PAYLOAD FLIGHT HAZARD REPORT		a. NO:	AMS-02-F04
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE:	III
d. SUBSYSTEM: Pressure Systems	e. HAZARD GROUP: Structural	f. DATE:	August 4, 2010
g. HAZARD TITLE:	Overpressurization of Orbiter Payload Bay	i. HAZARD CATEGORY:	CATASTROPHIC X CRITICAL

h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B, 200.1, 200.2, 200.3, 200.4a, 201.3, 202.6, 205, 206, 208.4, 208.4a, 208.4b, 208.4c, 208.4e
j. DESCRIPTION OF HAZARD:	Nominal or fault venting/release of stored gases (TRD Gas Supply (CO_2, Xe) and the Thermal Control System (Ammonia, CO_2) generates excessive volume/pressure within the Orbiter payload bay during ascent or entry (doors closed) damaging the payload bay doors or aft bulkhead. Damage of these critical structures can result in the loss of Orbiter safe entry capability.

k. CAUSES

(list)

1. Nominal boil off of cryogenic helium <Deleted>
2. Loss of Vacuum Case thermal isolation <Deleted>
3. Leakage of Warm Helium Gas Supply <Deleted>
4. Leakage of TRD Gas System
5. Leakage of Thermal Control Systems
6. Blockage of Payload Bay Vents with MLI

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III	[signature] TRENT MARTIN 8/4/10	[signature] 8/6/10

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F04
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: III

l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)	OPS CONTROL
1. CAUSE: <Deleted. Cryomagnet System Removed from AMS-02>	
2. CAUSE: <Deleted. Cryomagnet System Removed from AMS-02>	
3. CAUSE: <Deleted. Warm Helium Gas Supply Removed from AMS-02>	
4. CAUSE: Leakage of TRD Gas System	

4.1 CONTROL: During ascent and landing phases, each of the TRD Xenon and Carbon Dioxide gas tanks are isolated by three valves and flow limiting orifices. Valves are normally closed and close when power is removed. During Ascent the AMS-02 is depowered and no power is available for operations. If these valves are open, by three fault conditions in the valve mechanisms, and the gas pressure released through a flow restricting orifice to the vent line, protected by burst disk and pressure relief valves (will open under direct pressure of tanks), Xenon and Carbon Dioxide gas will be released into the payload bay. Xenon will have the highest continuous mass flow rate potential through a single burst disc with a value of 5 g/sec (0.0017 ft^3/s). Carbon dioxide will have the flow rate of 0.3 g/s (0.005 ft^3/s). These continuous rate values are achieved after a release of stored pressure within the mixing tank of 10 grams for the Xenon or 3 grams for the Carbon Dioxide. Operation of valves would require powering of AMS control systems that are unpowered during ascent. Under nominal operations (installed on ISS) the worst case leakage through the sensor straws has been established by testing to be 3.1×10^{-6} l/sec. During operations on the ISS, a mixed gas purge may be used to assure a known mix of gases within Box C.

4.1.1 SVM: Review of design to confirm implementation of valves and orifices to isolate gas supply tanks.

4.1.2 SVM: Inspection of as built hardware to confirm implementation of valves to isolate gas supply tanks.

4.1.3 SVM: Functional testing of TRD confirms operation of valves to close with power removal.

4.1.4 SVM: Environmental/vibration testing to confirm valves remain closed during ascent/descent conditions.

4.1.5 SVM: Xenon and Carbon Dioxide Tanks will be filled with the appropriate gases per ground filling procedures.

4.1.6 SVM: Vent Rate Analysis

4.1.7 SVM: Approval of Venting Analysis

4.1.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

4.1.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

4.1.3 STATUS: Closed. "UG and UGPD test report," A. Bartoloni, B. Borgia, T. Siedenburg, F. R. Spada, CERN, 6/17/2009

4.1.4 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

4.1.5 STATUS: Closed. AMS-02 Task Sheet (ATS) TRD 090131-1, "TRD_GAS_SUPPLY_SYSTEM_CO2_VESSEL_FILLING_FOR_FLIGHT," and TRD 090522-1, "TRD_GAS_SUPPLY_SYSTEM_XENON_VESSEL_FILLING_FOR_FLIGHT," establish filling procedures.

4.1.6 STATUS: Closed. "Determination of venting flow rate for AMS TRD Gas System," 23 June 2004, Ulrich Becker, Peter Fisher.

4.1.7 STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred to by Shuttle Integration Representative to PSRP.

4.2 CONTROL: The construction of the TRD high pressure gas supply utilizes stainless steel lines, (orbital) welded joints and fittings. Rupture of these DFMR lines would be required to release the pressure tank supply of gas. Reference DFMR compliance in AMS-02-F05.

4.2.1 SVM: Review of Design

4.2.2 SVM: Inspection of As Built Design.

4.2.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

4.2.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009. TRD Leak Repair, CERN weld inspection report EDMS No: 1078985 dated May 26, 2010

4.3 CONTROL: Fill and drain ports for the TRD tanks (Box S) utilize check valves and dual sealed caps to preclude gas release.

4.3.1 SVM: Review of design

4.3.2 SVM: Inspection of as built hardware.

4.3.3 SVM: Post filling inspection of cap installation

4.3.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

4.3.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

4.3.3 STATUS: Closed to SVTL.

4.4 CONTROL: The amount of gas that can be released from the TRD Box C, including the mixing tank is limited by the volumes and pressure of mixed gases present and will not present a danger of over pressurization of the Orbiter Payload Bay during ascent and entry as the system is unpowered and the supply of gas is isolated though unpowered closed valves (7). The entire box operates at pressures lower than 17.4 psia and the total gas volume is 0.0028m^3 (0.1 ft^3). The "straw" volume is divided into 41 segments, each is isolatable by redundant valves (provided for mission success reasons). A leak in any segment would release at most 0.007 m^3 (0.25 ft^3) of mixed gas. If the volume of the entire straw system is released 0.23 m^3 (8 ft^3) of mixed gas could be released. Mixed gas is nominally a 4 to 1 ratio of xenon to carbon dioxide. The TRD sensor straws have been tested for leakage, which easily enveloped by the fault condition, with an established leak rate for an operational TRD of 3.1 x 10^{-6} l/sec.

4.4.1 SVM: Review of design

4.4.2 SVM: Inspection of as built hardware.

4.4.1 STATUS: Closed. ESCG Memorandum ESCG-4175-09-REENTES-MEMO-0011, "Review of TRD Gas Supply Design," dated March 20, 2009

4.4.2 STATUS: Closed. ESCG Memorandum ESCG-4295-09-CPAS-MEMO-0019, "Review of the AMS-02 TRD Gas Supply Acceptance Data Package," dated December 22, 2009.

5. CAUSE: Leakage of Thermal Control Systems

5.1 CONTROL: The Tracker TCS (TTCS) utilizes two actively pumped carbon dioxide loops that contain approximately 842 grams of CO_2 in the largest of the two loops (approx 15.05 ft^3 (0.426 m^3) @ STP). Loops operate in a sealed mode qualified under DFMR without nominal or fault venting, reference AMS-02-F05.

5.1.1 SVM: Review of Design

5.1.2 SVM: Approval of AMS-02 Potential Gas Release

5.1.1 STATUS: Closed. Email from NLR/J. Van Es, "TTCS Pressure Tables," on May 29, 2010 with fill volumes of Primary 816 g and Secondary 842 g quantities. TTCS Fill report, transmitted by NLR/Johannes Van Es for Primary (819 grams CO2) and Secondary (850 grams CO2) Loops, dated 7/26/2010. Fill quantities make mass per liter of internal volume under the maximum allowed for establishing MDP.

5.1.2 STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred to by Shuttle Integration Representative to PSRP.

5.2 CONTROL: <Deleted. Cryocooler Loop Heat Pipe Removed from the AMS-02>

5.3 CONTROL: Radiator panels contain isolated heat pipe (and USS-02) elements with ammonia as a working fluid. Largest single heat pipe quantity of ammonia is less than 41 grams (32.7 grams maximum final fill of a single heat pipe). Heat pipes operate as closed systems qualified under DFMR and have no nominal or fault venting conditions, reference AMS-02-F05.

5.3.1 SVM: Review of Design

5.3.2 SVM: Approval of AMS-02 Potential Gas Release

5.3.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

5.3.2 STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred to by Shuttle Integration Representative to PSRP.

5.4 CONTROL: <Deleted. OHP Removed from AMS-02>

5.5 CONTROL: <Deleted. The CAB Loop Heat Pipes Removed from AMS-02>

5.6 CONTROL: <Deleted. The Cryocooler Removed from AMS-02>

5.7 CONTROL: TTCS Accumulator Heat Pipes contains 3.6 grams (max) of ammonia. The TTCS Accumulator Heat Pipe is a closed system qualified under DFMR and has no nominal or fault venting conditions, reference AMS-02-F05.

5.7.1 SVM: Review of the Design

5.7.2 SVM: Approval of AMS-02 Potential Gas Release

5.7.1 STATUS: Closed. ESCG-4470-09-TEAN-DOC-0121, "AMS-02 Heat Pipes and Loop Heat Pipes Fluid Fill Quantities," dated September 1, 2009

5.7.2 STATUS: STATUS: Closed. Contractor Shuttle Integration Office has assessed all possible gas release scenarios and provided acceptance of them. This is documented in Boeing technical memorandums TS-TM02-064 dated December 12, 2002, additionally gas release from associated sources were reviewed and found acceptable in Boeing Technical Memorandums TS-TM-05-37, dated December 9, 2005 and TS-TM-07-035 dated August 8, 2007. All have been concurred with by Shuttle Integration Representative to PSRP.

6. CAUSE: Blockage of Payload Bay Vents with MLI

6.1 CONTROL: All MLI and thermal blankets used on the AMS-02 will be secured to AMS using positive mechanical means. "Soft": techniques such as hook and loop fasteners (Velcro ®) will not be used as a primary means of retaining the AMS-02 MLI and thermal blankets. Note GFE provided by Shuttle/ISS Programs are independently certified and used by tha AMS-02 in accordance with their certifications, may exclusively use hook and loop fasteners for retaining thermal blankets.

6.1.1 SVM: Review of design

6.1.2 SVM: Inspection of as built hardware.

6.1.1 STATUS: Closed. ESCG Memorandum ESCG-4470-09-TEAN-DOC-0025, "Attachment of AMS-02 Thermal Blankets". Dated February 27, 2009

6.1.2 STATUS: Closed to SVTL.

Notes:

Fluid/Gas (at STP)	g/l	lb/ft^3
Ammonia	0.7710	0.11135
Carbon Dioxide	1.9769	0.12341
Xenon	5.85	0.365

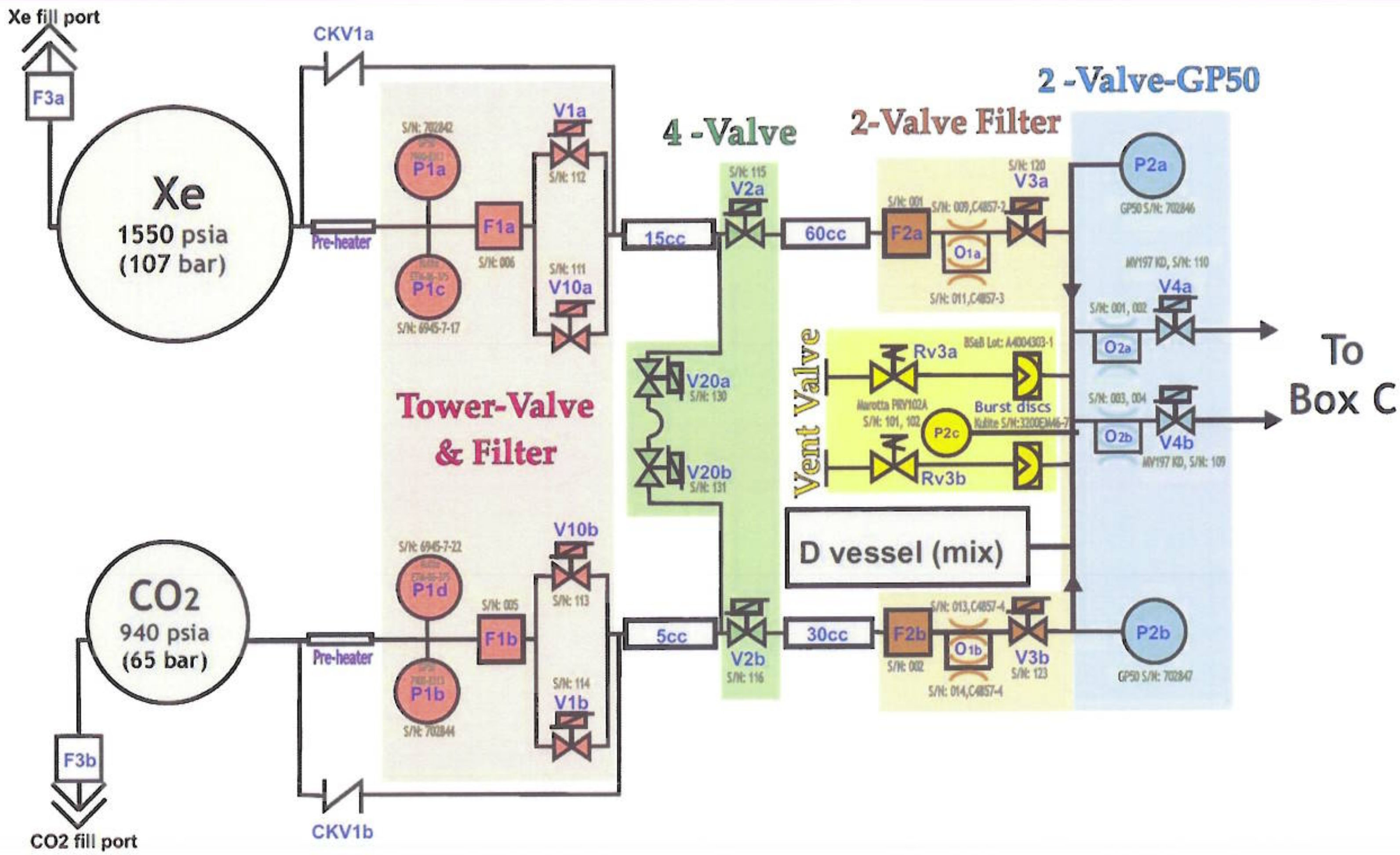
ACRONYMS	
°C – Degrees Centigrade (Celsius)	MDP – Maximum Design Pressure
°F – Degrees Fahrenheit	mg/sec – milligrams per second
AMS-02 – Alpha Magnetic Spectrometer 02	min – Minutes
atm – atmospheres	MLI – Multilayer Insulation
C of C – Certificate of Compliance	MUA – Material Usage Agreements
CAB – Cryomagnet Avionics Box	Ops – Operations
CDC – Cool Down Circuit	PGSC – Payload General Support Computer
CHX – Cold Heat Exchanger	psia – pounds per square inch absolute
CO_2 – Carbon Dioxide	psid – pounds per square inch differential
COTS – Commercial Off the Shelf	PSRP – Payload Safety Review Panel
DDRS2 – Digital Data Recording System 2	QA – Quality Assurance
DFMR – Design for Minimum Risk	SCL – Space Cryomagnetics Limited
ft^3 – Cubic Feet	SCL – Superfluid Cooling Loop
ft^3/s – Cubic feet per second	SFHe – Superfluid Helium
g/l – Grams per liter	STA – Structural Test Article
He – Helium	STA – Structural Test Article
K – Kelvin	STP – Standard Temperature and Pressure
K – Kelvin	SVM – Safety Verification Method
kg/sec – kilograms per second	SVP – Safety Verification Plan
ksi – kilo pounds per square inch	TCS – Thermal Control System
lb/ft^3 – Pound per cubic foot	TIM – Technical Interchange Meeting
lb/sec – Pounds (mass) per second	TRD – Transition Radiation Detector

ACRONYMS	
lbf – pound force	TTCS – Tracker Thermal Control System
M/OD – Meteoroid/Orbital Debris	ult – Ultimate
m^3 – Cubic Meters	USS-02 – Unique Support Structure 02
m^3/sec – Cubic meters per second	VC – Vacuum Case
mbar – millibar	Xe – Xenon
MUA – Material Usage Agreements	OHP – Oscillating Heat Pipe (Deleted from Design)

Stored Gas Reservoirs

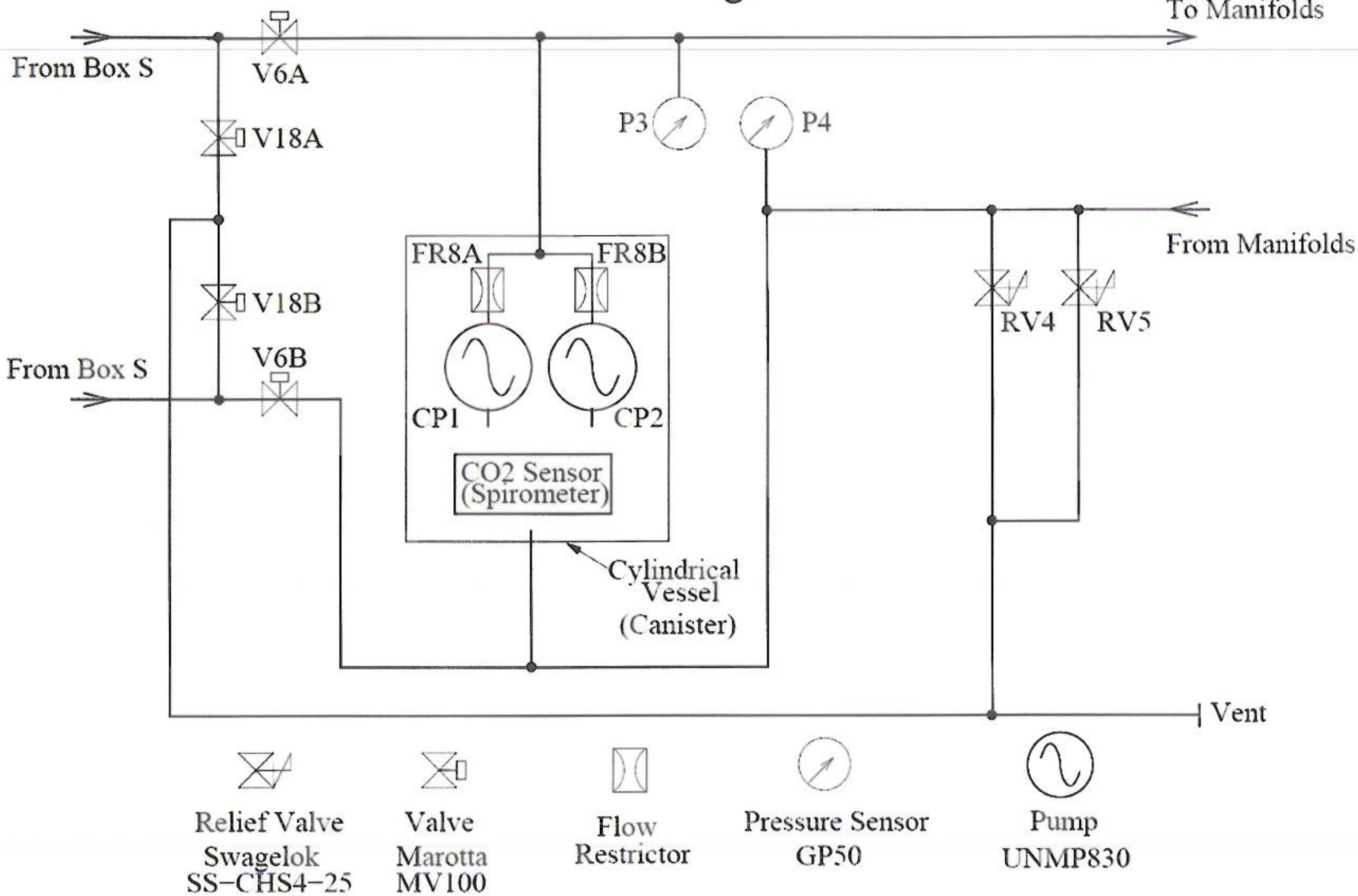
System	Working Fluid	Quantity	Gas Volume (at STP)	Notes:
TRD Xenon Gas Supply	Xenon (Xe)	109 lbs (49.4 kg)	299 ft^3 (8.46 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.03 ft^3/s (Single burst disc open).
TRD Carbon Dioxide Gas Supply	Carbon dioxide (CO_2)	12 lbs (5.5 kg)	98.2 ft^3 (2.78 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.005 ft^3/s (Single burst dic open).
TRD Mixing Vessel/Box C	4:1 Xenon: CO_2 mix	Quantity supplied from TRD Box S ⇒ 0.04 lbs (0.03 kg)	0.012 m^3	During ascent/descent this is a non-operational system that requires the Box S to charge Box C with gas pressure and a failure of a relief valve.
TRD proportional counters "Straws", manifold & delivery from Box C	4:1 Xenon: CO_2 mix	Quantity supplied from TRD Box C ⇒ 2.58 lbs (1.17 kg)	0.23 m^3 total with 0.0056 m^3 per straw segment with interconnecting tubing and connection to Box C	Straw Modules are approximately 500 m in length with sixteen straws per module (dia. of 6 mm). Interconnecting tubing and connection to the Box C account for less than 0.001 m^3 each. This value is rounded up to 0.23 m^3.
Tracker TCS	Carbon dioxide	816g/842g grams (two loops)	15.05 ft^3 (0.426 m^3) max per loop	Closed system design qualified under Design for Minimum Risk (DFMR) Criteria
Heat Pipes (various)	Ammonia	Largest Quantity in single heat pipe is 32.7 grams	2.01 ft^3 (0.057 m^3)	Closed heat pipe systems qualified under DFMR criteria
USS-02 Heat Pipes	Ammonia	3 pipes with 7.6 grams each	0.35ft^3 (0.01m^3)	Closed heat pipe qualified under DFMR criteria
TTCS Accumulator Heat Pipe	Ammonia	2 pipes, 3.6, 3.3 grams	0.16ft^3 (0.0046m^3)	Closed heat pipe qualified under DFMR.

Box S Schematic

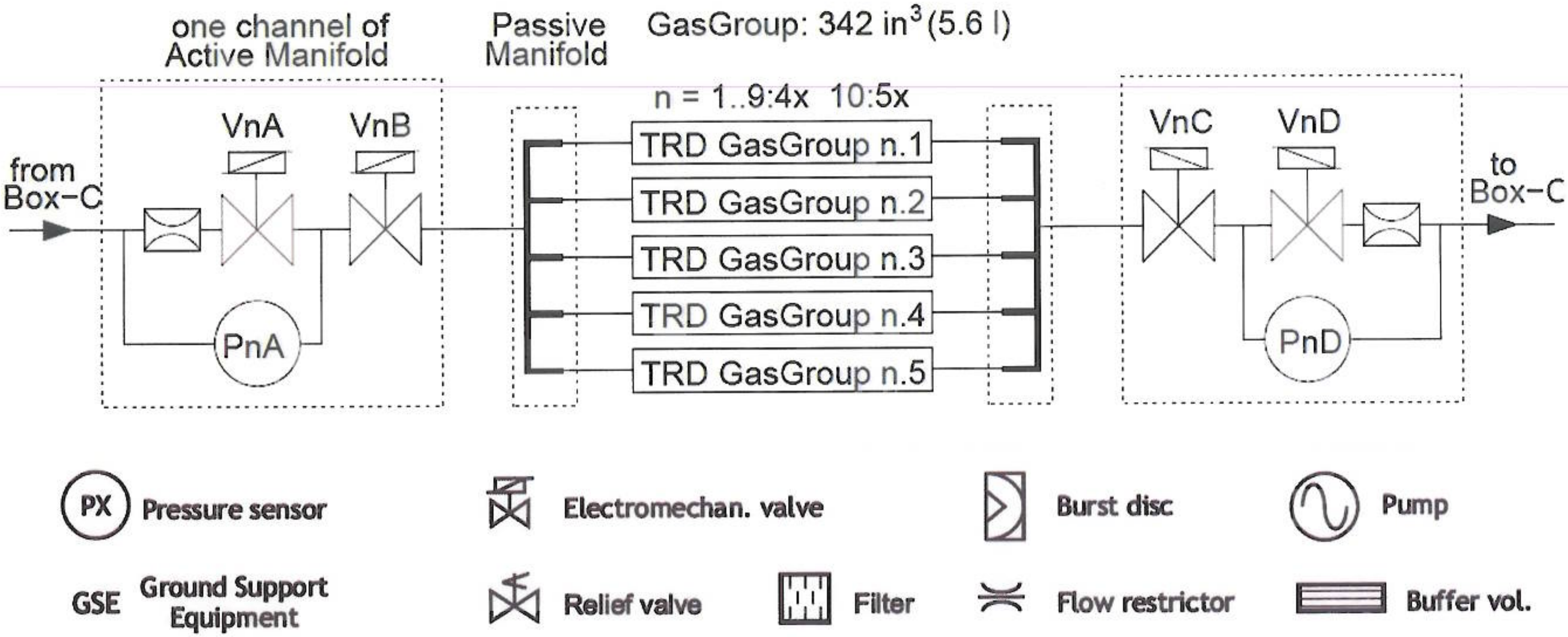


TRD Box S (Pressures are nominal operating pressure)

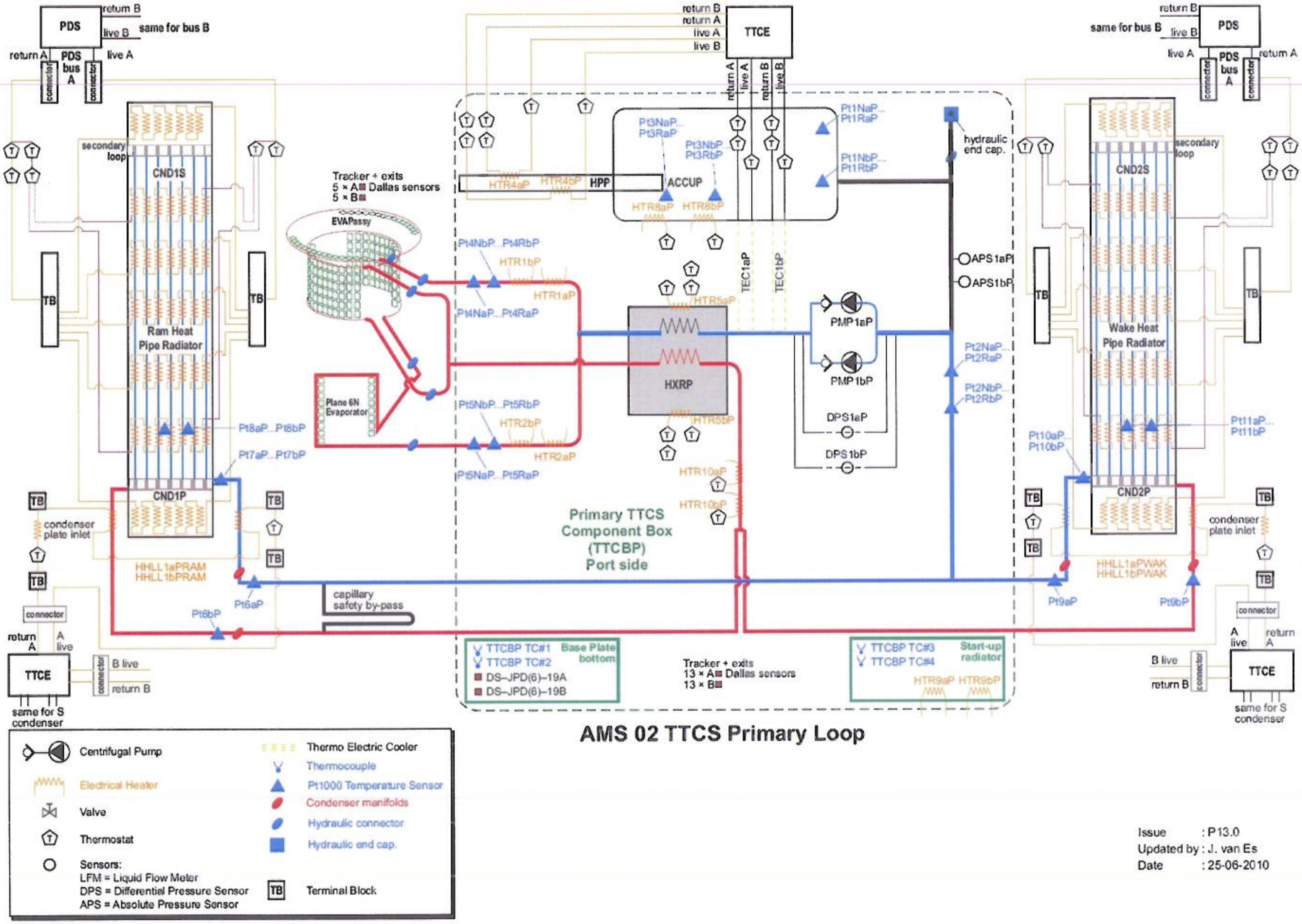
Box−C Gas Diagram



TRD Box C

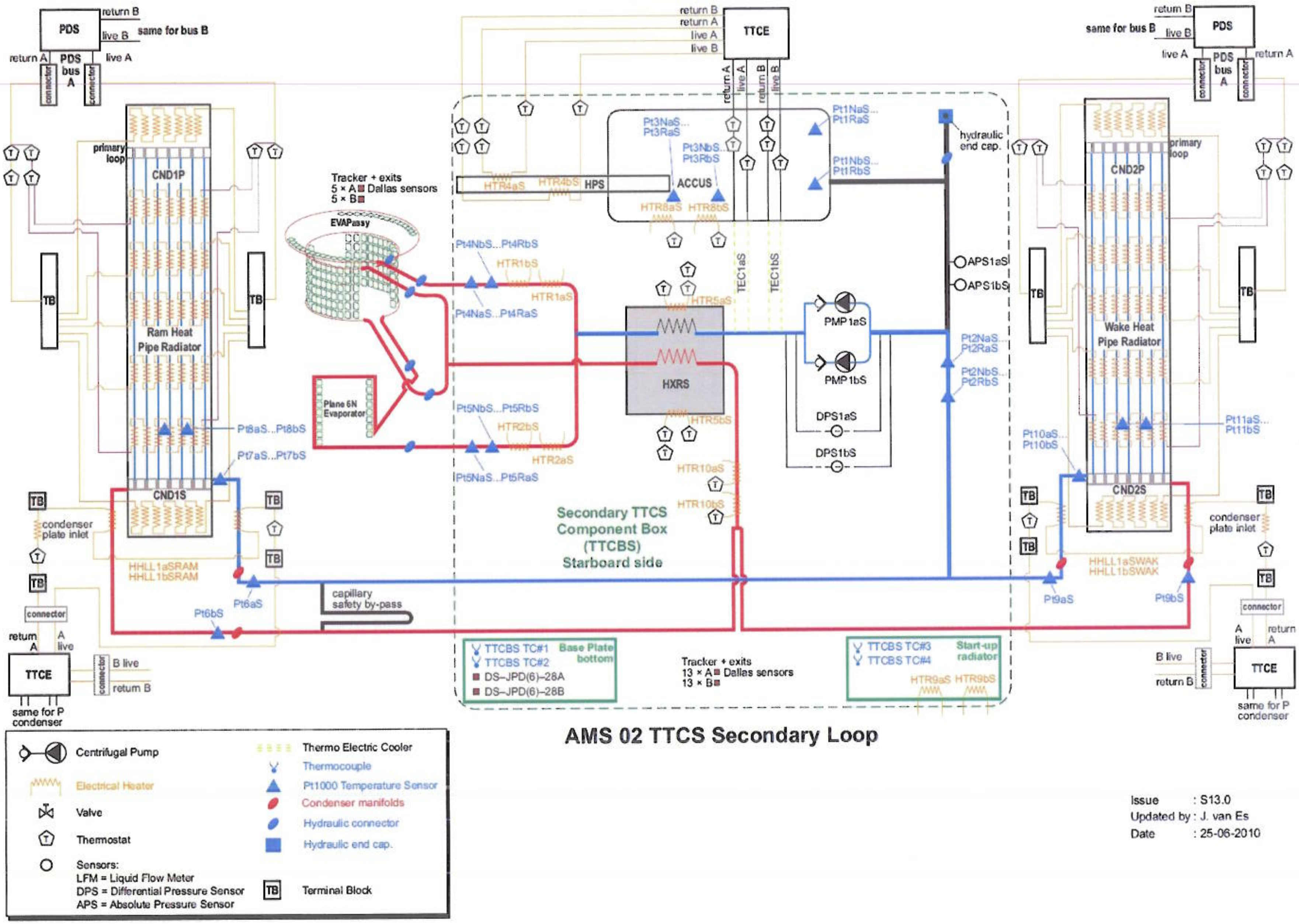


TRD Manifold-Straw Representation



AMS 02 TTCS Primary Loop

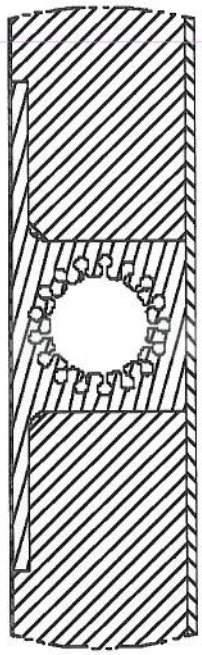
Issue : P13.0
Updated by : J. van Es
Date : 25-06-2010

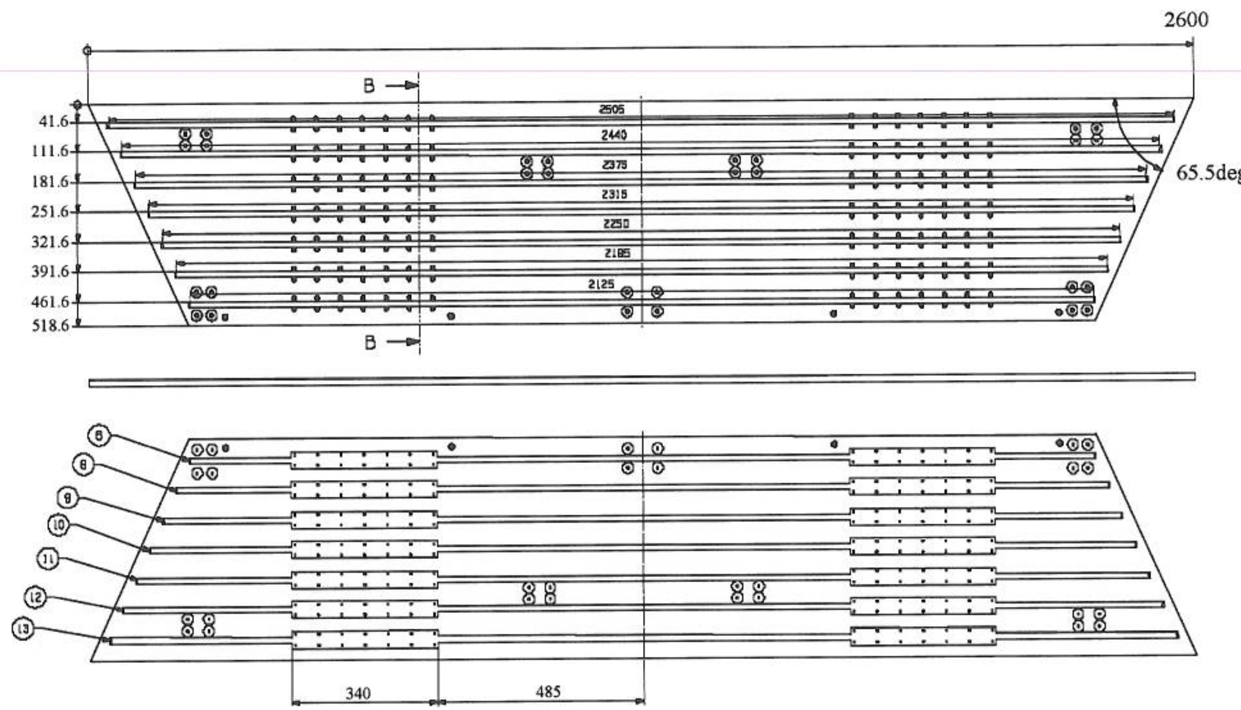


AMS 02 TTCS Secondary Loop

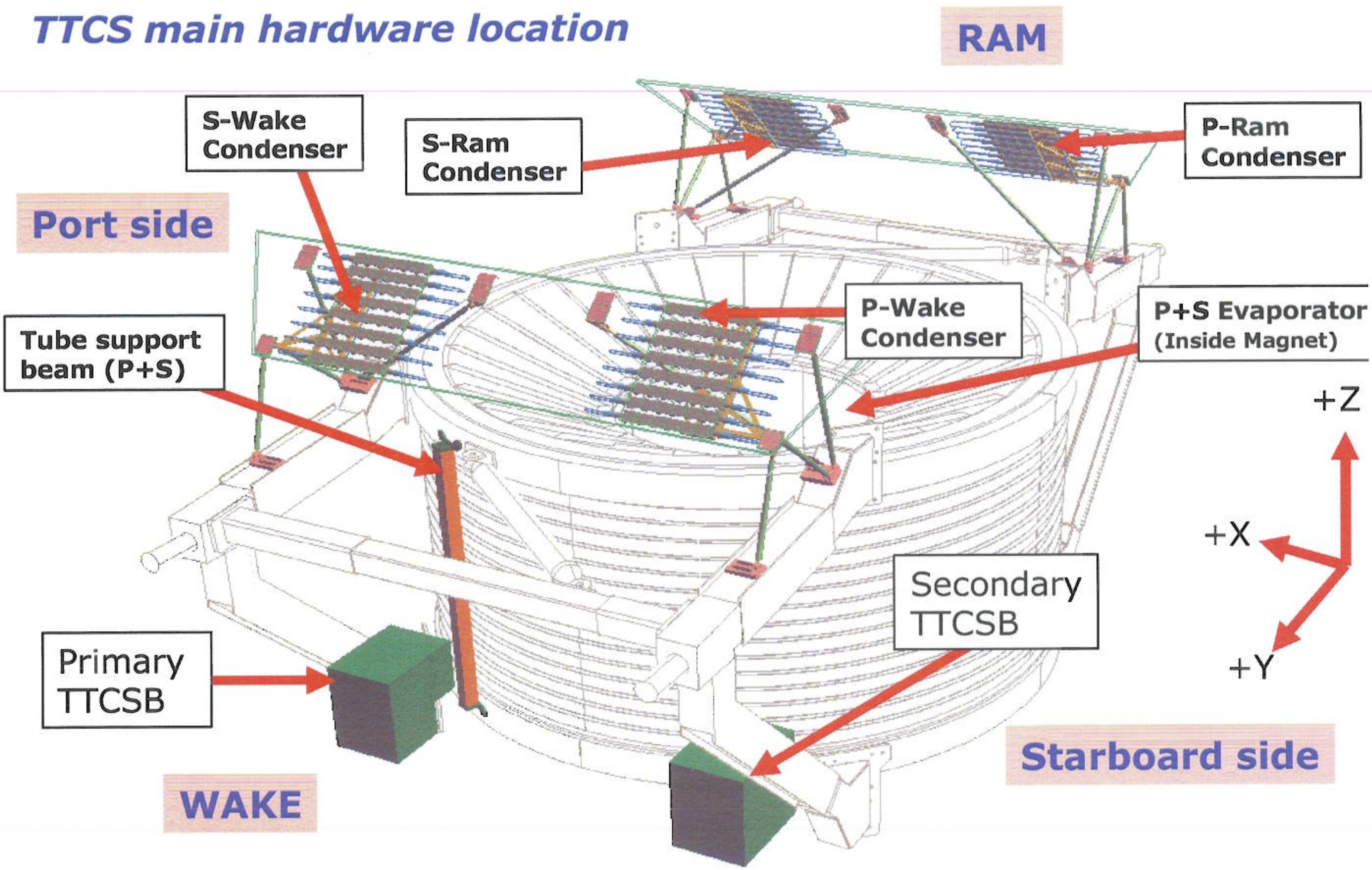
Issue : S13.0
Updated by : J. van Es
Date : 25-06-2010

Tracker
Heat
Pipe

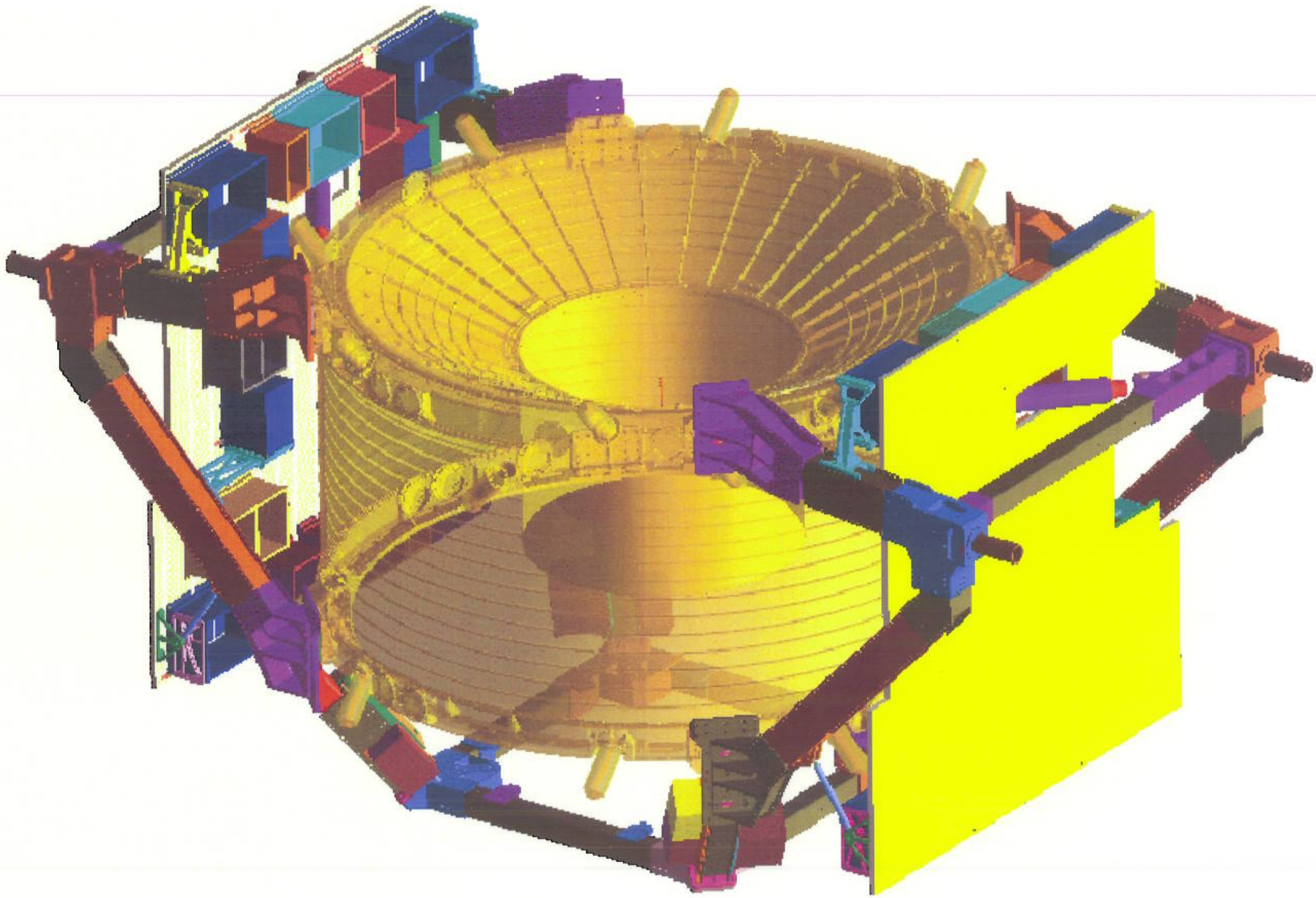




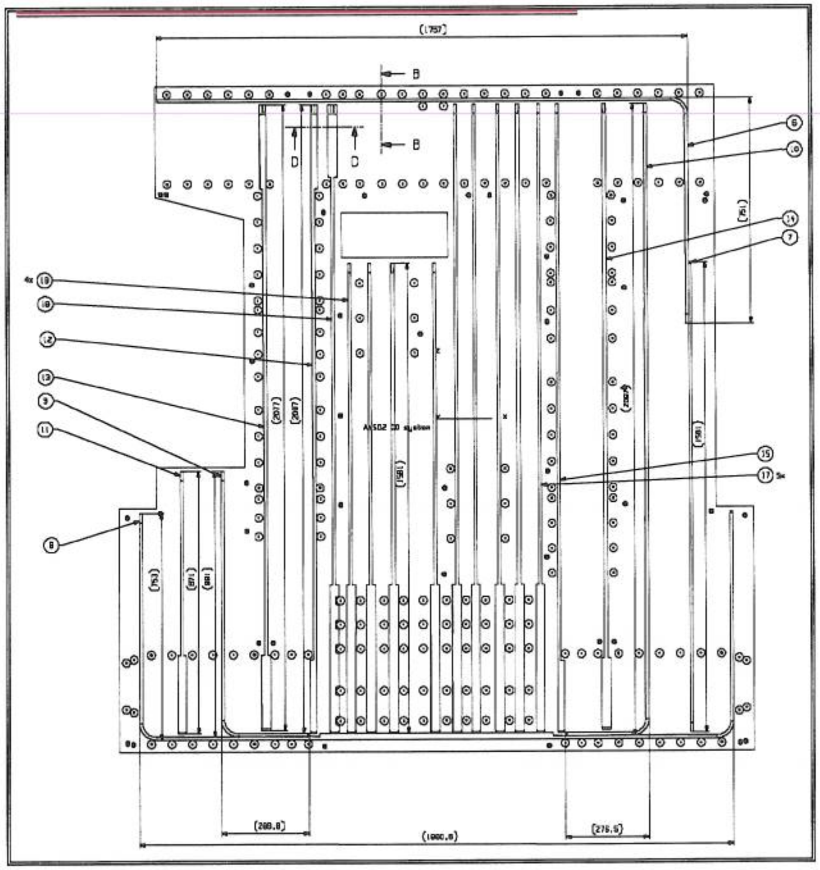
Tracker TCS Heat Pipe Layout



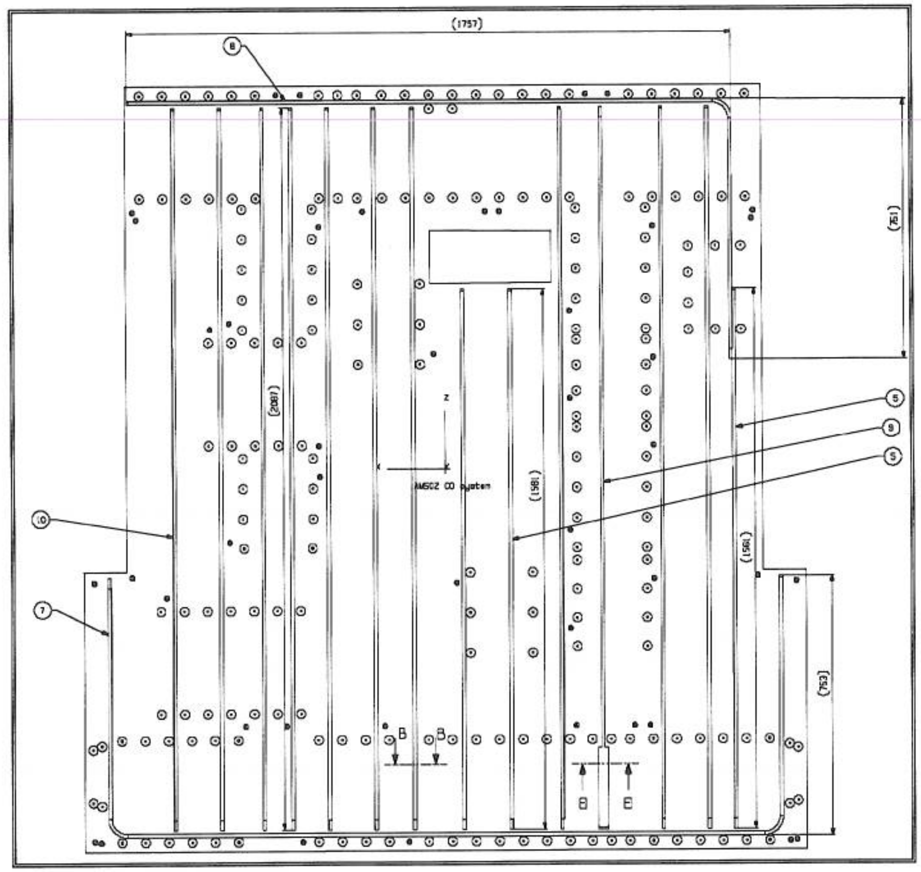
Components of the Tracker Thermal Control System



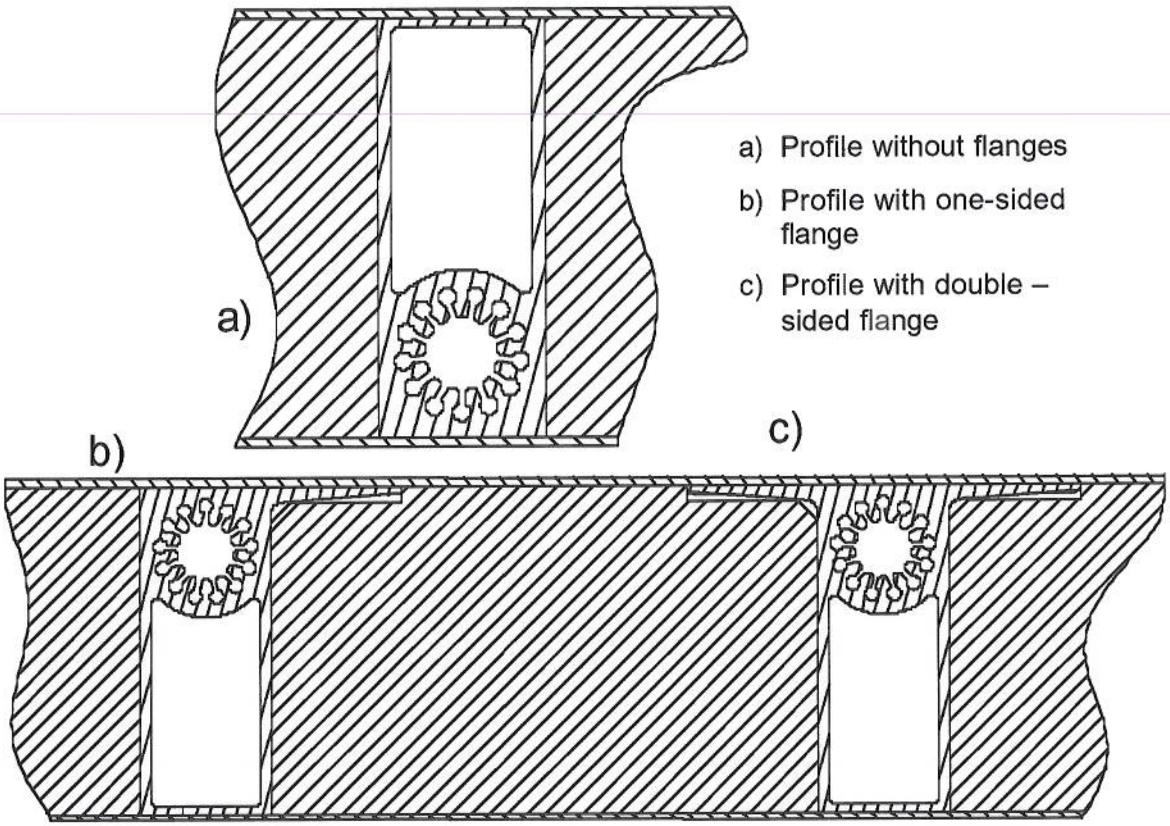
AMS-02 Wake and Ram Radiators



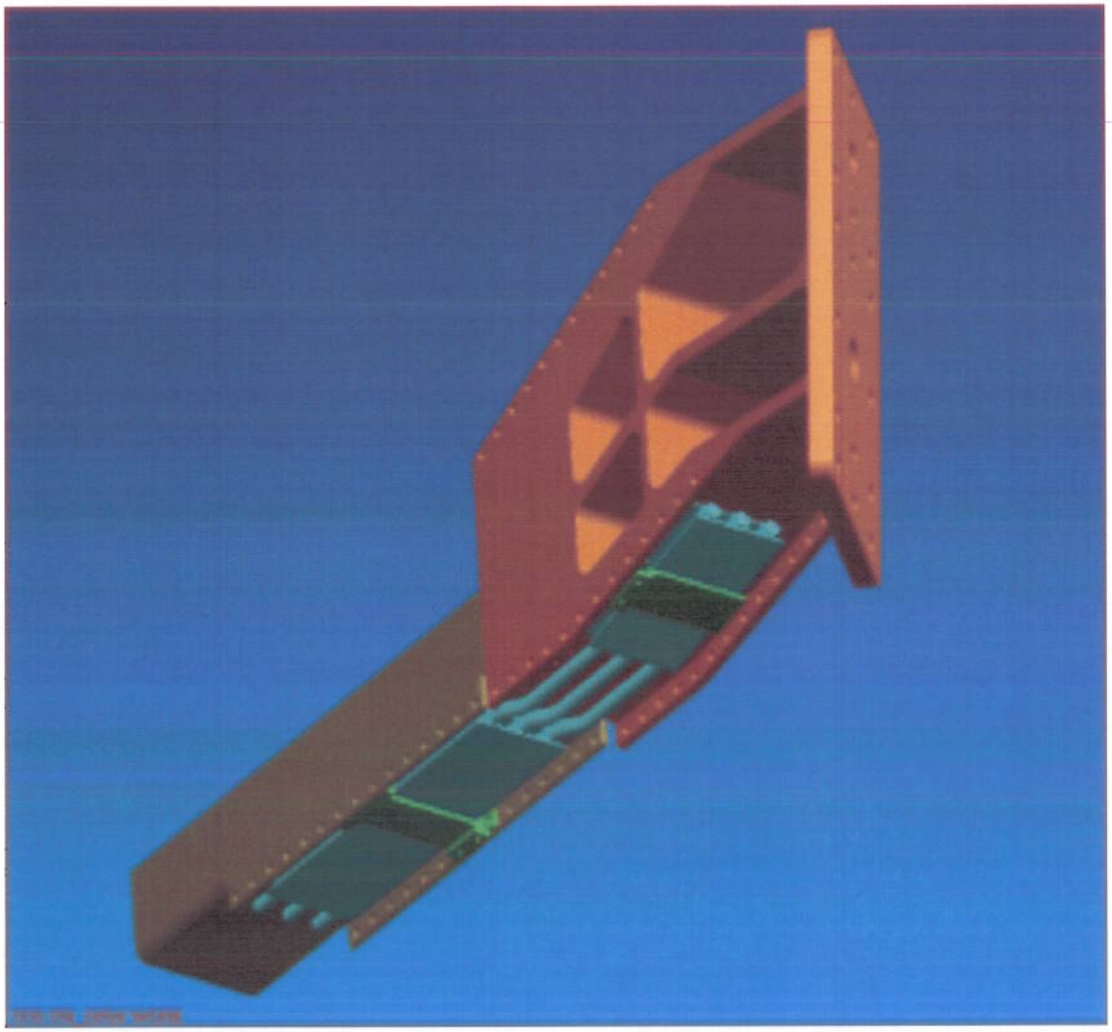
TCS – Wake Side Radiator for Avionics Crates



TCS – Ram Side Radiator for Avionics Crates



TCS Wake and Ram Radiators Heat Pipe Methods of Mounting



CAB USS Heat Pipes – Enveloped in Heat Pipe Analyses

BOEING **Technical Memorandum**

The Boeing Company
IDS – NASA Systems
13100 Space Center Blvd.
Houston, TX 77059

Date	December 19, 2002	No.	TS-TM-02-064
To:	Darryl L. Archer IDS – NASA Systems D/J387, HS3-30	From:	Mark E. Fields IDS – NASA Systems D/J351, HS3-30 281-226-5814

Subject: Alpha Magnetic Spectrometer II During Ascent and Descent Orbiter Operations

Contract:	NAS9-20000
Purchase Order:	1970483303
PDRD No.:	N/A
WBS No.:	1.7.1.1
Task No.:	70004
Artemis No:	N/A

References:

1. Request for Assessment, B. Harris, USA, Tracking # TH-GEN-010, December 16, 2002.
2. Fields, M. E., "Superfluid Helium Venting into the Payload Bay from the Alpha Magnetic Spectrometer II During Ascent and Descent Mission Phases", TM-TS-00-048, December 15, 2000.
3. Harrison, S. M., "Loss of Vacuum and Venting from the AMS-02 Cryostat", Lockheed Martin Technical Report, December 11, 2002

1.0 Summary

The Alpha Magnetic Spectrometer II (AMS-2) is an experiment proposed for flight to the International Space Station. The AMS-2 is comprised of a large superfluid helium dewar insulated by a vacuum jacket. The large volume of the superfluid helium if vented into the payload bay during ascent or descent phases would cause pressure increases on structures above Orbiter certification. Current failure venting scenarios of the AMS-2 specify that any release of helium into the payload bay would be after the critical portion of the ascent phase or would happen after landing of the descent phase (Ref 1).

2.0 Background

The AMS-2 contains 2460 liters (86.87 ft^3) of superfluid helium cooled to a temperature of 1.8°K (-456.4°F). The helium, if released, would vaporize to a volume of approximately 76000 ft^3. The payload bay and lower mid-fuselage volume is 18400 ft^3. Previous venting analysis of the AMS-2 (Ref 2) has demonstrated that the increase in the pressure due to the release of the helium would exceed Orbiter certification of existing structures. That study analyzed the helium leaking into the payload bay during the first 3 minutes of the ascent mission phase and during the open vent door portion of the descent mission phase. The leak rate was a blow-down curve that had a duration of 700+ seconds. The failure scenario involved a large hole in the vacuum jacket with an approximate area of 3.29 in^2 that allowed external air to compromise the AMS-2.

The current failure scenario of the AMS-2 involves the O-rings that seal the vacuum jacket. The equivalent hole size in the vacuum jacket is 0.0095 in^2 (Ref 3) due to the O-ring failure. This smaller hole along with factors associated with the size, allow for a longer time between vacuum jacket failure and the release of the helium. This extension prohibits the accumulation of external gasses due to the attainment of a near vacuum in the payload bay after 3 minutes of the ascent flight. During descent, the 23 minutes specified in Reference 2 would place the time of helium release after Orbiter landing.

3.0 Conclusion

The release of the superfluid helium from the AMS-2 cryostat into the payload bay would exceed the certification levels of many Orbiter structures if it occurred during the critical ascent and descent mission phases. The specified failure scenario of the protective O-rings sealing the vacuum jacket of the AMS-2 helium cryostat does not allow the release of helium during any of these critical mission phases.

Prepared By: ______________________
Mark E. Fields
Thermal Systems

Concurred By: ______________________
Daniel Reynolds
Team Manager

____
Douglas Cline
PV&D, SSM

Internal Distribution:

D. L. Archer	HS3-30
D. E. Cline	HZ1-10
D. R. Reynolds	HS3-30
W. K. Smith	HS2-30
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NASA/JSC	
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BOEING

The Boeing Company
Integrated Defense, NASA Systems
3700 Bay Area Blvd
Houston, TX 77058

Technical Memorandum

Date:	December 9, 2005	No.:	TS-TM-05-037
To:	W.K. Smith IDS-NASA Systems HB2-30 281-226-5760	From:	William R. Griebel IDS – NASA Systems HB2-30 281-226-8818

Subject: Venting Case s70: Overpressurization Assessment of AMS-02 Warm Helium System

Contract:	NAS9-20000
Purchase Order:	1970483303
PDRD No.:	N/A
WBS No.:	1.7.1.1
Task No.:	70004
Atremis No.:	N/A

References:

1. Email from L. Hill/Hernandez Engineering to Brad Harris, November 10, 2005. Subject was overpressurization of payload bay.
2. Nieder, R. L., "Venting Analysis Digital Computer Program (VADIC)", JSC-20779, September 1985.
3. Request for Assessment, TH-GEN-014, B. Harris, USA, November 17, 2005.

An analysis was performed to determine the effects of a helium leak into the orbiter payload bay. The leak is a failure scenario associated with the Alpha Magnetic Spectrometer II (AMS-02) payload Warm Helium System. The failure condition is a rupture of the helium container resulting in total release of the helium (Reference 3). The only hazardous gas problem analyzed in this study is possible overpressurization of the orbiter. The analysis was performed with the VADIC vent program (Reference 2) and the flight correlated models of the STS-63 ascent and descent.

The burst point of the helium vessel is 320 bars (668,334 pound/ft^2) at a temperature of 295 K. The total initial mass of the helium is 0.43349 kg. The vessel volume is 8.3 liters. The payload bay volume was set at 15000 cubic feet. The leak rate was modeled from a blowdown curve provided by Leland Hill at Hernandez Engineering Inc (Reference 1). The curve assumed a 3.2mm diameter hole venting to vacuum.

The ascent analysis investigated a helium leak beginning at liftoff (T+0) and near the peak payload bay to ambient pressure differential (T+35). The timeline ran for 180 seconds after launch, and the blowdown curve extended for approximately 22 seconds. The rate of helium mass flow would decrease to zero, but for simplicity the final value from the curve was assumed to continue for the remaining 158 seconds. This assumption is conservative because it models a higher mass flow into the payload bay than would actually occur.

The descent analyses investigated a leak beginning at entry interface (EI) and near the peak payload bay to ambient pressure differential (EI+930). The descent analyses looked only at the closed door phase of the descent. The open door phase was not included based on the results of the ascent analysis and because during descent the compartments are repressurizing rather than depressurizing. The descent timeline extends for 1937 seconds. The blowdown curve extends for 22 seconds. The helium mass flow was assumed to go to zero 40 seconds after the leak began. This was based on the mass flow rate at the end of the blowdown curve; if that rate were held constant the remaining helium would be gone 9 seconds later. The 9 seconds was doubled to account for the linear interpolation between data points.

An assessment of the predicted pressure increments resulting from the inadvertent/planned payload venting has been performed. The results have been determined to be acceptable and both the Orbiter PV&D and Orbiter Stress SSMs concur.

Payload venting was not considered in the Orbiter structural certification analysis. Although this failure case results in a pressure increment that is outside of Orbiter Certification, it was determined that the Orbiter has the capability to sustain this loading without structural damage or loss of mission. This contingency case assessment is valid for the AMS-02 payload on flight UF-4, and includes no other venting or leaking payloads.

Prepared by: for William Griebel
William Griebel
Shuttle Cargo Passive Thermal
(281) 226-8818
MC HB2-30

Concurred by: Freddie Merheb 12/19/05
Freddie Merheb
PV&D Subsystem Manager
(321) 383-6177
MC 721B-L325

Concurred by: ______________________
Michael J. Dunham
Stress Subsystem Manager
(281) 226-6046
MC HB6-30

Concurred by: ______________________
Guadalupe Gonzales
Shuttle Cargo Passive Thermal Manager
(281) 226-5710
MC HB2-30

Internal Distribution:

Mike DeVault	Mike.Devault@boeing.com
Guadalupe Gonzales	Guadalupe.Gonzales@boeing.com
Kurt Smith	Kurt.Smith@boeing.com
William Griebel	William.R.Griebel@boeing.com
JJ Gallegos	JJ.Gallegos@boeing.com
Mark Fields	Mark.E.Fields@boeing.com
Anita Gale	Anita.E.Gale@boeing.com
Micheal Dunham	Michael.J.Dunham@boeing.com
Freddie Merheb	Freddie.Merheb@boeing.ksc.nasa.gov

External Distribution:

USA

Brad Harris	Brad.P.Harris@usa-spaceops.com
Harry Maltby	Harry.A.Maltby@usa-spaceops.com
Patricia Pryor	Pat.A.Pryor@usa-spaceops.com
Nelson Fox	Nelson.P.Fox@usa-spaceops.com
Lisa Agnew	Lisa.M.Agnew@usa-spaceops.com
Pam Madera	Pam.L.Madera@usa-spaceops.com

NASA/JSC

C. R. Miller	C.R.Miller@nasa.gov
Raymond Serna	Raymond.Serna-1@nasa.gov
Randall Adams	Randall.W.Adams@nasa.gov

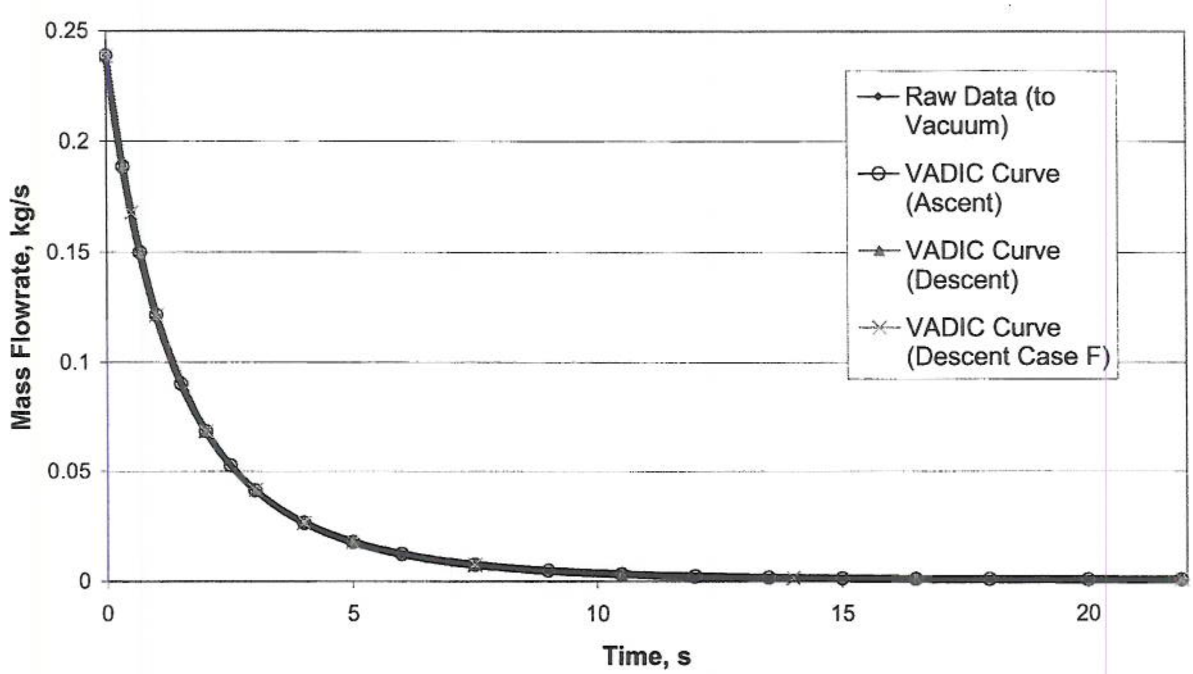
Table 1: Case Description Matrix

Case #	Model	Trajectory	Leak Time (sec)	Description
S70A	103FC	STS63 ASC BET	-	Baseline OV-103 Ascent Common Vent Model
S70B	103FC	STS63 ASC BET	T+0	Helium Disk Fails at Launch
S70C	103FC	STS63 ASC BET	T+35	Helium Disk Fails at T+35 (Max Baseline dP)
S70D	103FC	STS63 DSC BET	-	Baseline OV-103 Descent Common Vent Model
S70E	103FC	STS63 DSC BET	EI+0	Helium Disk Fails at Entry Interface
S70F	103FC	STS63 DSC BET	EI+930	Helium Disk Fails at EI + 930 (Max Baseline dP)

Table 2: Case s70 Timelines

	Ascent						Descent					
	Case B (Leak at Launch)			Case C (Leak at L+35)			Case E (Leak at EI)			Case F (Leak at EI+930)		
	Time	Event	Mass Flow	Time	Event	Mass Flow	Time	Event	Mass Flow	Time	Event	Mass Flow
	(seconds)		(slug/s)	(seconds)		(slug/s)	(seconds)		(slug/s)	(seconds)		(slug/s)
1	-60.00		0.000000	-60.00		0.000000	0.00	EI	0.016360	0.00	EI	0.000000
2	-0.10		0.000000	-0.10		0.000000	0.33		0.012930	1.00	EI+1	0.000000
3	0.00	Launch	0.016360	0.00	Launch	0.000000	0.67		0.010286	929.00	Leak -1	0.000000
4	0.33		0.012930	34.90	Leak -0.1	0.000000	1.00	EI+1	0.008336	930.00	Leak Starts	0.016360
5	0.67		0.010286	35.00	Leak	0.016360	2.00		0.004683	930.50		0.011514
6	1.00		0.008336	35.33		0.012930	3.00		0.002829	931.00		0.008336
7	1.50		0.006183	35.67		0.010286	4.00		0.001808	932.00		0.004683
8	2.00		0.004683	36.00		0.008336	5.00		0.001209	933.00		0.002829
9	2.50		0.003610	36.50		0.006183	7.50		0.000513	934.00		0.001808
10	3.00		0.002829	37.00		0.004683	10.50		0.000223	935.00		0.001209
11	4.00		0.001808	37.50		0.003610	16.50		0.000062	937.50		0.000513
12	5.00		0.001209	38.00		0.002829	21.89		0.000026	944.00		0.000101
13	6.00		0.000839	39.00		0.001808	40.00	Est. He gone	0.000000	951.89		0.000026
14	7.50		0.000513	40.00		0.001209	1337.00	V=5300	0.000000	970.00	Est. He gone	0.000000
15	9.00		0.000330	41.00		0.000839	1338.00	FULL UP PRG	0.000000	1337.00	V=5300	0.000000
16	10.50		0.000223	42.50		0.000513	1387.00	PRG+50	0.000000	1338.00	FULL UP PRG	0.000000
17	12.00		0.000156	44.00		0.000330	1457.00	PRG+120	0.000000	1387.00	PRG+50	0.000000
18	13.50		0.000112	45.50		0.000223	1487.00	PRG+150	0.000000	1457.00	PRG+120	0.000000
19	15.00		0.000082	47.00		0.000156	1497.00	VENT TO OPEN	0.000000	1487.00	PRG+150	0.000000
20	16.50		0.000062	48.50		0.000112	1501.00	FULL OPEN	0.000000	1497.00	VENT TO OPEN	0.000000
21	18.00		0.000047	50.00		0.000082	1887.00	PRG+550	0.000000	1501.00	FULL OPEN	0.000000
22	20.00		0.000034	51.50		0.000062	1936.00	TRAJ END-1	0.000000	1887.00	PRG+550	0.000000
23	21.89		0.000026	53.00		0.000047	1937.00	TRAJ END	0.000000	1936.00	TRAJ END-1	0.000000
24	179.90		0.000026	56.89		0.000026				1937.00	TRAJ END	0.000000
25	180.00		0.000026	180.00		0.000026				1937.00	PRG+600	

Figure 1: VADIC Approximation of Blowdown Curve
AMS-02 Helium Vessel



BOEING

Technical Memorandum

The Boeing Company
Integrated Defense, NASA Systems
3700 Bay Area Blvd
Houston, TX 77058

Date:	August 9, 2007	No.:	TS-TM-07-035
To:	W.K. Smith IDS-NASA Systems HB2-30 281-226-5760	From:	William R. Griebel IDS – NASA Systems HB2-30 281-226-8818

Subject: Venting Case s73: Venting of Miscellaneous Pressure Vessels On the AMS-02 Payload

Contract:	NNJ06VA01C
Subcontract:	6000132079
PDRD No.:	N/A
WBS No.:	2.2.1.4
Task No.:	60015

References:

1. Email from Brad Harris to Guadalupe Gonzales, July 12, 2007. Subject AMS Venting
2. Nieder, R. L., "Venting Analysis Digital Computer Program (VADIC)", JSC-20779, September 1985
3. "Space Station Payload Xenon Leak in Payload Bay During Ascent, On-Orbit and Descent", Rockwell No. 096-P&E-045, June 19, 1996
4. "Ammonia Venting into Payload Bay from ISS PVR/FSE Failed FQDC During Ascent and Descent Mission Phases", Boeing TM TS-TM-02-048, October 25, 2002
5. "Venting Case s70: Overpressurization Assessment of AMS-02 Warm Helium System", Boeing TM TS-TM-05-037, December 9, 2005

The Alpha Magnetic Spectrometer II (AMS-02) payload, currently scheduled for ISS flight ULF-4, contains several pressurized vessels that could leak under certain failure conditions. A summary of these leak scenarios (Reference 1) was delivered to Boeing with a request to evaluate them for overpressurization concerns during ascent and entry. A short description and numbering of the leak cases can be found in Table 1 of this document.

A total of 11 cases were evaluated. When possible, cases were evaluated by comparison to previous analyses of the same gas.

Case 1, a leak of 109 pounds of Xenon from the TRD Xenon gas supply, was compared to analysis "Space Station Payload Xenon Leak in Payload Bay During Ascent, On-Orbit and Descent" (Reference 3), which analyzed Xenon leaks at much higher leak rates. The analysis indicated a marginal violation for the ascent failure at T+0 case for a leak rate of 1 lbm/s. Because the leak rate for the AMS-02 payload is approximately 0.01 lbm/s (0.03 ft^3/s), case 1 was determined to be acceptable.

Cases 7, 8, 9, and 10 are ammonia (NH_3) leaks, the largest of which is 55 grams. These were compared to the analysis "Ammonia Venting into Payload Bay from ISS PVR/FSE Failed FQDC During Ascent and Descent Mission Phases" (Reference 4), which analyzed a leak of 62.2 lbm of ammonia at a constant leak rate of 0.73 lbm/s. Because the higher leak rate and mass of the previous analysis did not violate the pressurization limits, cases 7 through 10 were cleared.

Case 11 is a helium leak of 0.72 grams. This was compared to the venting analysis case number s70 (Reference 5), which analyzed a mass of 0.43349 kg leaking at an initial rate of over 0.2 kg/s. Because there was no violation for the higher mass and leak rate, case 11 was cleared.

Cases 2 and 5 involve leaks of carbon dioxide. Case 2 is a leak of 12 lbs of CO_2 gas from the TRD CO_2 gas supply. This amount is higher than that of previous CO_2 leaks analyzed; however the leak rate is extremely low, with a worst case leakage of 0.005 ft^3/s. Because of the low leak rate, combined with the relatively small volume of the gas (98.2 ft^3), case 2 was cleared. Case 5 is a leak of 743 grams of CO_2 from one of two Tracker TCS loops. This is equivalent to 13.27 ft^3 of the gas. Case 5 has been cleared because of the small amount of gas that could leak.

Cases 3 and 4 are leaks of a mixture of Xenon and CO_2 gas, at a ratio of 4:1. Case 3 is a leak of 0.04 lbs, and case 4 is a leak of 2.58 lbs. In case 4, however, the mass is divided into several small 'straws' containing approximately 0.063 lbm each. Because of the small amounts of gas that would result from each leak, cases 3 and 4 were cleared.

Case 6 is a propylene (C_3H_6) leak from one of eight Cryocooler Loop Heat Pipes. Each pipe contains 42 grams of gas (0.83 ft^3). Because of the small amount of gas in each pipe, case 6 was cleared.

Of the 11 cases, 6 were cleared through comparison to previous analyses of an increased amount of the same gas leaking at a faster rate. The remaining 5 cases were cleared based on the small amount of gas available to be leaked or a restricted leak rate. No new VADIC (Reference 2) runs were performed for any of these cases; however the previous analyses referenced in this document were preformed with VADIC. This review only relates to overpressurization concerns, no flammability or other limits were included.

An assessment of the predicted leak rates and masses has been performed. The leak scenarios have been determined to be acceptable based on previous analysis experience and both the Orbiter PV&D and Orbiter Stress SSMs concur.

Payload venting was not considered in the Orbiter structural certification analysis. Although these failure cases result in pressure increments that are outside of Orbiter Certification, it was determined that the Orbiter has the capability to sustain this loading without structural damage or loss of mission. This assessment is valid for the defined payload (AMS-2) manifest for ULF-4 which assumes no other venting or leaking payloads.

Prepared by: __/s/ Signature on File____________
William Griebel
Shuttle Cargo Passive Thermal
(281) 226-8818
MC HB2-30

Concurred by: __/s/ Signature on File____________
Freddie Merheb
PV&D Subsystem Manager
(321) 383-6177
MC 721B-L325

Concurred by: __/s/ Signature on File____________
Michael J. Dunham
Stress Subsystem Manager
(281) 226-6046
MC HB6-30

Concurred by: __/s/ Signature on File____________
Guadalupe Gonzales
Shuttle Cargo Passive Thermal Manager
(281) 226-5710
MC HB2-30

Internal Distribution:

Mike DeVault	Mike.Devault@boeing.com
Guadalupe Gonzales	Guadalupe.Gonzales@boeing.com
Kurt Smith	Kurt.Smith@boeing.com
William Griebel	William.R.Griebel@boeing.com
JJ Gallegos	JJ.Gallegos@boeing.com
Anita Gale	Anita.E.Gale@boeing.com
Michael Dunham	Michael.J.Dunham@boeing.com
Freddie Merheb	Freddie.Merheb@boeing.ksc.nasa.gov

External Distribution:

USA

Brad Harris	Brad.P.Harris@usa-spaceops.com
Harry Maltby	Harry.A.Maltby@usa-spaceops.com
Nelson Fox	Nelson.P.Fox@usa-spaceops.com
Pam Madera	Pam.L.Madera@usa-spaceops.com

NASA/JSC

C. R. Miller	C.R.Miller@nasa.gov
Raymond Serna	Raymond.Serna-1@nasa.gov
Joel Sills	Joel.W.Sills@nasa.gov

A.4-27

Table 1: Leak Description Matrix

#	Gas	Mass	Volume	Description
1	Xe	109 lbm	299 ft^3	TRD Xenon Gas Supply. Worst case sustained flow of 0.03 ft^3/s
2	CO_2	12 lbm	98.2 ft^3	TRD CO_2 Gas Supply. Worst case sustained flow of 0.005 ft^3/s
3	4:1 Xe:CO_2	0.04 lbm	0.012 m^3	TRD Mixing Vessel/Box C. Non-op during Ascent/Descent
4	4:1 Xe:CO_2	2.58 lbm	0.23 m^3 total, 0.0056 m^3 per straw	TRD Proportional Counters, Straws, Manifold, and Delivery from Box C. Straw modules approx. 500m long, 16 straws per module, 6mm diameter
5	CO_2	743g (x2)	13.27 ft^3 (x2)	Tracker TCS
6	C_3H_6	42g (x8)	0.83 ft^3	Cryocooler Loop Heat Pipe (Propylene)
7	NH_3	Largest 41g	1.88 ft^3	Heat Pipes, Various sizes. (Ammonia)
8	NH_3	55g (x2)	2.52 ft^3	CAB Loop Heat Pipe
9	NH_3	7g (x3)	0.19 ft^3	USS-02 Heat Pipes
10	NH_3	3g	0.8 ft^3	TTCS Accumulator Heat Pipe
11	He	0.72g	0.15 ft^3	Cryocooler

Appendix A:
Stored Gas Reservoirs Table from USA

19978C

AMS-02 Stored Gas Reservoirs

System	Working Fluid	Broken Line Diameter	MDP (psi)	Quantity	Gas Volume (at STP)	Notes:
~~Superfluid Helium Tank~~	~~Superfluid Helium~~	~~N/A~~	~~N/A~~	~~800 lbs (362.8 kg) ~2500 liters@ 145 g/l @ 1.8 K~~	~~Thermal design limits release rate with worst case failure, heat must be introduced to phase change the superfluid helium.~~	
~~Superfluid Helium Tank~~	~~Superfluid Helium~~	~~N/A~~	~~N/A~~		~~Given worst case credible leak of VC, requires 23 minutes to warm up the cryogenic helium sufficiently to open burst disks and allow venting to begin. (Extremely conservative analysis, reference SCL Report on Loss of Vacuum.) This conditioned is monitored to L-9 minutes or less with a LCC in place if leak is detected.~~	
~~Superfluid Helium Tank~~	~~Helium~~	~~N/A~~	~~N/A~~		~~At baroswitch operation at external pressure of approximately 5 mbar, the nominal vent rate of 0.11 ft3/min begins.~~	
~~Warm Helium Gas Supply~~	~~Helium~~	~~0.5"~~	~~3538~~	~~241 grams~~	~~47.68 ft3 (1.35 m³)~~	~~Worst case flow rate after failure two valve seats, through 6 bar regulator and out 8 bar pressure relief devices.~~
TRD Xenon Gas Supply	Xenon (Xe)	0.25"	3000	109 lbs (49.4 kg)	299 ft3 (8.46 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.03 ft3/s (Single burst disc

AMS-02 Stored Gas Reservoirs

System	Working Fluid	Broken Line Diameter	MDP (psi)	Quantity	Gas Volume (at STP)	Notes:
						open).
TRD Carbon Dioxide Gas Supply	Carbon dioxide (CO2)	0.25"	3000	12 lbs (5.5 kg)	98.2 ft3 (2.78 m^3)	Three failures to open valves during ascent/descent, worst case sustained flow is 0.005 ft3/s (Single burst dic open).
TRD Mixing Vessel/Box C	4:1 Xenon: CO2 mix	0.25"	300	Quantity supplied from TRD Box S ⇒ 0.04 lbs (0.03 kg)	0.012 m^3	During ascent/descent this is a non-operational system that requires the Box S to charge Box C with gas pressure and a failure of a relief valve.
TRD proportional counters "Straws", manifold & delivery from Box C	4:1 Xenon: (CO2) mix	.125"	17.4	Quantity supplied from TRD Box C ⇒ 2.58 lbs (1.17 kg)	0.23 m^3 total with 0.0056 m^3 per straw segment with interconnecting tubing and connection to Box C	Straw Modules are approximately 500 m in length with sixteen straws per module (dia. of 6 mm). Interconnecting tubing and connection to the Box C account for less than 0.001 m^3 each. This value is rounded up to 0.23 m^3.

AMS-02 Stored Gas Reservoirs

System	Working Fluid	Broken Line Diameter	MDP (psi)	Quantity	Gas Volume (at STP)	Notes:
Tracker TCS	Carbon dioxide	~0.236"	2320	743 grams (Repeated in two loops)	13.27 ft3 (0.376 m^3) @ STP per loop	Closed system design qualified under Design for Minimum Risk (DFMR) Criteria
Cryocooler Loop Heat Pipe (x8)	Propylene	~0.12"	261	42 grams each	0.83 ft3 (0.024m^3)	Closed heat pipe qualified under DFMR Criteria
Heat Pipes (various)	Ammonia	~0.31"	~300	Largest Quantity in single heat pipe is 41 grams	1.88 ft3 (0.053 m^3)	Closed heat pipe systems qualified under DFMR criteria
CAB Loop Heat Pipe (x2)	Ammonia	~0.12"	261	55 grams each	2.52ft3 (0.07 m^3)	CAB Loop Heat Pipe system qualified under DFMR Criteria
USS-02 Heat Pipes	Ammonia	*	*	3 pipes with 7 grams each	0.19ft3 (0.005m^3)	Closed heat pipe qualified under DFMR criteria
TTCS Accumulator Heat Pipe	Ammonia	*	*	3 grams	0.8ft3 (0.0023m^3)	Closed heat pipe qualified under DFMR.
Cryocooler	Helium	*	*	0.72 grams	0.15ft3 (0.004 m^3)	Closed Stirling Cycle Heat Pump under DFMR.

Note: Bypass valves used in the Cryocooler Loop Heat Pipe and the CAB Loop Heat Pipe have a small argon volume required for operations. The volume of argon has been calculated to be approximately 0.2 grams.