60009-DOC-010

CVX-2 Phase 2/3 Reflight Safety Data Package

Critical Viscosity of Xenon – 2 (CVX-2)

DRAFT

October 6, 2000

ZIN Technologies

Prepared For:

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Microgravity Science Division
Cleveland, Ohio 44135

Prepared By:

ZIN Technologies, Incorporated
3000 Aerospace Parkway
Brook Park, Ohio 44142
Under Contract NAS3-99154, 60061-DO-007

Critical Viscosity of Xenon - 2

CVX-2 REFLIGHT SAFETY DATA PACKAGE PHASE 2/3

Prepared by: Natalie Goldin CVX-2 Safety Engineer ZIN-Technologies (216-977-0634)	Date
Approved by: James Myers CVX-2 Project Lead ZIN-Technologies (216-977-0410)	Date
Approved by: John Andrasik Quality Manager ZIN Technologies (216-977-0353)	Date
Approved by: Susan M. Motil CVX-2 Project Manager NASA GRC (216-433-8589)	Date
Concurrence: Office of Safety and Assurance Technologies NASA GRC	Date

Table of Contents:

1 INTRODUCTION

The Critical Viscosity of Xenon - 2 (CVX-2) experiment is a continuation of the investigation of xenon viscosity and its shear rate dependence at temperatures very near xenon liquid-vapor critical temperature (T_C = ~16.7°C). The low-gravity environment of the STS orbiter minimizes stratification in the test sample that inhibits such measurements in normal gravity. The experiment will fly in the Shuttle payload bay on a Hitchhiker (HH) bridge on STS-107.

The CVX-2 is the second flight of the Critical Viscosity of Xenon experiment on a Hitchhiker bridge aboard Shuttle Orbiter. The first CVX-1 experiment was flown successfully on STS-85. Objectives of both CVX experiments (CVX-1 on STS-85, and CVX-2 on STS-107) are the same, with CVX-2 experiment being scientifically more advanced based on the results from CVX-1. The baseline CVX-1 Safety Data Package (Phase III) was submitted in January 1997, and it is on file at NASA/GRC/Office of Safety and Assurance Technologies and NASA/GFRC.

1.1 Purpose of the Document

This Phase 2/3 Safety Data Package documents the safety assessment performed on the CVX-2 hardware, software, and operations. It documents compliance with the applicable requirements of NSTS 1700.7B and NSTS/ISS 13830C Section 9, "Reflown and Series Payload Hardware".

1.2 Experiment Overview

CVX-1 and CVX-2 experiments have same objectives: to measure the viscosity and its shear rate dependence of a pure fluid (xenon) near its liquid-vapor critical point. The thermodynamic path will be an approach to the critical temperature, T_C = ~16.7°C, on an isochoric path at the critical density from the one phase (vapor) region.

A continuous scan of temperature will approach and pass (slightly below) the T_C to enable both precise location of T_C and measurement of viscosity at many temperatures around T_C. The primary viscosity data will be acquired during a series of measurements at select viscometer frequencies and amplitudes.

To provide data comparable to the best Earth-based laboratory data, it is required that viscosity be measured with a precision of 0.18% and the viscosity exponent be determined with an accuracy of 1.0%.

1.3 Operation Overview

The CVX-2 experiment is a continuation of CVX-1 experiment. The CVX-2 operation sequence is different from CVX-1 scenario and consists of three main actions (passes):

- To establish the location of T_c within 0.3 mK. A series of viscosity measurements during a fast temperature ramp starting at 0.1K above T_c. This temperature ramp should take about 24 hours. This operation will validate the viscometer response as compared to CVX-1 results.
- To acquire the primary viscosity data during a series of measurements at a single viscometer operating frequency and four different viscometer amplitudes at each of 10 temperatures logarithmically distributed from 0.3 mK to 3 mK above T_c.
- To repeat the measurements at two significantly different viscometer frequencies.

The CVX-2 experiment is expected to be powered as early as possible on orbit and will be operated for as long as possible during the mission. While the instrument can operate autonomously, the more desirable mode requires interaction to monitor data and experiment progress and to selectively command the instrument to accommodate unpredicted trends in the data or orbital events, which might perturb the measurements.

The timeline for the experiment is shown in CPR document (60009-DOC-023, NASA Hitchhiker Program Customer Payload Requirements (CPR) Customer Payload: CVX-2) indicating conservative scenario for startup (slow for both HH and CVX-2). There are no issues related to safety in the CVX-2 operation scenario. The only critical operation is the initial turn-on procedure, which might effect the health of the CVX instrument only and does not impact safety. This issue is addressed in datails in CPR Document for CVX-2, and discussed only for information purposes.

2 APPLICABLE DOCUMENTS

The following documents are applicable to the subject safety package:

NSTS 1700.7B	Safety Policy and Requirements for Payloads using the Space Transportation System
NSTS/ISS 13830C	Payload Safety Review and Data Submittal Requirements for Payloads Using the Space Shuttle and International Space Station
NSTS/ISS 18798B	Interpretations of NSTS/ISS Payload Safety Requirements
NASA-STD-5003	Fracture Control Requirements for Payloads using the Space Shuttle
740-SPEC-008 (formerly HHG-730-1503-07)	Hitchhiker Customer Accommodations and Requirement Specification
MSFC HDBK-527	Materials Selection List for Space Hardware Systems
60009-DOC-023	NASA Hitchhiker Program Customer Payload Requirements (CPR) Customer Payload: CVX-2
60009-DOC-010	Flight Safety Data package for Critical Viscosity of Xenon (CVX) Phase 3, Baseline, 01/97

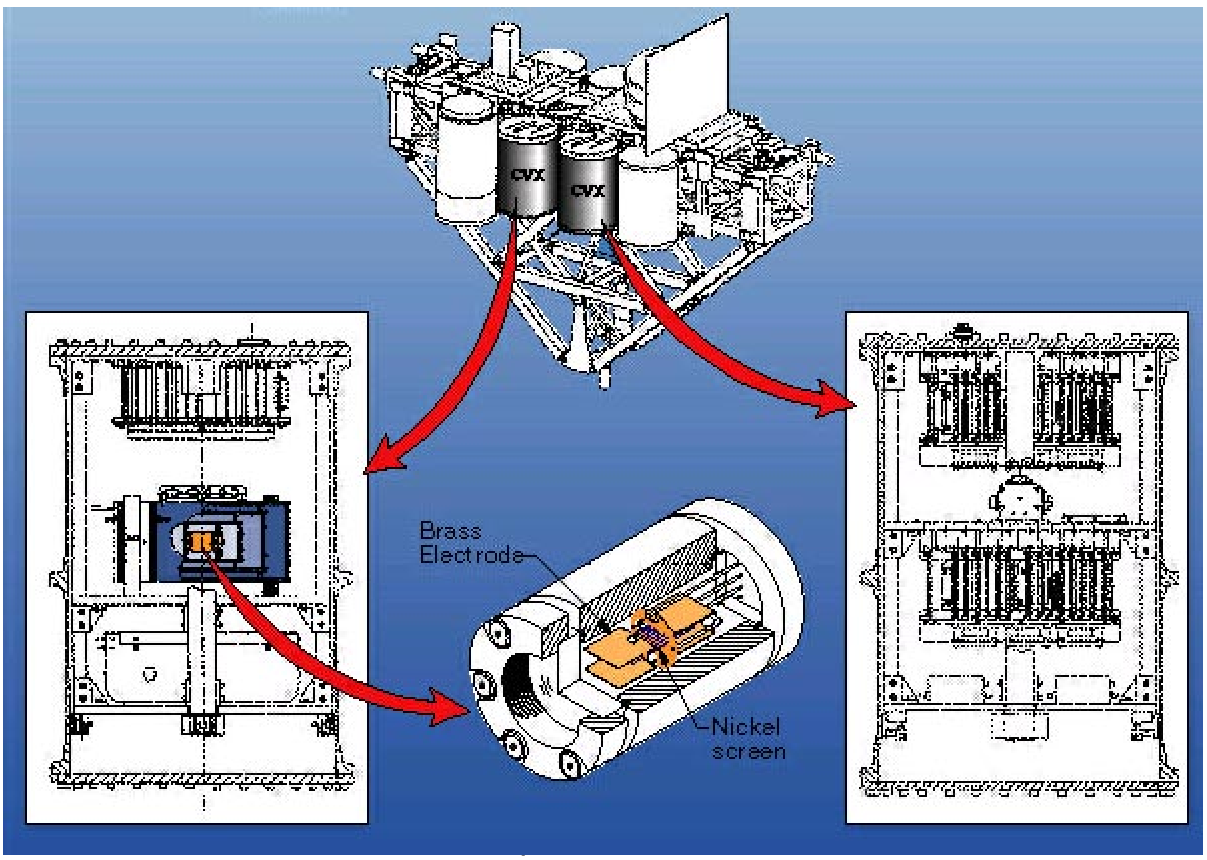
3 REFLIGHT SAFETY INFORMATION

3.1 Physical Description

The CVX-2 experiment will be performed using the hardware that was used for the CVX-1 experiment during STS-85 mission. All hardware components will be reflown, except for the replacement of the battery cells (described in section 3.1.1). The CVX-2 flight instrument (Fig.1) is physically separated into two functional units:

- CVX-2 Experiment Package (EP) which includes the viscometer and precision temperature control elements and,
- CVX-2 Avionics Package (AP) which includes the data acquisition/control electronics and the power conditioning systems.

Each package is mounted in a standard 5 ft^3 Hitchhiker canister and the canisters are connected at the upper endplates by a single, removable, external cable. The payload is provided power and communication support through Hitchhiker standard interface connections on the lower endplate of the Avionics Package.



Structural Design Overview

The structural design of the CVX-2 did not change compared to CVX-1. The CVX-2 hardware has the same configuration as CVX-1 hardware, all hardware components, including fasteners, are reflown.

On the basis of CVX-1 analysis the primary structures and the individual assemblies of both of the CVX-2 canisters can be classified as *non-fracture critical*. There are no safety critical elements within the payload canisters.

The materials of construction of the CVX-2 payload are chosen from Table 1 of MSFC-SPEC-522B and reflect appropriate stress corrosion properties for the described applications. The primary support structures are fabricated from aluminum (6061-T6) and steel fasteners are employed (300CRES or A286).

Containment analysis - a "punch-out" analysis has been performed to demonstrate containment of selected example elements of the payload under worst-case free translation conditions. The CVX-1 analysis, which applies to CVX-2, shows that there is substantial margin in this primary containment for all elements (including rotating elements of fans and disk drive) within both canisters.

Electrical Design Overview

To enhance scientific return from the experiment compared to the CVX-1, the following modifications were implemented in the electrical design of the experiment. Each modification is described in further detail in either section 3.1.1 or 3.1.2:

- Chirp Generator PCB (STD 1 Rack in AP) was replaced;
- Square Root PCB (STD 1 Rack in AP) was replaced;
- New Power PCB (STD 1 Rack in the AP) was added;
- PCU PCB was replaced by spare;
- New relay was added to the existing Pre-Amp (EP);
- Associated rewiring was done to accommodate the above items;
- New commercial “D” cells (string of 32) batteries.
  Note: Existing electrical connections are used.

Circuitry modifications include:

- Hitchhiker Interface Power cable backshell was removed and grounding wire was added (Fig. 2). This modification was done because due to the mechanical configuration of the HH end plate it was not possible to mate the connectors with the shielded backshells originally used.

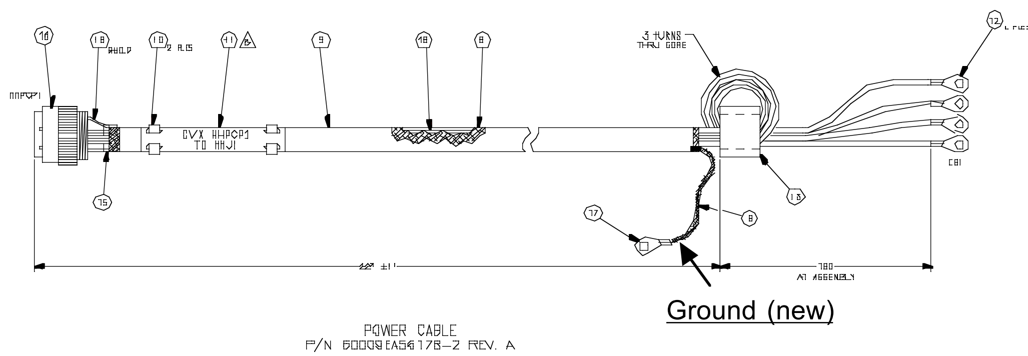


Fig. 2 HH Interface Power Cable

-
-

- Hitchhiker Interface Signal cable backshell was removed and grounding wire was added (Fig.3). This modification was done because due to the mechanical configuration of the HH end plate it was not possible to mate the connectors with the shielded backshells originally used.
-

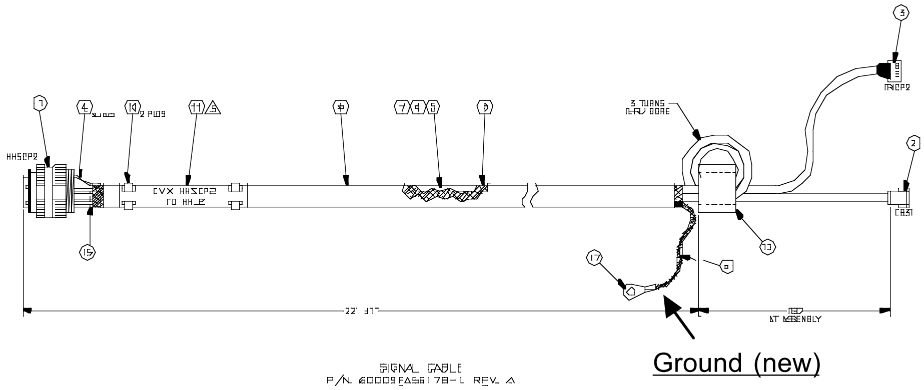


Fig. 3 HH Interface Signal Cable

– New grounding wire was added to CVX-2 power distribution fusing diagram to properly terminate the shields to HH frame ground to conform to accepted EMI practice. Power conversion and Power distribution diagram is shown on Fig. 4. Power is filtered and fused (15 amp fuses down rated to 7.5 amp) and conditioned to provide 24 V, 5 V, ±12 V, ±48 V, ±148 V within the AP. Power at 28 V, 24 V, and 5 V is routed from the AP to the EP, where an additional power conditioning module produces ±12 V. A high voltage signal of +48 V and +148 V will be transferred between the AP and EP. The signal line will support very low current (I < 1 mA). Wires are sized in compliance with the standards set forward in TA92-038. New fusing diagram (Fig.4) shows new grounding wire and replacement of one 4A fuse by 6A fuse to satisfy new requirements (shown). These modifications do not impact safety.

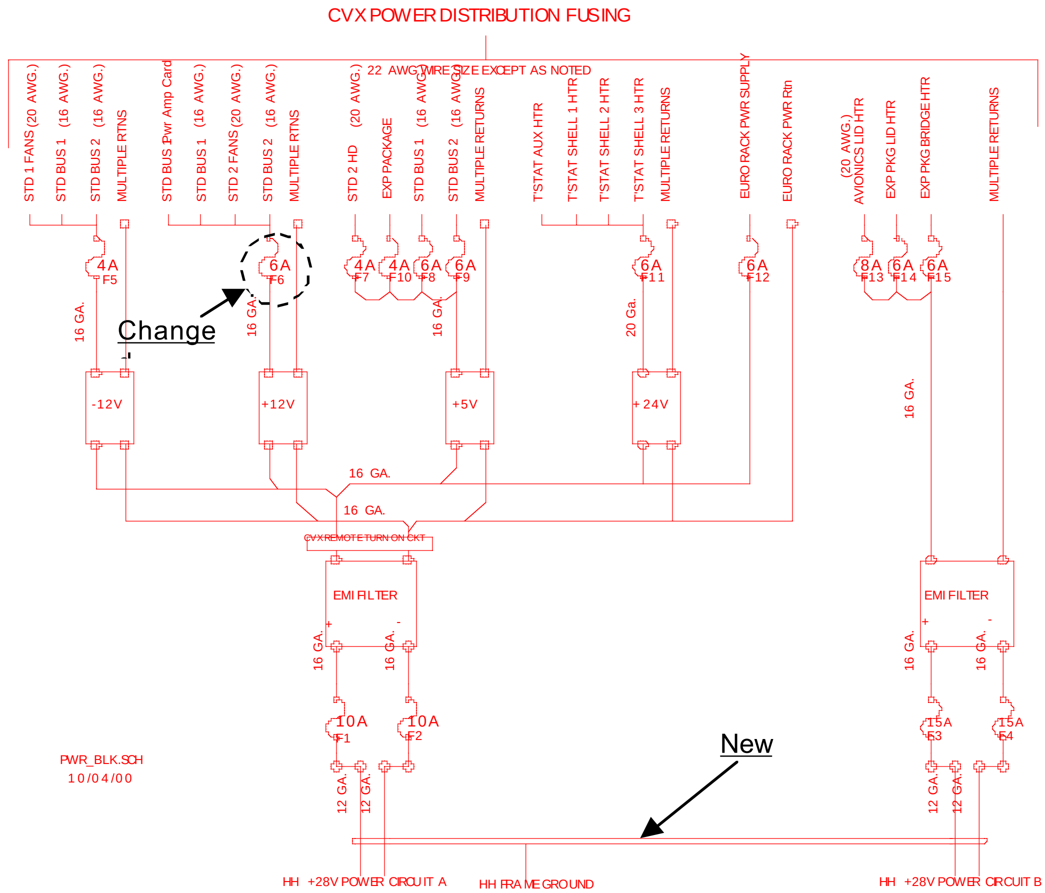


Fig.4 Fusing, Wire Sizing and Power Distribution Network

- Circuitry was also added to CVX-2 to permit, selectively, operation at single frequencies and, more importantly, to operate the viscometer with larger voltage offsets which drive the oscillating screen to larger displacements (producing the required higher shear rates).

As the result of all electrical hardware enhancements, power profile for CVX-2 experiment increased from 97 W to 135 W (nominal) and from 215 W to 307 W (peak). As mentioned above there will be a high voltage signal (~148 V) at very low current (I < 1 mA) transferred between AP and EP. The old Canister Interconnect Cable will be used. Three new wires were added (Fig.5). The Canister Interconnect Cable attaches to a hermetic feed through on the CVX-2 upper endplate of each canister. This cable was built per ICD-2-19001. The cable is not rigid, but it is a standard 66 wire flexible design secured by brackets. The cable will be installed by GSFC.

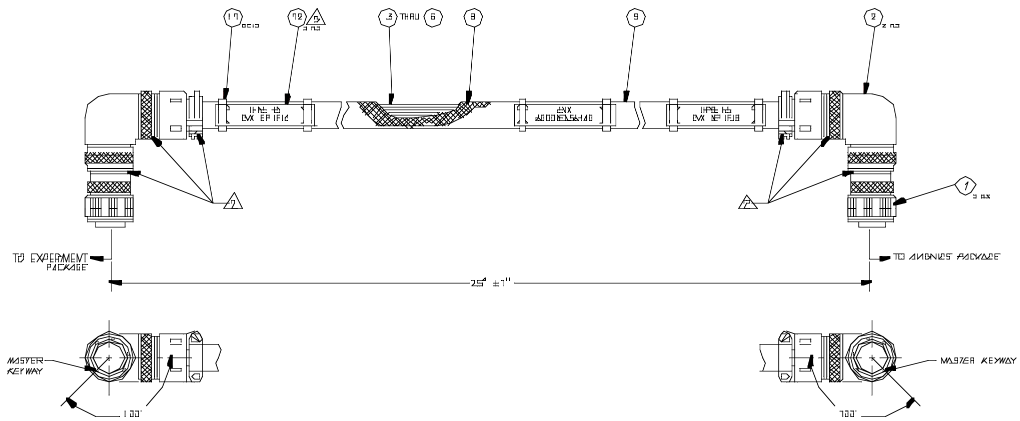


Fig.5 Canister Interconnect Cable

Due to new power profile a new requirement of no high voltage in the first 24 hours of the mission to avoid arching is introduced. This requirement is imposed to avoid arcing. Based on Memo below this new power profile is not safety critical, and might present concern only to the health of experiment itself.

MEMO

To: All Concerned
From: Donald Priebe, CVX-2 Electrical Engineer
Subject: High Voltage mode delay

Although there no safety issues involved, there is a self imposed project requirement that the high voltage mode of operation be delayed a minimum of 24 hours after the experiment is turned on. This requirement allows the can to can interconnect cable sufficient time to outgas to reduce the possibility of arcing within the cable. The electronics is designed to tolerate some arcing but it would degrade the data being collected at that time. The flight time reflects ample time for the outgasing period. The High voltage mode is defined as a DC potential of 75 volts, the low voltage has a DC potential of 30 volts.

Thermal Design Overview

Thermal design of both CVX-1 and CVX-2 is the same.

The following table summarizes the predicted temperatures of the CVX-2 assemblies during nominal operation on orbit and acceptable storage temperatures on the ground:

Table: PAYLOAD TEMPERATURE LIMITS

ASSEMBLY/ STATUS	MINIMUM TEMP. (°C)	MAXIMUM TEMP. (°C)	COMMENT
Avionics Package			
Operating	25	35	At Upper Endplate
Non-Operating	0	45	Payload Steady State
Storage	10	35	Payload Steady State
Experiment Package			
Operating	5	15	At Upper Endplate
Non-Operating	0	45	Payload Steady State
Storage	10	35	Payload Steady State

Temperature modes shown in the Table above are applicable for both CVX experiments.

The late change was implemented into the CVX-1 thermal design: CVX-1 Avionics Package had three foil heaters on the interior surface of the upper endplate, instead of two as described in CVX-1 Phase III SDP. This change was not reflected in the CVX-1 Safety Data Package. However, safety analysis performed for CVX-1 included the third foil heater (see CVX Project Memo 60009-TEC-035, November 22, 1996, regarding maximum temperature analysis).

Software design Overview

Software package for the CVX-2 experiment was modified. There is no safety impact related to software modification.

3.1.1 Experiment Package (EP)

The CVX-2 EP design is the same as a design employed for the CVX-1 (Fig. 6). The detailed description of the CVX EP is in CVX-1 Safety Data Package.

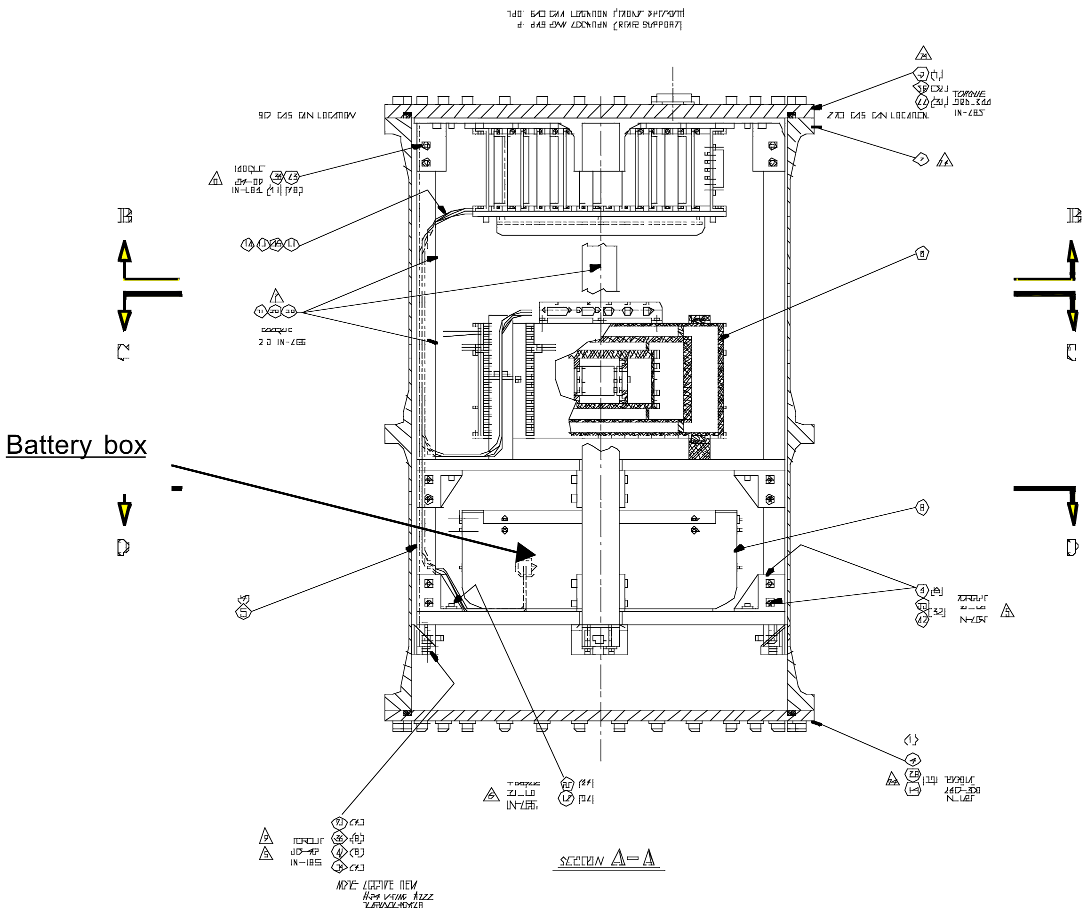


Fig.6 CVX Experiment Package

The following modifications were implemented:

Relay was added to the Pre-Amp (Fig. 7) to accommodate new science requirement of the experiment:

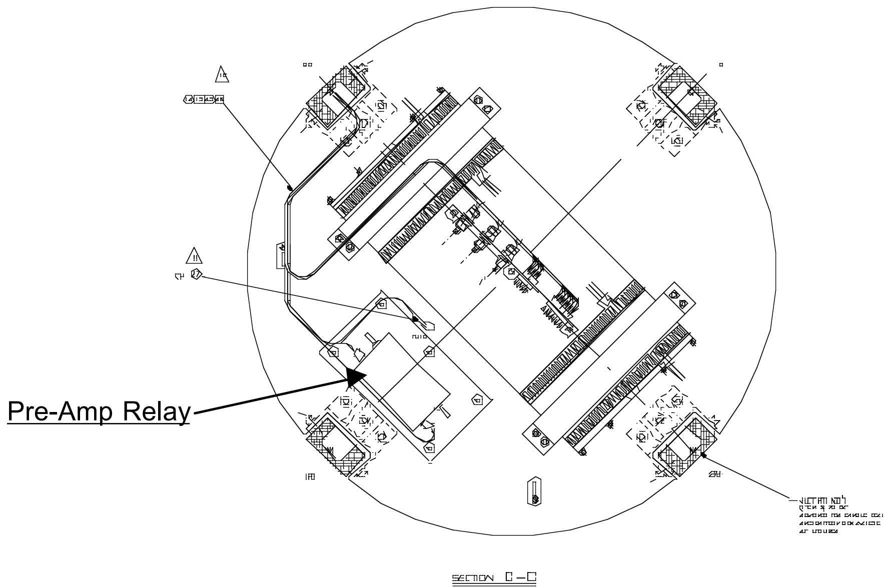


Fig.7 CVX EP: New Pre-Amp Relay shown

New set of batteries will be used for the CVX-2 experiment. The descent power battery box is located on the lower shelf of the Experiment Package (Fig 8).

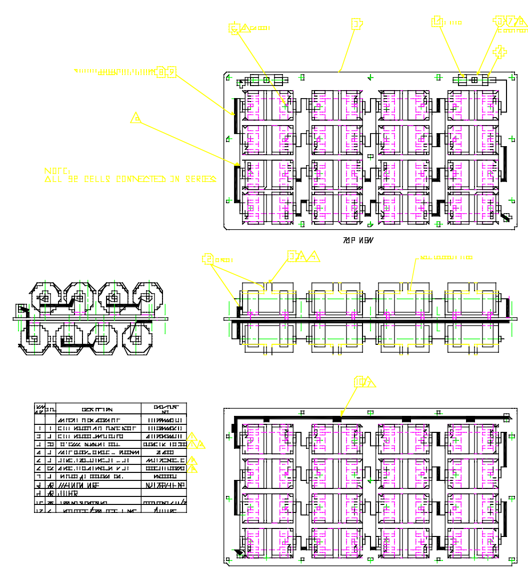


Fig.8 Battery Pack Assembly

New batteries will replace a series string of 32 commercial “D” cell, alkaline cell batteries used for CVX-1. New batteries are of the same type as batteries used before (Duracell PC1300) and are in compliance with Interpretation Letter MA2-98-069 “Small Commonly Used batteries” of NSTS/ISS 18798. The circuit complies with JSC-20793 Battery Safety Handbook. Battery cells test (60009-TAP-042) and battery box test (60009-TAP-043A) were performed. Payload Safety Hazard Report prepared for CVX-1 experiment is applicable.

3.1.2 Avionics Package (AP)

The CVX-2 AP design is basically the same as a design employed for the CVX-1 (See Fig. 9). The detailed description of the CVX AP is in CVX-1 Safety Data Package.

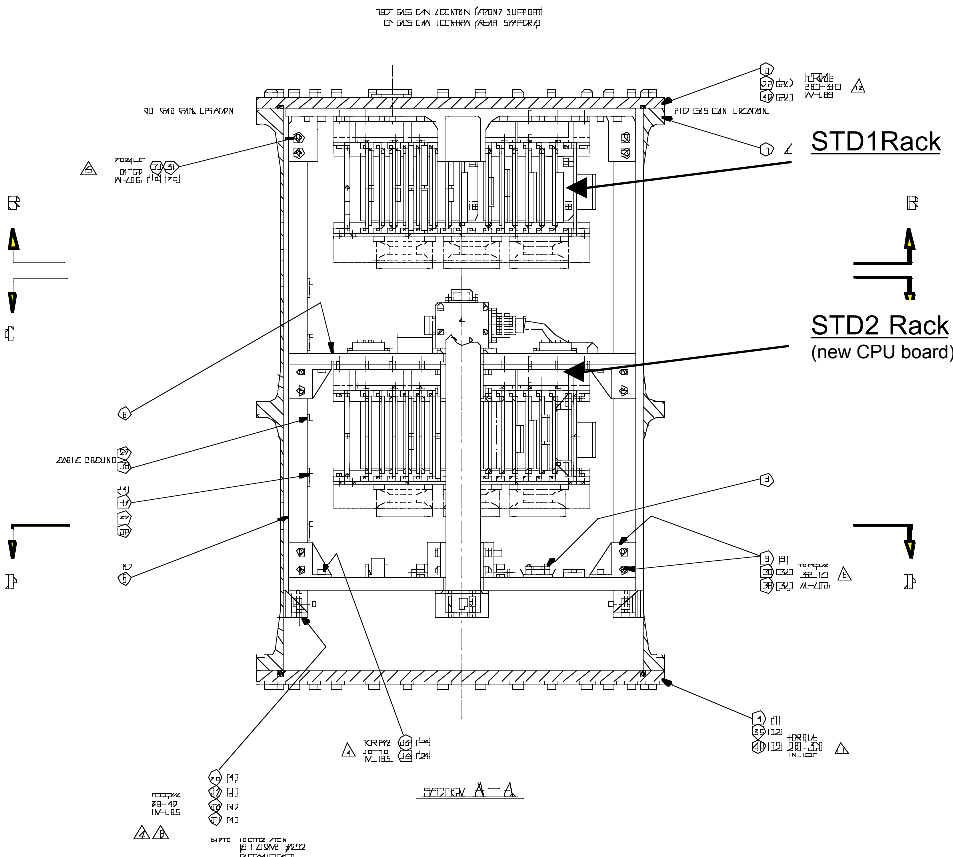


Fig.9 Avionics package

The following modifications were implemented (shown on Fig.10):

- Chirp Generator PCB (STD 1 Rack) was replaced;
- Square Root PCB (STD 1 Rack) was replaced;
- New Power PCB (STD 1 Rack) was added;
- PCU PCB was replaced by spare (STD2 Rack);

Associated rewiring was done to accommodate the above four items.

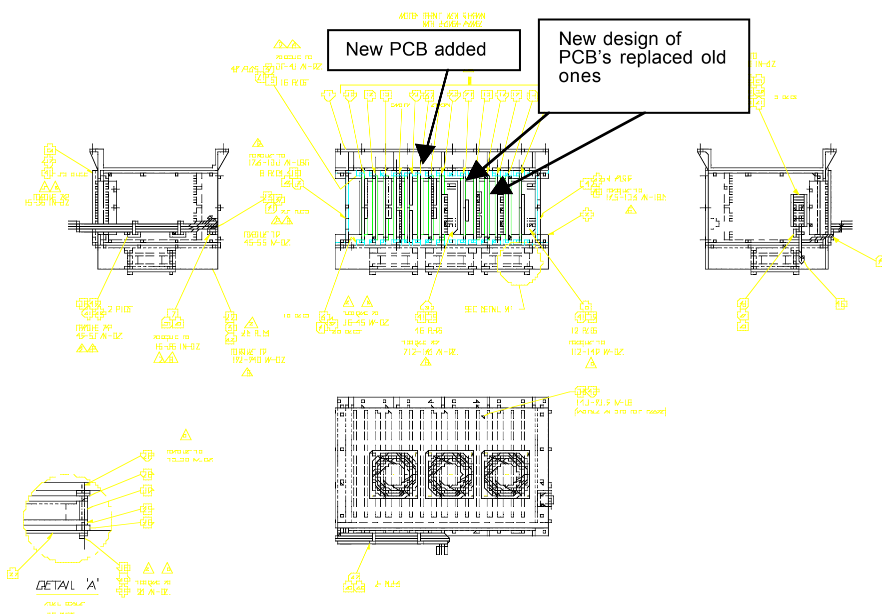


Fig.10 AP SDT1 rack with modification

Chirp Generator and Square Root PCB's are located in the STD 1 Rack (Board #7 and Board #8 respectively). Both Printed Control Boards are new. These PCB's were replaced to meet CVX-2 science requirements – to verify science return from CVX-1 experiment and to obtain new science data. The modification does not impact safety.

New custom made Power Amplifier was added to the STD 1 Rack (Board #11). The addition was made to enhance scientific return from the CVX-2 experiment: to permit, selectively, operation at single frequencies and, more importantly, to operate the viscometer with larger voltage offsets which drive the oscillating screen to larger displacements (producing the required higher shear rates).

The PCU PCB was replaced by a spare flight unit. The replacement was made due to reported "baked" diode on the flown PCU board, which was considered to be a post-flight problem. Although the fuse has never failed, appropriate nonconformance report was filed. The independent assessment was performed by External Engineering Review Board. Findings of the Review Board were summarized in Problem Report No 26 (see Attachment - TBD). There is no impact on safety.

3.3 Reflown Hardware maintenance, structural inspections, and refurbishment

Table below shows all procedures performed on flight hardware.

Procedure No	Name Of The Procedure	Comments
PROCESS-001	Canister Interconnect Cable Assembly Modifications	
PROCESS-002	Chirp2 Circuit Board Assembly	
PROCESS-003	SqRoot Circuit Board Assembly	
PROCESS-004	PwrAmp Circuit Board Assembly	
PROCESS-005	SX386cpu Tap-016 & Tap-012, Setup & Performance	
PROCESS-006	Chirp2 Tap-063, Performance	
PROCESS-007	SqRoot TAP-064, Performance	
PROCESS-008	PwrAmp TAP-065, Performance	
PROCESS-009	ITHACO Pre-Amp Machining. DEV	
PROCESS-010	ITHACO Pre-Amp Machining. FLT Backup	
PROCESS-011	ITHACO Pre-Amp Machining. FLT	
PROCESS-012	ITHACO Pre-Amp Mod. & Tap-066, FLT	
PROCESS-013	ITHACO Pre-Amp Mod. & Tap-066, FLT Backup	
PROCESS-014	Experiment Assembly Wiring Mods.	
PROCESS-015	Avionics Assembly Wiring Mods.	
PROCESS-016	Triaxial Sensor Head Installation	
PROCESS-017	SqRoot Circuit Board Assembly & TAP (Backup)	
PROCESS-018	PwrAmp Circuit Board Assembly & TAP (Backup)	
PROCESS-019	Chirp2 Circuit Board Assembly & Tap (Backup)	
PROCESS-020	SqRoot Circuit Board Vib & Thermal TAP (Backup)	
PROCESS-021	PwrAmp Circuit Board Vib & Thermal TAP (Backup)	
PROCESS-022	Chirp2 Circuit Board Vib & Thermal Tap (Backup)	
PROCESS-023	ITHACO PreAmp Installation In AP	
PROCESS-024	Incorporate ECO CVX2-006, Chirp2 Boards	
PROCESS-025	Diode Installation In Connector MPAPWR	
PROCESS-026	Battery Box Assembly, Battery Installation	
PROCESS-027	Replacement Of Flight Harddrive	

3.4.1 Hazard reports

There are no new hazards associated with the CVX-2 experiment. All CVX-1 Hazard Reports are applicable.

3.4.1.1 **CVX-2 Experiment Payload Electrical (HH-F-1 and HH-F-2)**

Hazard report HH-F-1: “Damage to STS Electrical System” (see CVX-1 Phase III baseline Data Package) is applicable.
Hazards description: Payload electrical system damages the Shuttle electrical system.
This hazard might be caused by:

1. Electrical fault in payload while it is connected to the Shuttle due to short-circuit or abrasion. GSFC Code 740 will perform or concur with (1) circuit analysis to verify proper circuit protection to be incorporated in HH electronics and experiment circuit design; (2) with inspection to verify that as built circuit protection is consistent with design. In addition GSFC QA will perform or concur with inspection to verify harness installed per NHB 5300.4. Safety verification shall be closed to CVX-2 VTL.
2. Improper sizing of wiring/fuses. GSFC Code 740 will perform or concur with payload electrical power distribution design review and perform inspection to verify compliance with TA-92-038 Letter from NSTS/ISS 18798B Interpretations of NSTS/ISS Payload Safety Requirements. Safety verification shall be closed to CVX-2 VTL.
3. Improper electrical load management. GSFC Code 740 will perform analysis. Safety verification shall be closed to CVX–2 VTL.

Hazard report HH-F-2: "Electromagnetic Interference with Space Shuttle operations" (see CVX-1 Phase III baseline Data Package) is applicable.
Hazard description: EMI generated from HH payload exceeds allowable ICD limits and interferes with the Shuttle avionics and/or other payloads.
This hazard might be caused by:
Improper design, associated shielding, or grounding. GSFC Code 740 will perform EMI test. Safety verification shall be closed to CVX-2 VTL.

3.4.1.2 Ignition of Flammable Payload Bay Atmosphere (CVX-F-1)

Hazard report CVX-F-1: (see CVX-1 Phase III baseline Data Package) is applicable.
Hazard description: Ignition of payload bay atmosphere during Shuttle entry, landing and post-landing.
This hazard might be caused by;

1. Electrical ignition due CVX-2 main circuit or battery powered circuit. Power-down configuration by HH will be input to PIP Annexes – safety verification closed by CVX-1. GSFC Procedure will be employed to back fill canisters, leak test will be performed on seal – safety verification shall be closed to CVX-2 VTL. CVX-1 maximum temperature analysis is applicable – safety verification is closed to CVX-1 VTL.
2. Hot surfaces inside canisters. CVX-1 maximum temperature analysis is applicable – safety verification is closed to CVX-1 VTL.
3. Canister MLI improper grounding. GSFC will inspect MLI and perform electrical continuity test. Safety verification closed shall be closed by CVX-2.

3.4.1.3 Battery Rupture/Release of Corrosive Electrolyte (CVX-F-2)

Hazard report CVX-F-2: (see CVX-1 Phase III baseline Data Package) is applicable. The CVX-2 will use a string of new commercial "D" cells batteries. Drawing 60009-ES-56143 has not been changed. Batteries were purchased from the same vendor.
Hazard description: Rupture of battery and escape of electrolyte or build-up of combustible gas could lead to explosion.
This hazard might be caused by:

1. Battery Circuit Overload Protection. Analysis and Inspection performed for CVX-1 are applicable. Safety verification is closed by CVX-1 VTL.
2. Build-up or venting of flammable gases. Analysis performed for CVX-1 is applicable. Safety verification is closed to CVX-1 VTL.
3. Electrolyte leakage from individual cells. Inspection will be performed. Safety verification shall be closed to CVX-2 VTL.
4. Build-up or venting of gases cases over pressurization of canister. Analysis performed for CVX-1 is applicable. Safety verification is closed by CVX-1 VTL.

3.4.1.5 Flammable Materials (HH-F-4)

Hazard report HH-F-4 (see CVX-1 Phase III baseline Data Package) is applicable.
Hazard description: Uncontrolled fire hazard to the STS or other payloads.
This hazard might be caused by improper material selection. Material Lists will be submitted to GSFC for evaluation and approval. Safety verification shall be closed to CVX-2 VTL.

3.4.1.5 Failure of Experiment Support within Sealed Canister (HH-F-6)

Hazard report HH-F-6 (see CVX-1 Phase III baseline Data Package) is applicable. See Section 3.1 Structural Design Overview.
Hazard description: During launch, landing, on-orbit, or emergency landing phases the experiment support structure fails resulting in release of experiment.
This hazard might be caused by:

1. Structural Design. GSFC will review and approve CVX structural analysis, test procedures and results – safety verification closed to CVX-1 VTL.
2. Structural Materials. GSFC will approve all materials. Safety verification shall be closed to CVX-2 VTL.
3. Potential Defective Components. GSFC will verify completion of "Standard Sealed gas canister Assembly/Integration Procedure. Safety Verification shall be closed to CVX-2 VTL.

4. Potential Defective Manufacturing and/or Assembly. GSFC will perform or concur with inspection to ensure that assembly and materials are in accordance to design drawings and specifications and positive means were implemented to preclude backoff of fasteners. Also GSFC will verify vendor certification. Safety verification shall be close to CVX-2 VTL.

3.5 Safety Noncompliance

N/A

3.6 Limited life items for reflown hardware

N/A.

3.7 Failure and anomalies

N/A (Comments about Problem Reports– TBD)

3.8 Radioactive Material

N/A

3.9 Certificate of NSTS/ISS payload Safety Compliance

See Attachment

Attachment

Certificate of Compliance
Problem Report No 26 (TBD)
Safety Package Cover Sheet
Verification Tracking Log

CERTIFICATE OF NSTS/ISS

PAYLOAD SAFETY COMPLIANCE

FOR

a. PAYLOAD AND MISSION:

b. Applicable to:

___ Payload Design and Flight Operations

___ Ground Support Equipment Design and Ground Operations

The Payload Organization Hereby Certifies that:

1) The Payload Is Safe.

2) The Payload Complies with all Applicable Requirements of the NSTS 1700.7 (current issue), “Safety Policy and Requirements for Payloads Using the National Space Transportation System” and the NSTS 1700.7 Addendum (current issue), “Safety Policy and Requirements for Payloads Using the International Space Station,” if applicable.

c. Approved Waivers/Deviations:

d. Approved (Payload Organization Manager):

e. Date:

SAFETY PACKAGE COVER SHEET

PAYLOAD	PHASE	DATE
Critical Viscosity of Xenon –2 (CVX-2); Hitchhiker	Phase 3	9/26/0 0

NUMBER	HAZARD TITLE	REMARKS	DISPOSITION
CVX-F-1	Ignition of Flammable Payload Bay Atmosphere	Open	
CVX-F-2	Battery Rupture/Release or Corrosive Electrolyte	Open	
HH-F-1	Damage to STS Electrical Systems	Open	
HH-F-2	Electromagnetic Interference with Space Shuttle Operations	Open	
HH-F-4	Flammable Materials	Open	
HH-F-6	Failure of Experiment Support Structure within Canister	Open	

GENERAL COMMENTS

CONCURRENCE/APPROVAL

PAYLOAD ORGANIZATION	STS OPERATOR