are specified in figure TBD.

3.1.1.2 Other Upper Stage Subsystem Interfaces

3.1.1.2.1 Interfaces with Structure

3.1.1.2.1.1 Structure to TPA Interface

Each TPA shall interface with the Upper Stage thrust structure at the TPA mounting points as shown in figure TBD.

3.1.1.2.1.1.1 TPA Mounting Provisions

TPA to structure mounting provisions are specified in figure TBD.

3.1.1.2.1.2 Structure to TPA Propellant Control Valve

The TPA propellant control valve shall be mounted to the Upper Stage structure at the location shown in figure TBD.

3.1.1.2.1.2.1 Mounting Provisions

The propellant control valve mounting provisions are specified in figure TBD.

3.1.1.2.2 Interfaces with MPS

3.1.1.2.2.1 MPS to Propellant Control Valve

The TPA propellant control valve shall interface with the Upper Stage MPS LH_2 re-pressurization line for TPA propellant (GH_2) per TBD.

3.1.1.2.3 Interface with GN&C

3.1.1.2.3.1 Propellant Control Valve to GN&C

The TPA propellant control valve shall interface with the Upper Stage GN&C to receive commands to open and close the flow of MPS hydrogen to the TPA.

3.1.1.3 Interfaces with the Thrust Vector Control Subsystem

3.1.1.3.1 Supply and Return Pressure

The TPA shall meet the hydraulic supply and return pressures shown in *Table XX*.

3.1.1.3.2 Hydraulic Fluid

The TPA shall perform in accordance with the requirements herein when using hydraulic fluid conforming to MIL-H-83282 (or equivalent).

3.1.2 Physical Properties

3.1.2.1 Overall Envelope

The TPA envelope shall not exceed the dimensions shown on figure TBD with a total volume not to exceed 5000 in^3.

3.1.2.2 Turbine Pump Assembly Mass

The total mass of the Turbine Pump Assembly shall not exceed 105 lbm. This includes containment provisions and any redundancy required.

3.2. Characteristics

The TPA shall be a gas turbine driven positive displacement hydraulic pump assembly.

3.2.1. Assembly Performance

Unless otherwise specified, the Turbine Pump Assembly shall meet the specified performance requirements.

3.2.1.1. Turbine Propellant Inlet Conditions

The TPA shall operate using both GHe and GH_2. Hydrogen is the propellant to be used for upper stage ascent and therefore is the propellant to which the

TPA should be optimized. Helium will be used for ground/pad check outs. *Table X* contains the required gas inlet conditions for the TPA turbine inlet.

Table X

Hydrogen (GH_2)	Pressure (psia)	Temperature (R)
Condition 1	1562	476
Condition 2	1364	414
Condition 3	1485	476
Helium (GHe)	**Pressure (psia)**	**Temperature (R)**
Condition 1	750	530
Condition 2	750	635

3.2.1.2. Hydraulic Pump Performance

The hydraulic pump shall be a variable displacement positive displacement pump with pressure compensation per *MIL-P-19692* that can operate using hydraulic fluid that meets *MIL-H-83282 (or equivalent)*. The pump will be incorporated into a Type II hydraulic system per *MIL-H-5440H*. The performance specifications are shown in *Table XX*.

Table XX

Performance Characteristic	Value Required
Inlet Temperature	35-240^{0}F
Inlet Pressure	50-100 psia
Maximum Outlet Pressure	3000-3200 psia
Maximum Flow Rate	25 GPM
Rated Efficiency	85% Minimum

3.2.1.2.1. Hydraulic Pump Thermal Conditioning

The TPA hydraulic pump shall have a provision for thermal conditioning of the hydraulic fluid.

3.2.1.3. Speed Control

The TPA shall have a mechanical means of controlling rotational turbine speed.

3.2.1.4. Propellant Consumption

The TPA shall consume GH_2 at a rate of not more than TBD lbm/sec during the first 20 seconds of Upper Stage flight and TBD lbm/sec during the remaining 450 seconds of Upper Stage flight. At these consumption rates, the TPA shall provide full hydraulic performance. The Contractor shall supply NASA with the GHe consumption rates for ground check outs.

3.2.1.5. Containment

The TPA shall have integral containment to fully contain the rotating turbine assembly in the event of catastrophic turbine failure including tri-hub burst.

3.2.1.6. Over-Speed Protection

The TPA shall have protection against over-speed of the turbine by TBD method.

3.2.1.7. Start-Up Time

The TPA shall provide full performance per *Table XX* within 1 second of TPA start-up initiation (definition TBD).

3.2.1.8. Dynamic Seal Leakage

External leakage through the TPA dynamic seal and propellant seals shall be measured by a TBD pressurization method. There shall be no evidence of leakage when TBD psig of TBD gas is applied to these seals.

3.2.1.9 External Leakage

There shall be no external fluid leakage from static oil seals. Seepage from seals insufficient to form a drop shall not be considered leakage

3.2.1.10 Response to Failures

The Turbine Pump Assembly shall report pertinent parameters that determine health status to GN&C.

3.2.1.11 Thermal Control

The Turbine Pump Assembly shall not require heating or cooling during flight unless otherwise specified.

3.2.2. Electrical Design

3.2.2.1. Electrical Bonding and Grounding

The Turbine Pump Assembly shall meet the electrical bonding requirements of NASA-STD-4003 as necessary in order to meet the E3 requirements of this document.

3.2.2.2. Instrumentation

3.2.2.2.1. Health and Status

The Turbine Pump Assembly shall provide instrumentation to determine the health and status of the assembly per TBD.

3.2.2.2.2. TPA Speed

The Turbine Pump Assembly shall provide TPA turbine speed feedback to the GN&C at a rate of TBD as defined in the TVC /US IRD

3.2.2.3. Electromagnetic Compatibility

The Ares I TVC will tailor to MIL-STD-461E, "Requirements for the Control of Electromagnetic Interference (EMI) Characteristics of Systems and Equipment" to assist in establishing the Orion/Ares I requirements to meet the overall Electromagnetic Compatibility (EMC) requirements for the Turbine Pump Assembly. This tailoring will be documented in an Orion/Ares I Electromagnetic Environmental Effects (E3) Control Plan(s).

3.2.3. Failure Redundancies

3.2.3.1. TPA Mechanical Speed Control

The TPA mechanical speed control shall be TBD fault tolerant.

3.2.3.2. TPA Propellant Control Valve

The TPA control valve shall be TBD fault tolerant.

3.2.3.3. TPA Speed Sensor

The TPA speed sensor shall be TBD fault tolerant.

3.2.4. Life Requirements

3.2.4.1. Turbine Pump Assembly Life Cycle

The Turbine Pump Assembly shall be designed for a combined flight and ground operation time of TBD seconds after delivery without maintenance. Lifetime cycle loads, amplitudes and rates are defined in table TBD. Total operating life of the Turbine Pump Assembly shall be TBD seconds minimum.

3.2.4.2. Turbine Pump Assembly Shelf Life

The Turbine Pump Assembly shall meet or exceed a shelf life of 6 years without need for repair or refurbishment.

3.2.4.3. Turbine Pump Assembly Pad Stay Time

The Turbine Pump Assembly shall remain mission capable for a duration of up to 70 days while the vehicle is in the vertically mounted (fully stacked) configuration at the launch pad.

3.2.4.4. Integrated Space Vehicle Checkout

The Turbine Pump Assembly shall allow for complete end-to-end static and dynamic functional verification testing in 30 minutes and without manual flight or ground system reconfiguration.

3.2.4.5. TVC Subsystem Servicing on Launcher—Pad Commodity Servicing

The Turbine Pump Assembly shall not require any hazardous commodity servicing on the launcher or at the launch pad

3.2.4.6. Turbine Pump Assembly Servicing on Launcher—Pad Arms and Umbilicals

TBD

3.2.4.7. Turbine Pump Assembly Failure Notification

The Turbine Pump Assembly shall provide notification to GN&C so that Orion and ground can be informed within TBD milliseconds of a failure which could result in any of the following: loss of human life, loss of vehicle, or loss of mission.

3.2.5. Maintainability

3.2.5.1. Scheduled Maintenance Allowance

The Turbine Pump Assembly shall not require scheduled maintenance unless approved by NASA.

3.2.5.2. Replaceability

The Turbine Pump Assembly shall be designed to allow a failed subassembly i.e.: the TPA or the propellant control valve or part, to be easily replaced.

3.2.5.3. Precluding Special Tools

The Turbine Pump Assembly shall be designed to preclude the use of special tools and equipment for site maintenance and repairs except as approved by NASA.

3.2.5.4. Requirements for Special Tools

Special tools, if required and approved by NASA, shall be designed to withstand the intended use for 20 years. The special tools shall be provided as GSE, in quantity TBD

3.2.5.5. Prevention of Misconnection

Where similar connectors are in close physical proximity, the design shall preclude the capability of cross-connection.

3.2.5.6. Prevention of Incorrect Installation

All unidirectional components shall be designed to preclude backward installation by using non-symmetry of configuration, different connector sizes, color coding, labeling or comparable means.

3.2.5.7. GSE (Ground Support Equipment) Attachments

Provisions shall be provided on the TPA for attaching any necessary GSE for verification activities including lifting/handling and subsequent operation of the equipment.

3.2.5.8. Calibration and Adjustment

The Turbine Pump Assembly shall not require on-vehicle adjustments or calibration permitted except as identified and approved by NASA.

3.2.5.9. Pre-Installation Acceptance and Checkout

The Turbine Pump Assembly design shall accommodate acceptance checkout prior to installation.

3.2.5.10. Mounting and Installation

Mounting provisions shall permit Turbine Pump Assembly removal and replacement by using standard hand tools.

3.2.5.11. Provisions for Visual Position Verification

The design of the TPA shall provide for visual verification of the TPA position with the TPA installed or removed from the vehicle.

3.2.5.12. Accessibility and Marking of Service and Test Ports

Servicing and test points shall be accessible and clearly marked. This is a flight design phase requirement.

3.2.5.13. Tool Clearances

The TPA design shall provide adequate tool clearances for all removable of all parts except as approved by NASA. This requirement shall include consideration of removal of the Turbine Pump Assembly without removal of any other functioning hardware, plumbing, or wiring whenever practical. Wire bundle accessibility shall be provided without invalidating other wiring circuits or their related equipment. Accessibility to threaded fasteners will be accomplished without the use of universals, angular extensions, handle extensions, or combinations thereof, in conjunction with torque tools. This is a flight design phase requirement.

3.2.5.14. Protection Against Collateral Damage During Maintenance

Protection of subcomponents susceptible to damage during maintenance of the Turbine Pump Assembly or adjacent equipment in the Upper Stage shall be provided to minimize risk of collateral damage

3.2.5.15. NDE Compatibility

Capability shall be provided to permit use of nondestructive evaluation (NDE) inspection equipment for fracture critical structural areas as defined by NASA.

4. Operational Requirements

4.1. Pre-Launch Check

The Turbine Pump Assembly shall allow for a full hydraulic pressure for hydraulic system checkout.

4.2. TVC Turbine Pump Assembly

The Turbine Pump Assembly shall be tested, calibrated, and certified by NASA and arrive at the integration site ready for upper stage vehicle integration and integrated Ares I/Orion checkout.

4.3. Mission Duration

The Turbine Pump Assembly shall be capable of operation for the 600 second mission from launch to upper stage main engine cut-off (MECO).

4.4. Operation Termination

The Turbine Pump Assembly shall terminate operation at upper stage main engine cut-off.

4.5. Launch Delays

The Turbine Pump Assembly shall be mission ready within 24 hours after a launch delay.

4.6. Launch Ready State

Turbine Pump Assembly servicing shall be complete prior to main propellant loading.

4.7. Automated Ascent Operations

The Turbine Pump Assembly shall operate as a fully automated system (via US GN&C) from lift-command until Orion separation.

4.8. TVC Functionality During Ascent

The Turbine Pump Assembly shall be fully functional while the Ares I is in the horizontal and/or vertical position.

4.9. TVC Launch Opportunities

The Turbine Pump Assembly shall support a daily launch opportunity of not less than 4 consecutive days.

4.10. TVC Launch Ready State

The Turbine Pump Assembly shall remain in a launch ready state for a period of not less than 2.5 hours.

5. Environmental Requirements

5.1. Flight Environment

The following environments are applicable to the flight operational performance requirements of the Turbine Pump Assembly both individually and in any feasible combination. The Turbine Pump Assembly shall perform as specified in section 3 of this specification during and after exposure to these environments.

a. Pressure	Maximum: TBD psia. 1. Minimum: TBD Torr. 2. Line Internal Transient: TBD psi/sec
b. Temperature	From minus TBD°F to plus TBD°F. 1. Transient TBD°F to TBD°F at TBD°F per second
c. Random Vibration	Maximum random vibration occurs at liftoff, transonic, and qmax; and during main engine operation. These vibrations will not exceed the following:
Main engine burn for vehicle aft fuselage locations	Acceleration spectral density increasing at the rate of 6 dB/octave from 20 to 60 Hz; constant at 0.05 g2/Hz from 60 to 300 Hz; increasing at the rate of 6 dB/octave from 300 to 700 Hz; constant at 0.3 g2/Hz from 700 to 2000 Hz. The excitation occurs for a duration of 8 minutes per mission. The grms for the environment is equal to 21.3 grms.
d. Solar Constant	443.7 Btu/ft^2/hour.
e. Rain (Surface to 32,800 ft)	Surface extreme rates of 19 inches in 24 hour period 1. maximum including short period extremes of four inches for one hour. Adjust for altitude as follows:

TABLE IX. Rain Correction for Altitude

Altitude (Ft.)	Percent of Surface Rate
0	100
3,280	90
6,560	75
9,840	57
16,400	15
26,240	1
32,800	0.1

f.	Acceleration	+/- 5 g all axes.
g.	Transient Vibration	Sinusoidal vibration from 5 to 35 Hz at +/- 0.25g and at the sweep rate of one octave/minute.
h.	Altitude	The TPA shall operate from sea level to 400,000 feet

5.2. Checkout Environment

The following environments are applicable to the installed performance requirements of the Turbine Pump Assembly both individually and in any feasible combination. The TVC shall perform as specified in section 3 of this specification during and after exposure to these environments.

External or Uncontrolled Areas:

a.	Pressure	Maximum: TBD psia. Minimum: TBD psia.
b.	Temperature	From minus TBD°F to plus TBD°F. Transient TBD°F to TBD°F at TBD°F per second
c.	Sand and Dust	As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 gram per cubic foot
d.	Humidity	8 to 100 percent relative humidity
e.	Salt Fog	Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight for 30 days.

f. Solar Radiation — Solar radiation of 377.6 Btu/ft^2/hour total normal incident.

g. Rain — Maximum of 19 inches in 24 hour period including short period extremes of four inches for one hour.

h. Hail — Hail (nominal) diameter equals 0.30 inches with a fall velocity of TBD

6. Safety

6.1. TBD

7. Quality Assurance

7.1. General Requirements

The Contractor is to submit a written Verification and Validation Plan for all program phases, to the Government for approval, as specified in the SOW.

7.1.1. General Verification Guidelines and Criteria

The contractor will use the following general guidelines in developing a verification program that shall satisfy the requirements of this specification:

a. Verification of transportation packaging performance shall be accomplished by analysis whenever possible. When verification by analysis cannot be accomplished, then testing shall be performed per the requirements in NPR6000.1.

b. Where new materials or existing materials under new conditions are to be used, adequate testing shall be performed to statistically identify material property values.

b. Application of non-destructive evaluation techniques shall be verified.

c. Verification shall be structured to verify the full range of the design requirements under the specified environments.

d. Wherever practical and technically sound, accelerated life test techniques shall be utilized.

e. Testing shall be conducted at the most cost effective level of assembly.

f. All verification test specimens shall be processed through specified acceptance testing prior to verification test.

g. Where redundancy in design exists, each redundancy shall be verified through normal output sources designed for that purpose.

7.1.2. Methods of Verification

Each performance and design requirement specified in Sections 3, 4 and 5 of this specification shall be verified by inspection, analysis, and/or test defined as follows:

7.1.2.1. Inspection

Verification by inspection is the process of determining compliance to requirements by the review of drawings, data, by examination (visual or visual with aid of NDE) of the item using standard quality control methods, without the use of special laboratory procedures. Inspection also includes evaluation of planning for assurance that considerations are made in the plan to address requirements. This is particularly applicable to the development phase.

7.1.2.2. Analysis

Verification by analysis is the process of utilizing analytical techniques to verify that the requirements are satisfied. Verification by analysis may be used when verification by test is not possible, introduces significant risk into the item, or is not cost effective. Analysis in conjunction with limited testing is an acceptable method where conditions dictate.

7.1.2.3. Test

Verification by test is a method in which technical means such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures are used for the evaluation of components to determine compliance to requirements. Testing shall be selected as the primary verification method when analytical techniques do not produce adequate results. Tests may be used to support analytical techniques and to evaluate large range requirements where test of all conditions is not feasible or cost effective. The analysis of data derived from tests is an integral part of the test program and should not be confused with analysis defined in previous specification sections. Tests shall be used to determine quantitative compliance to requirements and produce quantitative results.

7.1.3. Verification Phasing

The verification of the Turbine Pump Assembly will be structured coincident to the three main program phases, 1) Development, 2) Qualification and 3) Acceptance. The Verification matrix of TBD identifies the phase and verification method for each of the requirements of section 3, 4 and 5.

7.1.3.1. Development

This phase of the verification coincides with the development of the hardware prior to the Critical Design Review (CDR). This verification will establish feasibility of the proposed concepts to satisfy the design prior to authorization to make the flight qualification unit and begin qualification testing. The CDR package will constitute a large portion of the verification data for this phase.

7.1.3.2. Qualification

This phase of verification will coincide with the fabrication and testing of the qualification unit which will verify suitability of the post CDR baselined design with the requirements of this specification under the comprehensive environments and loads defined for the preflight ground and flight operations. The purpose here is to verify that the design meets the requirements of the specification. The first article (qualification unit) acceptance and the qualification test reports will constitute a large portion of this verification package.

7.1.3.3. Acceptance

The acceptance phase of verification will be performed on articles fabricated in accordance with the post qualification design baseline. The acceptance verification will be a subset of the qualification verification implemented in accordance with a cost effective and timely effort to assure compliance with the design baseline. The purpose being to verify that the hardware produced is in compliance with the design baseline. Each article produced will have a unique acceptance verification data package though the content will be similar or identical for each.

7.1.4. Test Conditions

7.1.4.1. Standard Test Conditions

Environmental standard test conditions for tests required by this specification shall be made at an atmospheric pressure of 28.5 plus 2 or minus 4.5 inches of Hg at a temperature of 73 plus or minus 18°F and at a relative humidity of 50 plus or minus 30 percent.

7.1.4.2. Test Tolerances

Test tolerances shall be used as specified in MIL-STD-810 as applicable except as follows:

7.1.4.2.1. Shock (acceleration vs. time)

Peak amplitude: +/-10 %
Pulse duration: +/-10 %

7.1.4.2.2. Acceleration

Specified acceleration: Plus 10 percent
Minus 0 percent

7.1.4.2.3. Measuring Instrumentation

Instrumentation sensitivity shall have one tenth of the tolerance specified for the parameter being measured and shall have current calibration per NIST.

7.1.5. Test Responsibility and Location

The seller shall be responsible for the performance of all inspections and tests. The contractor shall be responsible for implementing any quality assurance requirements. Except as otherwise noted, the seller may use his own facilities, government furnished facility, or any commercial laboratory acceptable to the buyer. NASA/GRC reserves the right to perform any of the inspections necessary to ensure conformance to the requirements of Section 3, 4, or 5.

7.2. Conformance Verification

7.2.1. Development

Development verification will be composed primarily of analyses and inspections of drawings and plans for the implementation of the development program. The development verification provides evidence that the proposed concept is in conformance to requirements and that plans and processes will assure quality control assurance against workmanship or material deficiencies. If the contractor builds and tests prototypes or engineering models in lieu of or to support the analyses these tests shall be performed in the sequence which provides assurance that the test results are representative of the article performance under the test conditions and are repeatable. The sequence identified in TABLE TBD is recommended to provide this assurance. It is advantageous that these tests and inspections shall be performed in a manner and under conditions, which simulate end use to the highest degree practicable however reasonable extrapolation of test

results via analytical techniques is appropriate and allowed. Development verification shall include as a minimum those item described in TABLE TBD.

7.2.1.1. Inspections for Design Compliance

Inspection in the development phase will constitute a review of data presented as evidence that the conceptual design meets or at least addresses all of the requirements identified for verification at this phase of the project. Since the design will be immature, pre CDR, a complete compliance to a baseline design is not expected. It is however necessary for the data package to address all requirements particularly those associated with design features and functions. Assurance that the proposed concept is feasible will be goal of this activity. Alternative methods to be pursued as risk abatement is acceptable however each of the alternate concepts shall have feasibility for all requirements.

7.2.1.2. Inspections for Process Compliance

Inspections of the processes to be implemented in the Qualification and Acceptance phases will be performed to verify that the necessary level of quality control is provided to assure compliance and repeatability. All development phase verification requirements denoted as inspections in TABLE TBD Shall be addressed in the data package.

7.2.1.3. Development Analyses

The analyses provided for verifications will provide a high level of confidence that the proposed concept will result in compliance with requirements. Since the design is immature analyses may not be based on a final design configuration, however the risks associated with configuration changes must be quantified.

7.2.1.4. Development Tests

No specific development tests are required. Tests on prototypes or engineering models may be used to add validity to the analyses provided for development verification. Tests will be evaluated to a high level of scrutiny with respect to applicability to the proposed concept and its configuration. The controls and processes used in the test will also be subject to a high level of scrutiny.

7.2.2. Qualification

Qualification shall be performed in the sequence specified in TABLE TBD on all deliverable Qualification assemblies. This verification demonstrates conformance of the design to the entire range of end item requirements. Pre test inspections and functional tests will be used to provide quality control assurance against

workmanship or material deficiencies for the test article. These pre Qualifications tests and inspections will include all planned Acceptance verification. These tests and inspections shall be performed in a manner and under conditions, which simulate end use to the highest degree practicable, affordable and feasible with the understanding that the Qualification article may be used up at the end of the Qualification program. The sequencing provided in the table and the Qualification test planning will take this life limited aspect into consideration with the assumption that only one Qualification unit will be used in the program. The degree, duration, and number of tests and pre/post test inspections shall be sufficient to provide assurance that the quality required is present prior to and maintained throughout the verification activity. Qualification shall include as a minimum those item described in TABLE TBD. In addition the contractor shall identify and perform those other pre Qualification tests deemed necessary by the contractor to ensure successful evaluation of the test item.

7.2.2.1. Qualifications Inspections

Qualification inspections shall be used to verify that the qualification unit is in compliance with the baselined design, manufacturing and procurement requirements as defined in the drawings and specifications. Inspections shall be made to the process paperwork to assure that all quality assurance provisions have been implemented in the test program procedures. All test equipment used in the test program will be inspected to assure compliance with the test program plans and procedures.

7.2.2.2. Qualification Analyses

Analyses used as part of Qualification shall provide undisputable evidence that the design is in compliance with the requirements of this specification. If necessary, analysis combined with test results may be combined to provide this evidence. Every aspect of, and the entire range of environments and loads will be addressed by analysis or an actual test. Analyses will be traceable to the paragraphs of this specification and the specific revision level of the design drawings and related documentation.

7.2.2.3. Qualification Tests

7.2.2.3.1. Qualification Test Hardware

Qualification test hardware shall be of the same configuration as the delivered flight hardware. All Qualification testing shall be performed on a single serial number unit unless otherwise necessary based on life requirements and otherwise approved by NASA. Spare or additional qualification units may be incorporated into the test program as provided by the statement of work to mitigate risk due to loss of unit, i.e.

unrecoverable failure of the qualification unit, during testing, and only with the written approval of NASA.

7.2.2.3.2. Performance Tests

The functional performance tests on the TPA shall be tested in flight configurations and under flight environments. As a minimum these tests shall include nominal, and worst case environment functional tests for each of the requirements identified in TABLE TBD.

7.2.2.3.2.1. Vibration Test

Perform vibration tests on the TPA as specified below:

Vibration Test information TBD.

7.2.2.3.2.2. Life Cycle Test

a. TBD

7.2.2.4. Weight

The test Turbine Pump Assembly shall be weighed and recorded in lbs to 2 decimal places.

7.2.2.5. Identification of Center of Gravity (CG) and Moment of Inertia

The test Turbine Pump Assembly shall have the CG and moment of inertia measured in inches to 2 decimal places.

7.2.2.6. Post Test Inspection

Disassemble and visually inspect the TPA. Record any evidence of degradation, contamination, and/or excessive wear.

7.2.2.7. Explosion Proofing

The TPA shall pass explosion proofing test in accordance with MIL-STD-810 method 511.4.

7.2.2.8. Lifting Equipment Proof Test

Lifting equipment GSE for the Turbine Pump Assembly handling shall be proof tested in accordance with requirements of NASA-STD-8719.9.

7.2.2.9. Electrical Protection Devices

Electrical protection devices shall be tested before use to verify intervention when power is applied in reverse polarity. This test shall be performed before application of power to the test unit.

7.2.2.10. NDE Compatibility

The test TPA shall be subjected to Non-Destructive Evaluation (technique to be selected by GRC/NASA) for compatibility assessment.

7.2.3. Acceptance

Acceptance verification shall be performed in the sequence specified in TABLE XVII on all deliverable assemblies. This verification demonstrates conformance to requirements and provides quality control assurance against workmanship or material deficiencies. These tests and inspections shall be performed in a manner and under conditions, which simulate end use to the highest degree practicable without damage to the assemblies. The degree, duration, and number of tests and pre/post test inspections shall be sufficient to provide assurance that the quality required is present prior to and after Acceptance verification. Acceptance verification shall include as a minimum those item described in TABLE TBD. In addition the contractor shall identify and perform those other tests deemed necessary by either the contractor or NASA to ensure successful operation of the deliverable assemblies.

TABLE XVII. Acceptance Verification Sequence

Test	*Sequence Order*
Examination of Product	1
Ambient Functional	2
Design Features	3

7.2.3.1. Examination of Product

Each Turbine Pump Assembly shall be carefully examined to determine conformance to the requirements of this specification. Particular attention shall be given to valve performance, weight, workmanship, finish, dimensions, construction, cleanliness, identification markings, traceability level, and that certified materials and processes have been used. Locking inserts shall be individually inspected to verify proper installation.

8. Delivery Requirements

The requirements specified herein govern the preparation for shipment and the transport of the item to all Government facilities. The methods of preservation, packaging, and levels of packing used for shipment, together with the necessary special control during transportation, shall be in accordance with NPR6000.1 G The item shall adequately be protected from damage and degradation of performance due to the natural and induced environments encountered during transportation and subsequent storage.

8.1. Preservation Requirements

Preservation methods shall include the application of protective measures and materials to maintain the item within the appropriate cleanliness levels and to prevent damage or degradation in reliability or performance of the item when exposed to the natural and induced ground based transportation and ground handling environments. The requirements for preservation methods and levels of protection shall be in accordance with NPR6000.1 G.

8.2. Packing Requirements

Packing shall include special design containers used for the transportation and storage of the item. Packing shall be used in conjunction with the appropriate preservation methods, handling procedures, and methods of transport to prevent damage or degradation in reliability or performance of the item when exposed to the natural and induced ground based transportation and ground handling environment. Packing requirements shall be in accordance with NPR6000.1 G and supplemented by the following paragraphs.

8.3. Monitoring Devices

Use of instrumentation for monitoring or recording in-transit environments (e.g. shock, vibration, temperature, etc.), shall be approved by GRC prior to implementation.

8.4. Packaging of Precision Clean Items

Prior to packaging in accordance with NPR6000.1 G, items cleaned to the level of cleanliness specified in paragraph 3.3 shall first be pre-packaged to assure maintenance of the prescribed cleanliness level. Materials and methods of packaging shall be in accordance with MSFC-SPEC-164 B.

8.5. Temporarily Installed Hardware Identification

All temporarily installed devices such as caps, plugs, covers, support bracketry, protective plates, etc., shall be highly visible, red in color or shall have attached

highly visible red colored streamers to ensure that they are easily identified under casual observation.

8.6. Marking for Shipment

Interior and exterior containers shall be marked and labeled in accordance with NPR6000.1 G and MIL-STD-129 P including precautionary markings necessary to ensure safety of personnel and facilities and to ensure safe handling, transport, and storage. NASA Critical Item Label (NASA Form 1368) shall be applied in accordance with NPR6000. The following identification information on interior and exterior containers shall include as a minimum:

a. NASA Contract Number
b. Item Name
c. Manufacturer's Part Number
d. Serial Number
e. Manufacturer's Name
f. Manufacturer's Cage Code Number
g. Quantity
h. Cleaning Marking – Add the words "THIS PART HAS BEEN CLEANED TO LEVEL _____ OF MSFC-SPEC-164 B."
i. Gross Weight

9. Notes

9.1. Definitions

9.1.1. Design Burst Pressure

Design burst pressure is the maximum operation pressure multiplied by the design factor of safety.

9.1.2. Failure

The inability of a system, system, component, or part to perform its required function within specified limits and under specified conditions for a specified duration.

9.1.3. Limit Pressure

Limit pressure is the maximum differential pressure to which the structure will be subjected under specified conditions of operation. Limit pressure is defined as the relief valve nominal pressure plus its tolerance and plus hydrostatic head.

9.1.4. Operating Cycles

The cumulative number of times an item completes a sequence of activation and return to its initial state; e.g., a switched-on/switched-off sequence, a valve-closed/valve-opened sequence, a tank pressurized/depressurized.

9.1.5. Operating Life

The specified operating time/cycles which an item can accrue before replacement or refurbishment without risk of degradation of performance beyond acceptable limits.

9.1.6. Shelf Life

The period of time, during which an item can remain in storage without having its operability affected. Preventive maintenance, servicing, and replacement of age-sensitive material and parts shall be permitted on a scheduled basis during the storage period.

9.1.7. Ultimate Factor of Safety

The ultimate factor of safety is applied to the specified limit loads to produce design loads which, when exceeded, would result in failure of the structure.

9.1.8. Useful Life

The item's total life span including operating life and storage with normal preventive maintenance, servicing, repair, and replacement of parts before item is considered unacceptable for further usage. This life span may be equal to (throw away), or greater than (repair, refurbish, etc.) the specified operating life.

9.1.9. Yield Factor of Safety

The yield factor of safety is applied to the specified limit loads to provide design loads which, when exceeded, would result in permanent deformation of the structure.

9.1.10. Batch/Lot

A batch or lot is defined as all material manufactured in one continuous production run or lot of each ingredient.

9.2. Abbreviations and Acronyms

Abbreviations and acronyms used in this specification are defined as follows:

A	Analysis
CDR	Critical design review
CEV	Crew Exploration Vehicle
CG	Center of Gravity
db	decibel
dc	Direct Current
E	Exempt from Traceability
E3	Electromagnetic Environmental Effects
ECF	Environmental Correction Factor
EEE	Electronic/Electrical/Electromechanical
ELP	Electrical Power Loss
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
F	Fahrenheit
ft	Foot or feet
ft^2	Square foot or feet
g	Gravity
GN2	Gaseous nitrogen
GN&C	Guidance Navigation & Control
GSE	Ground Support Equipment
He	Helium
H_2	Hydrogen
Hg	Mercury
hr	Hour
Hz	Hertz (cycles per second)
I	Inspection
lb	Pound
lbm	Pound mass
lbf	Pound force
LRU	Line Replaceable Unit
MEOP	Maximum Expected Operating Pressure
MSFC	Marshall Space Flight Center

NA	Not applicable
NASA	National Aeronautics and Space Administration
NDE	Non-destructive evaluation
NIST	National Institute of Standards and Traceability
N_2	Nitrogen
O_2	Oxygen
psi	Pounds per square inch
psia	Pounds per square inch absolute
psid	Pounds per square inch differential
psig	Pounds per square inch gauge
rms	Root mean square
SCCS	Standard cubic centimeters per second
SCIM	Standard cubic inches per minute
sec	second
STD	Standard
T	Test
TBD	To be determined by buyer or seller after award of contract
TBS	To be supplied
TPA	Turbine Pump Assembly
Ts	Serial traceability
T_L	Lot Traceability
vdc	Volts direct current
vs	versus