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Fluids and Combustion Facility Document

Specification Control Document for the Design, Fabrication, and Test of the Water Flow Control Assembly

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Change Record

Rev.	Effective Date	Description
Initial Release	5/26/04	Conversion of contract specification into a FCF Project Document. This document represents the "As-Delivered" configuration of the FCF hardware delivered under contract NAS 3-00095.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose

This Specification Control Document (SCD) sets forth the requirements for the design, fabrication and test of the Water Flow Control Assembly (WFCA). The WFCA is hardware that will be a part of the Water Thermal Control Subsystem (WTCS) being used to remove heat from the Fluids and Combustion Facility (FCF) racks.

This SCD sets forth the requirements of the WFCA's major components:

- Flow Control Valve
- Flow Sensor
- Valve Controller

The major components are separate from each other and able to be mounted individually in different areas of the Rack.

1.2 Scope

This document provides the procurement salient specifications for the Water Flow Control Assembly utilized in the Fluids and Combustion Facility. This document is applicable to the hardware procured under the National Aeronautics and Space Administration (NASA) contract NAS 3-00095. The contract was with Preece Incorporated and their overall part number is N1059.

2.0 REFERENCES

2.1 Applicable Documents

Document Number	Document Title
MIL-C-38999J Series III	Connectors
MIL-STD-1246C	Product Cleanliness Levels and Contamination Control Program, Rev. C
MSFC-DOC-2142	Thermal Requirements for Qualification and Acceptance Testing
MSFC-Form-847	Deviation/Waiver Approval Request (DAR)
MSFC-PLAN-2854	Materials Science Research Rack-1 EEE Parts Program Plan
MSFC-STD-2903	MSFC Tailoring Guide for NASA-STD-8739.3 Soldered Electrical Connectors
MSFC-STD-2904	MSFC Tailoring Guide for NAS 5300.4 (3M), Workmanship Standard For Surface Mount Technology
MSFC-STD-2906	MSFC Tailoring Guide for NAS 5300.4 (3J-1), Workmanship Standard For Staking And Conformal Coating of Printed Wiring Boards and Electronic Assemblies
MSFC-STD-2907	Workmanship Standard For Printed Wiring Boards
NASA-STD-8739.3	NASA Technical Standard – Soldered Electrical Connectors
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring

Document Number	Document Title
NPG-6000.1E	Requirements For Packaging, Handling, and Transportation For Aeronautical and Space Systems, Equipment, and Associated Components
SN-C-0005D	Space Shuttle Contamination Control Requirements
SSP-30233E	Space Station Requirements for Materials and Processes
SSP-30237	Space Station Electromagnetic Emission and Susceptibility Requirements
SSP-30240C	Space Station Grounding Requirements
SSP-30242D	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility
SSP-30245D	Space Station Electrical Bonding Requirements
SSP-30423F	Space Station Approved Electrical, Electronic, and Electromechanical Parts List
SSP-30512	Space Station Ionizing Radiation Design Environment
SSP-30573A	Space Station Program Fluid Procurements and Use Control Specification
SSP-41173A	Space Station Quality Assurance Requirement
SSP-57000D, paragraphs 3.2.4 and 4.3.2.4	Pressurized Payloads Interface Requirements Document
TA-92-038	Protection of Payload Electrical Power Circuits

2.2 Reference Documents

Document Number	Document Title
FCF-SPC-0229	Critical Item Product Specification: Water Thermal Control System

2.3 Records and Forms

The following records and forms are generated from the design, fabrication, and testing called out in this SCD:

- Acceptance Data Packages (ADPs)
- Receiving inspection sheets
- EEE Bills of Material
- Radiation Analysis Report
- Electrical De-rating Analysis
- Material Identification and Usage List
- Reliability Prediction Analysis Mean Time Between Failure (MTBF)
- Depressurization/Re-pressurization Analysis
- Top level drawings

2.4 Acronyms

Acronym	Definition
ADP	Acceptance Data Package
Amp	Ampere
CDR	Critical Design Review
dB	Decibel
EEE	Electrical, Electronics, Electrochemical
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FCF	Fluids and Combustion Facility
FSO	Full Scale Operation
He	Helium
hr	hour
Hz	Hertz
in	Inch
ISS	International Space Station
Lbm	pounds mass
MIL	Military
mm	Millimeter
MS	Military Standard
MSFC	Marshall Space Flight Center
MTBF	Mean Time Between Failure
NASA	National Aeronautics and Space Administration
NSPAR	Nonstandard Part Approval Request
NSTS	National Space Transportation System
Pa	Pascal
PDR	Preliminary Design Review
psia	pounds per square inch absolute
psid	pounds per square inch differential
QD	Quick Disconnect
rms	root mean square
scc	standard cubic centimeters
SCD	Specification Control Document
sec	second
SSP	Space Station Program
STD	Standard
TM	Technical Memo
VC	Visually Clean
WFCA	Water Flow Control Assembly
WTCS	Water Thermal Control Subsystem

3.0 REQUIREMENTS

3.1 WFCA Contractual Design Requirements

3.1.1 Fluid

Operating Fluid: ITC Water per SSP-30573 Table 4.1-2.8 (Heat Transport Fluid – Internal Active Thermal Control).

Test, Checkout, Cleaning, and Assembly Fluids: After component cleaning is performed, only fluids meeting SSP-30573A Table 4.1-1.9.2 requirements are acceptable for use in fluid passages.

3.1.2 Materials and Processes

Materials and processes shall be in accordance with SSP-30233E.

3.1.3 Materials (Wetted Surface)

Fluid wetted surfaces shall be 300-series stainless steel. All materials shall be compatible with SSP30573A, Table 4.1-2.8, Note 11.

3.1.4 Tubing

Tubing used shall be 300-series stainless steel interconnecting tubing, 3/8” OD.

3.1.5 Water Connections

The flow control valve shall be provided with 3/8” (-6) boss fittings per MS33649 for both inlet and outlet. The flow sensor shall be provided with male NASA KC105-6 fittings for both inlet and outlet. An extra set of PTFE seals shall be provided for each flow sensor.

The flow straightening tubes shall be provided with KC105-6 matching female fittings (NASA KC142K6 nut and KC143K6 sleeve) on each end.

3.1.6 Weight

Major components of the WFCA shall meet the following weight constraints:

- Flow Control Valve: < 1.5 Lbs.
- Flow Sensor: < 1.0 Lbs.
- Valve Controller (Excluding cables): < 2.0 Lbs.

3.1.7 Envelope

Major components of the WFCA shall meet the following dimensional constraints:

- Flow Control Valve: 3.3” x 4.8” x 1.5”
- Flow Sensor: 5.0” x 2.0” x 2.0”
- Valve Controller (excluding cables): 4.25” x 4.0” x 2.0”

All electrical and fluid connectors shall be on the same plane (XY), which cannot be the plane containing the smallest dimension. (See Figure No. 1 in Appendix A.)

3.1.8 Mounting Points

Mounting points will be per approved drawings.

3.1.9 Coolant Flow Range

The WFCA shall provide controllable fluid flow range of 25-500 lbm/hr H_2O and provide full shutoff capability.

3.1.10 Time to Full Open From Full Close Position

The valve design, by itself, shall be capable of transit from full open to full close in less than 30 seconds. Actual valve transit speed shall be controlled by firmware, in the electronic controller, to perform valve transit from full open to full close in a minimum 120 seconds and a maximum 130 seconds.

Valve transit from full close to full open shall be firmware controlled to the same performance as from full open to full close.

3.1.11 Maximum Pressure

WFCA fluid containing components shall meet the following pressure requirements:

- Operating Pressure: 121 psia
- Proof Pressure: 250 psia
- Burst Pressure: 500 psia

3.1.12 Leakage

Internal to External leakage shall meet the following:

- Valve: $\leq 1x10^{-6}$ scc He/sec at 125 psia max.
- Flow Sensor: $\leq 1x10^{-6}$ scc He/sec at 125 psia max.

Internal leakage across the valve (inlet to outlet) when fully closed shall meet the following:
Valve: $\leq$ 0.03 sccm H_2O at 125 psid

3.1.13 Pressure Drop

Fluid pressure drop across the major WFCA fluid components shall meet the following:

- Flow Control Valve: <0.5 psid @ 500 lbm/hr
- Flow Sensor: <0.2 psid @ 500 lbm/hr

3.1.14 Throttle Capability

Resolve to +/- 3 lbm/hr at operating pressure and temperature. (Max. operating pressure is 121 psia with max. delta of 10 psid).

3.1.15 WFCA Accuracy

Total Error Band:

- ±3% FSO for 25 lbm/hr flow
- ±2% FSO for 500 lbm/hr flow

Total error band includes linearity, hysteresis, endpoint and ambient temperature effects.

3.1.16 Temperature

The WFCA shall be capable of meeting the following thermal conditions without degradation of performance:

- On-Orbit Operating Environment 18°C to 45°C.
- (The WFCA shall be capable to operate in the above environment by conduction and/or radiation cooling).
- Non-Op Environment 0.5°C to 65°C.
- On-Orbit Fluid Temperature 15°C to 50°C.

3.1.17 EEE Parts

EEE parts shall conform to Grade 2 Plus per MSFC-PLAN-2854.

For Ionizing Radiation, MSFC-PLAN-2854 refers to MSFC-RQMT-2871, which refers to SSP30512.

3.1.18 Cleanliness

Wetted surfaces shall be cleaned to meet MIL-STD-1246C, Level 200A.

Exterior surfaces shall be cleaned to meet SN-C-0005D, visibly clean.

3.1.19 Soldering

Soldering shall be in accordance with MSFC-STD-2903. except that soldering per NHB5300.4 is acceptable.

3.1.20 Printed Wiring Boards

Printed wiring boards shall be designed and fabricated in accordance with MSFC-STD-2904 and 2907.

3.1.21 Conformal Coating

Conformal coating shall be in accordance with MSFC-STD-2906.

3.1.22 Bonding

Electrical bonding shall be in accordance with SSP-30245D.

3.1.23 Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC)

The design shall produce EMI/EMC levels that satisfy the requirements of SSP-57000D, paragraphs 3.2.4.4 and 4.3.2.4.4, and SSP-30237.

Radiated susceptibility levels may be used per paragraph 3.2.4.4 of SSP-57000.

3.1.24 Grounding

Electrical grounding shall be in accordance with SSP-30240C.

3.1.25 Cables/Wiring

Per SSP-30242D. Maximum interconnecting cable length: 25 feet. Wire de-rating per NASA Technical Memo (TM) 102179 as interpreted by NSTS 18798, TA-92-038. Flight cables shall be delivered un-assembled. Each cable shall be packaged separately and shall include 25-feet of cable and the proper connectors for each end of the cable. The proper number and type of cables shall be shipped with each WFCA delivery.

3.1.26 Crimping

Crimping shall meet NASA-STD-8739.4 requirements.

3.1.27 Input/Power Interface

Flow Control Valve/Valve Controller/Flow Sensor:

- 28 ± 10% Vdc power input with reverse polarity protection *
- Flow Control Valve/Valve Controller: 1.0 Amps. Maximum
- Flow Sensor: 0.1 amps. Maximum

> * Note: 28 Vdc is the voltage available to power the unit. Although the 28 Vdc return line is connected to the chassis ground, this return line at the flow control valve or valve controller must not be connected to chassis and must be isolated from chassis by a minimum of 1 Megohm. If a “secondary” voltage is developed within the valve controller unit, and this secondary voltage return is isolated from the 28 Vdc return by greater than 1 Megohm, (by using an isolated DC/DC converter for example) then the secondary voltage output from the DC/DC converter must be connected to chassis ground at one point only. The goal is to prevent any structure from being used as a current return path, except for fault conditions.

The WFCA controller shall provide power to the Flow Control Valve and Flow Sensor.

3.1.28 Power Consumption

The total power consumption of the WFCA shall not exceed 18.0 Watts.

3.1.29 Data Interface / Control Type

The WFCA control architecture is an Open Loop System.

Valve position error signal (NASA command signal) from NASA computer to WFCA valve controller shall have the following performance:

WFCA INPUT	MAX SPEED CLOSE	THROTTLE CLOSE	HOLD	THROTTLE OPEN	MAX SPEED OPEN
COM_SIG+	-2.5 V	- 2.5 to - 0.25V	- 0.25V to +0.25V	+0.25V to +2.5V	+2.5V
COM_SIG-	+2.5 V	+2.5 to +0.25V	+0.25V to - 0.25V	- 0.25V to - 2.5V	- 2.5V

Summary effects of command signal differential voltage with respect to COM_SIG-:

- -5.0 Vdc: Fastest Motor Rotation Speed for closing
- -0.5 Vdc to +0.5 Vdc: Flow Control Valve to not rotate (hold present position).
- +5 Vdc: Fastest Motor Rotation Speed for opening
- -5.0 to -0.5 Vdc: Linear Range for Valve Closing Speed
- 0.5 to +5.0 Vdc: Linear Range for Valve Opening Speed

Flow Rate feedback signal from the WFCA valve controller to the NASA controller shall be 0 to 5 Vdc differential with the following performance:

WFCA OUTPUT	NO FLOW	NO FLOW	0.0 lbm/hr	Linear Range	520.0 lbm/hr
SEN_SIG+	+0.0 V	+0.0 to +0.25V	+0.25V	+0.25V to +2.5V	+2.5V
SEN_SIG-	- 0.0 V	- 0.0 to - 0.25V	- 0.25V	- 0.25V to - 2.5V	- 2.5V

Summary of WFCA valve controller flow sensor output differential voltage with respect to SEN_SIG-:

0.0 Vdc to 0.5 Vdc differential corresponding to no flow
0.5 Vdc to 5.0 Vdc differential corresponding to the linear range
where 0.5 Vdc = 0.0 lbm/hr
5.0 Vdc = 520.0 lbm/hr

The WFCA valve controller output can be converted to engineering units of Pounds Per Hour (PPH) by the following formulas:

- PPH from Frequency : 3.0821428*frequency + 2.99
- Voltage from Frequency: 0.02486*frequency + 0.5
- PPH from Voltage: 123.98*voltage – 5

Please note that there is a time delay inherent in the system when the flow control valve is commanded to change directions while moving. This is because of the physical tolerances (or looseness) in the stem to ball and gear box and valve stepper motor shaft. The value (in stepper motor steps) is somewhere in the 200-330 step range.

The WFCA valve controller shall receive input valve position error signal from NASA controller and adjust the flow controller valve accordingly. The WFCA shall not respond to the Flow Rate Feedback. The Flow Rate Feedback through the WFCA valve controller to the NASA controller shall be buffered and isolated by 6000 Ohms minimum from supply return and capable of handling a 2000 Ohm resistive load. The NASA controller, once it gets the Flow Rate Feedback, will determine if further error signal input to the WFCA valve controller is necessary

3.1.30 Electrical Connectors

- All contacts shall be #20 AWG
- Both halves of mating connectors shall display a code or identifier, which is unique to that connection.
- The labels or codes for connectors shall be located so they are visible when connected or disconnected.
- Space between connectors and adjacent obstructions shall be a minimum of 1.0 inch in the x or y In the z direction connectors shall be located as near to the top as possible. (See Figure No. 1 in Appendix A.)
- Connectors shall be different in shape, size, or keying to prevent mating connectors when lines differ in content within the same box.
- Connectors shall require no more than six turns to disconnect.
- Connectors shall provide a self-locking feature.

Electrical Connector Identification Scheme: Each connector shall be numbered according to the following general scheme:

- For the Flow Control Valve: JWFV1
- For the Flow Sensor: JWFS1
- For the Valve Controller: JWFC1, JWFC2, JWFC3

For the matching cable connector, the same designation shall be used except that the first letter shall be "P" instead of "J". For example, PWFC1 is the cable connector identification and it will connect to the device connector labeled as JWFC1.

3.1.31 Failure Mode

- Loss of NASA Command Signal: Fail at present position.
- Loss of Power: Fail at present position.
- Loss of Signal from Flow Sensor: Maintain control using NASA command signal.
- The WFCA valve controller shall provide a separate, isolated, flow sensor raw signal output.

3.1.32 Reliability

250,000 hour operating MTBF (mean time between failure) at system level. Compliance shall be by Testing and/or Analysis. If analysis is used it shall identify the source of the basic reliability values used in evaluating the performance.

Data from accelerated life tests shall be used where applicable.

Each unit shall be designed to meet all requirements after 5 launch cycles. (Exposed 5 times to the vibration and thermal environments listed).

3.1.33 Design Life

The design life of the WFCA shall be at least 10 years.

3.1.34 Operational Life

The operational life of the WFCA shall be at least 5 years.

3.1.35 Sharp Edges and Corners Protection

Design shall be in accordance with:

- Exposed edges 6.4 mm (0.25 in.) thick or greater shall be rounded to a min. radius of 3.0 mm (0.12 in.).
- Exposed edges 3.0 to 6.4 mm (0.12 to 0.25 in.) thick shall be rounded to a min. radius of 1.5 mm (0.06 in.)
- Exposed edges 0.6 to 3.0 mm (0.02 to 0.12 in.) thick shall be rounded to a full radius.
- The edges of thin sheets less than 0.5 mm (0.02 in.) thick shall be rolled or curled.
- Exposed corners of materials less than 25 mm (1.0 in.) thick shall be rounded to a min. radius of 13 mm (0.5 in.).

3.1.36 Burrs

Exposed surfaces shall be free of burrs.

3.1.37 Depressurization / Re-pressurization

WFCA shall maintain positive margins of safety for depressurization rates of 890 Pa/second (7.75 psi/minute) and re-pressurization rates of 800 Pa/second (6.96 psi/minute).

3.1.38 Reverse Polarity Protection

Required.

3.1.39 Acoustic Requirement

Do not exceed the overall A-weighted sound pressure level of 50-dB (A) when measured 0.6 meters from the loudest side of the WFCA. The test shall be conducted in the loudest mode of operation.

3.1.40 Input Voltage Range/Transient

The WFCA shall operate within the voltage transient range of Figure No. 3 in Appendix A.

3.1.41 Noise/Ripple

The WFCA shall operate within the ripple voltage as specified in Figure No.1 in Appendix A.

3.1.42 Reverse Current

The WFCA shall not exceed the reverse current depicted in the table show below.

Power Output Performance Values (T=25 degrees C)		
Power Parameter	**Limits/Rating**	**Value**
Reverse Current – 28 Vdc Outputs	Pulse – t< 1 msec	450 A
	Peak – t< 1sec	40 Amps
	Steady-State – t > 1 sec	2 A
Reverse Energy	Any SSPC output	4 J

Table I - Power Output Performance Values

3.1.43 Reverse Energy

Each WFCA shall not exceed the reverse energy of 4 Joules. Reverse energy is depicted in Table No. I.

3.1.44 Maximum Turn-on Capacitance

Maximum load capacitance is as follows: 50uF/A of rated output current for 10-amp circuit.

3.1.45 Shipping

The shipping container shall provide protection for each component during shipping and handling and shall meet the requirements of NPG-6000.1E and the carrier for safe transportation.

3.1.46 Testing

Successful completion of qualification testing is required before the first delivery. Qualification units shall not be refurbished and delivered as flight units. The successful tests shall show compliance with ALL WFCA requirements.

Thermal Qualification and Acceptance Testing:

- High Purity De-ionized water per SSP30573A, Table 4.1-2.17 shall be used for testing. Also for Testing: Helium per SSP30573A, Table 4.1-2.9, or Nitrogen per SSP30573A, Table 4.1-2.13, Grade A or better may be used.
- Qualification and Acceptance testing shall be performed per MSFC-DOC-2142. “Electronics” and “Fluid or Propulsion Equipment” is the applicable classification. Acceptance testing for the “burn-in” requirement shall be for a 100-hour test duration.

Vibration Qualification and Acceptance Testing:

Test each flow sensor, flow control valve, and valve controller individually as a component in accordance with the following:

Non-operating, all axes

- 20 Hz @ 0.01 G2/Hz
- 20 – 80 HZ @ +3.3 dB / Octave
- 80 – 350 Hz @ 0.04 G2/Hz
- 350 – 2000 Hz @ -3.0 dB / Octave
- 2000 Hz @ 0.007 G2/Hz
- Composite = 6.1 GRMS

Qualification test one unit for 180 seconds per axis at 3 db higher the vibration environment provided above. Acceptance test all units for 60 seconds per axis at the vibration environment provided above.

3.1.47 Quality Assurance

Quality system shall satisfy NASA SSP-41173A “Space Station Quality Assurance Requirements.” This publication requires a quality program plan to be submitted to the Contracting Officer.

All deviation requests and waivers submitted to the Contracting Officer for approval shall be made by use of MSFC form 847, “Deviation Approval Request” or equivalent.

The Government will perform monitoring activities at the contractor's plant for in-process work. The Government reserves the right to witness all qualification and acceptance tests (whether conducted at the contractor's plant or at a subcontractor's plant). The Government will verify end item ADPs and inspect

packaged hardware prior to shipment. This does not relieve the contractor of their inspection responsibilities. The contractor shall notify the Government a minimum of 48 hours in advance of all qualification and acceptance tests. The contractor shall notify the Government a minimum of 48 hours in advance of when end item ADPs require verification and prior to end item shipment.

An ADP shall be shipped with each contract end item. Each ADP shall contain the following (subject to refinement):

- Certification papers
- Top-level assembly drawing(s) and an interface control drawing
- Detailed parts lists and EEE "As Built" parts list
- All test results/reports and inspection records for each piece of hardware and/or material manufactured
- Material Certifications – The contractor shall provide a Certificate of Compliance signed by a responsible quality representative of the company to the effect that all materials, processes, and/or finished items supplied under this Purchase Order (PO) are as specified. The certificate must be typed and include part numbers and date code(s).
- All materials identification and usage list and/or a list of all materials, coatings, and plating used in manufacturing shall be provided.
- The contractor shall provide in writing (typed) the start date, shelf life, and expiration date of all life limited shelf items supplied under this PO. The supplied items must have at least 75% of their useful shelf life remaining at time of shipment to NASA.
- A copy of these quality requirements
- Flow Sensor flow rate calibration curves
- Deviations and waivers

Data Items included in the table below shall be supplied to NASA at indicated times.

Data Item	NASA Approval	Draft Due	Final Due
Acceptance Data Package (ADP)	Yes	-	Delivery
Acceptance Test Procedure	Yes	PDR	CDR
Acceptance Test Report	Yes	-	with ADP
Certificate of Compliance and Matrix	Yes	-	with ADP
Detailed Drawings (with Parts Lists)	Yes	PDR	CDR
EEE "As Built" Parts List	Yes	PDR	with ADP
EEE "As Designed" Parts List	Yes	PDR	CDR
EEE Parts Control Plan per MSFC-PLAN-2854, Paragraph 4.2	Yes	PDR	CDR
Failure Modes, Effects Analysis	No		CDR
Failure Reports, as required	No		CDR
Flow Sensor flow rate calibration curves	No	PDR	CDR and with ADP
Material Identification Usage List	Yes	PDR	CDR
Monthly Progress Reports	No	-	-
MTBF Analysis	Yes		CDR
Nonstandard Part Approval Request (NSPAR) according to MSFC-PLAN-2854, Paragraph 4.3.2	Yes	PDR	CDR
Qualification Test Procedure	Yes	PDR	CDR
Qualification Test Report	Yes	-	Qual testing + 1 month
Quality Program Plan	No	PDR	CDR
Software Test Plans and Procedures	Yes	PDR	CDR

Table II – Data Items

3.1.48 Alerts

The contractor shall respond to alerts by NASA. Alerts will be distributed by NASA. The contractor will review each Alert for applicability and impact to contract hardware. An initial response to NASA shall be required within 15 working days of the distribution. The response shall explicitly identify that the suspect part or material is not used or include justification for "use-as-is" or corrective action for any Alerts impacting contractor hardware.

Contractor shall be responsible to respond to Alerts for one year after final hardware delivery.

APPENDIX A – FIGURES

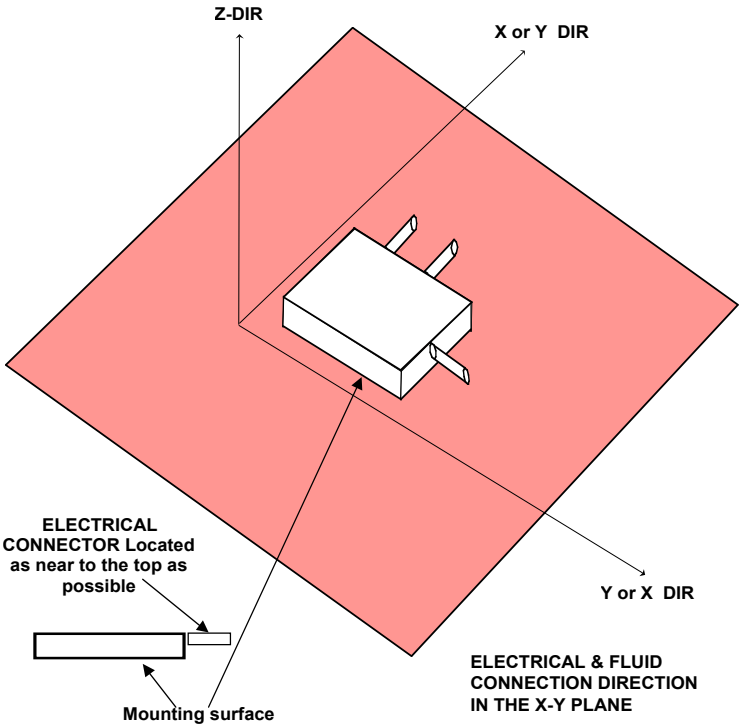

Figure 1 - WFCA Connectors

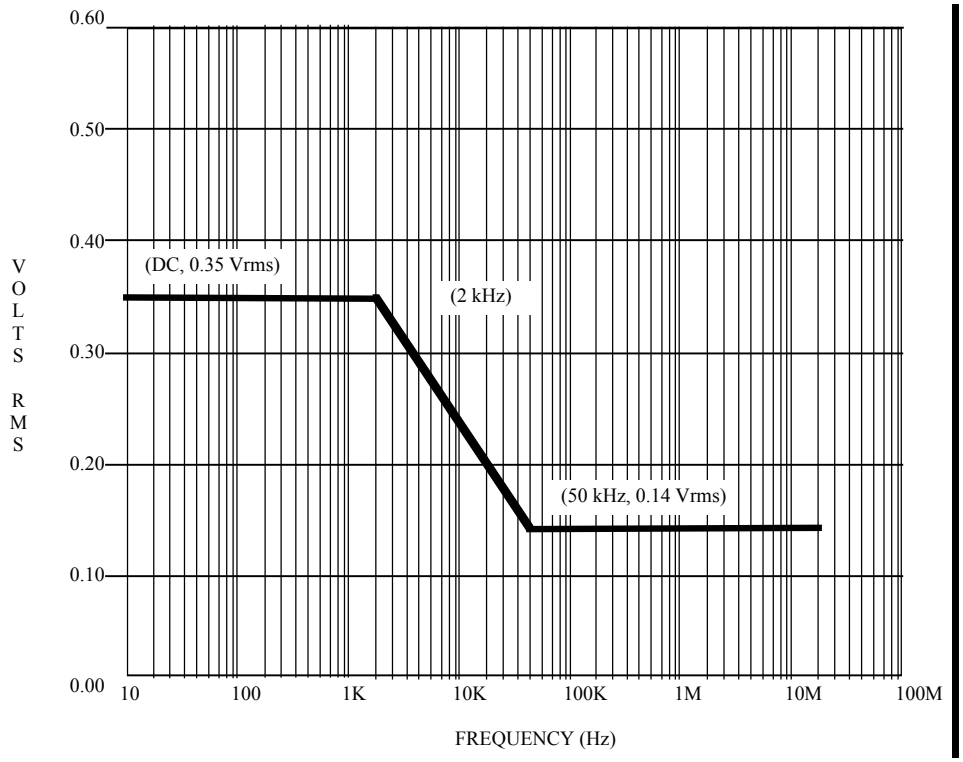

Figure 2 – Output Ripple Voltage Frequency Spectrum

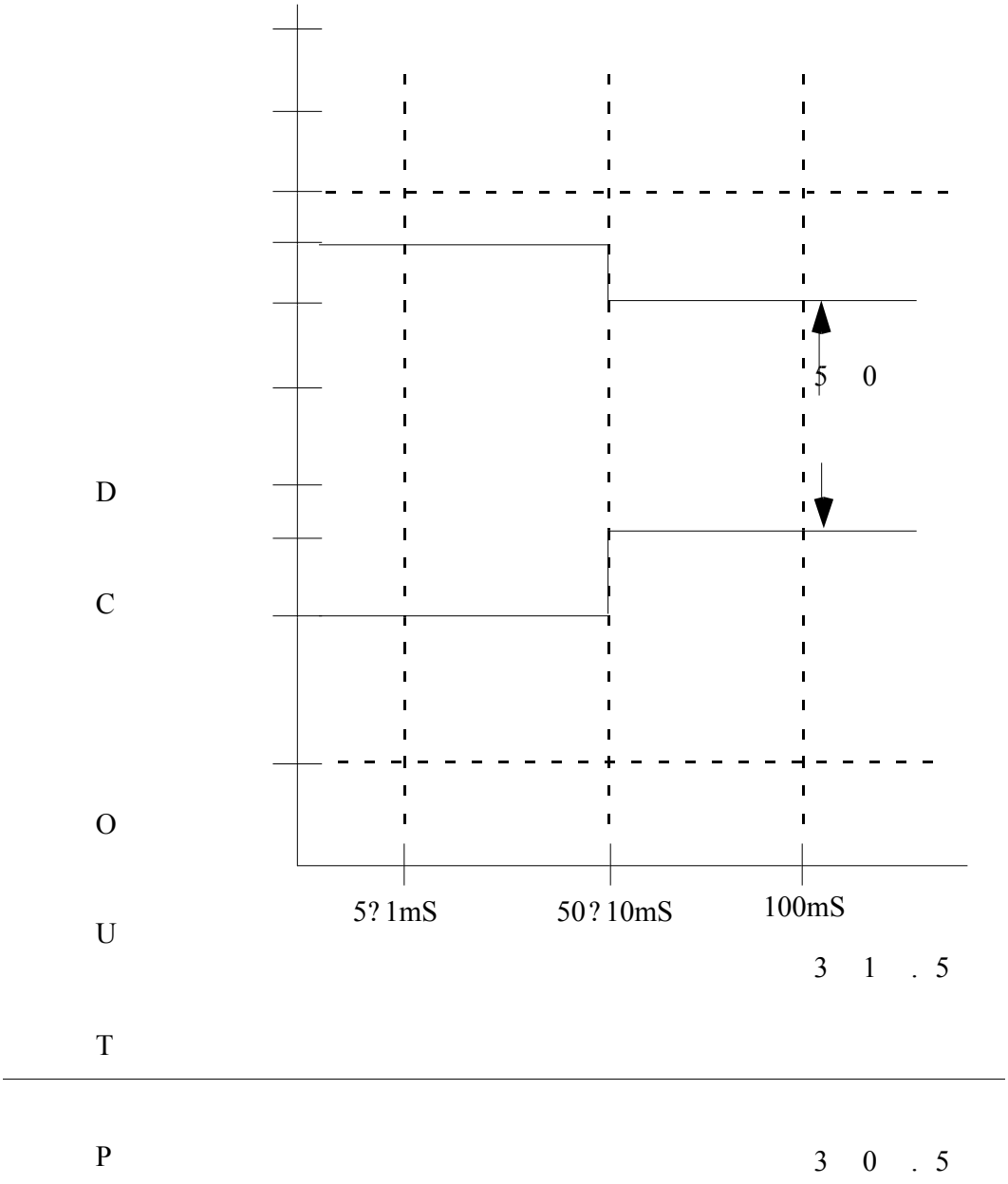

Figure 3 – Power Output Performance