TRD Gas System Summary

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Concept

The 41 TRD segments are connected through manifolds to Box C. Box C contains controls, monitors, and recirculation pumps. Box S provides Box C with pre-mixed gas and contains all gas supplies as well as a limited mixture volume. A feed control between Boxes S and C is activated by computer and the density monitor. The general layout is shown in Fig. 1. The 41 sealed TRD segments of approx. 430 cu in. each are at 17.4 psi, Box C of estimated 150 cu in at < 29 psi and box S is described below.

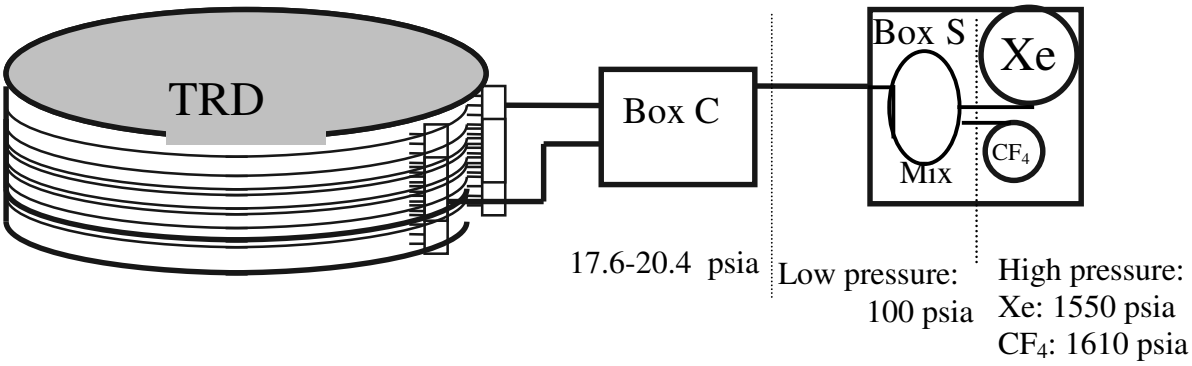


Figure 1. Schematic Arrangement of the AMS-TRD gas system. All pressures are given at 25 C.

Box S

Box S contains the gas supply so that 7 l/day of mixed gas may be provided to the TRD system. The schematic of the system is shown in Fig. 2. A component list is also shown.

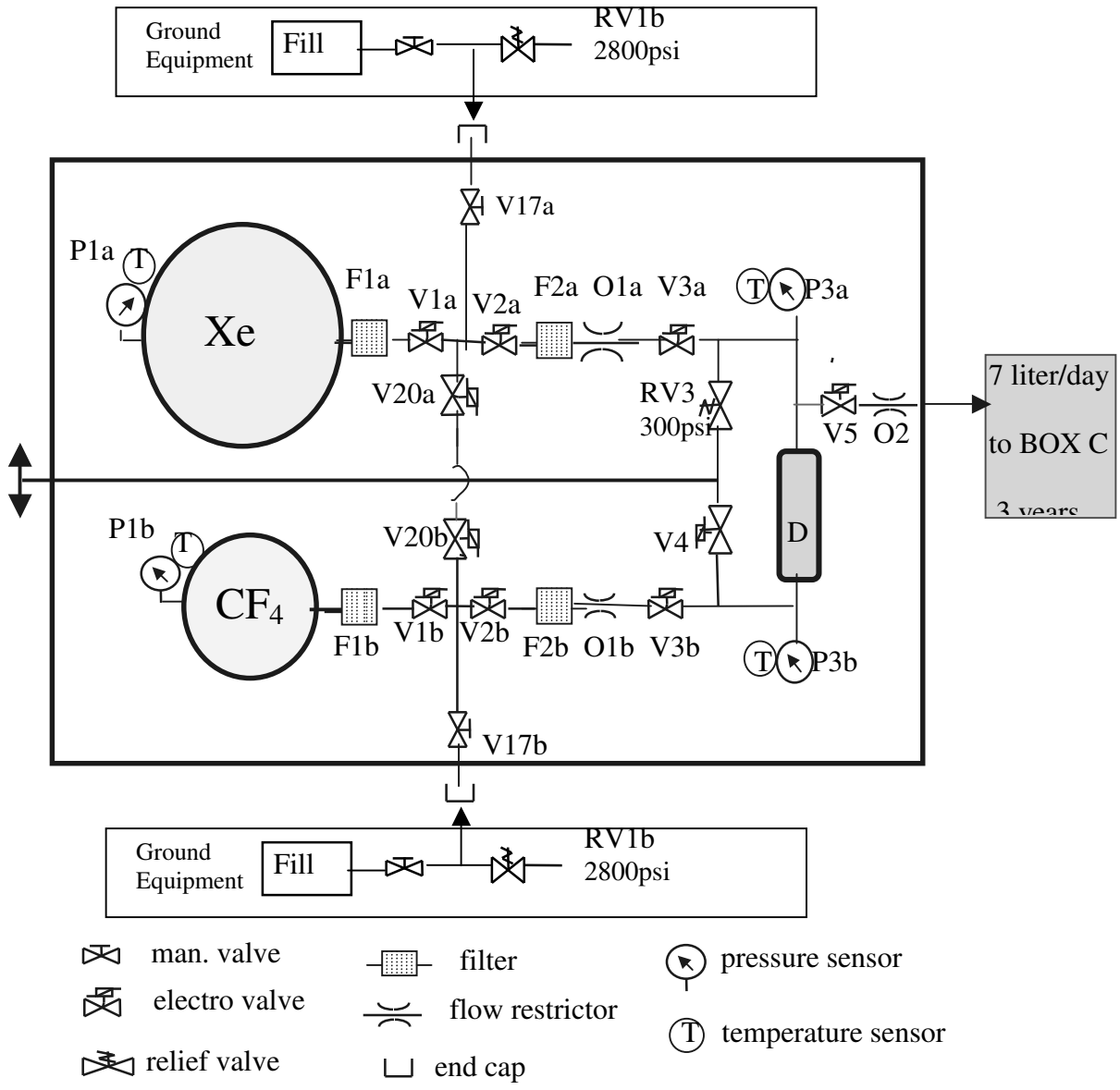
Box S Operations

Filling Ground state: Vessel cleaned. Connect Xenon ground supply to filling port of Box S at V17A. Close V2A and evacuate the fill lines and pressure vessel. Open valve to Xenon ground supply. Transfer liquid Xenon into container until weight = 109lb. Close V1A. Close V17A. Record temperature and pressure for 4 hours. If performance is as desired, cap V17A. Repeat process for CO_2 line.

Mixing: Once per day: For the Xe line: Open V1A briefly (approx.100ms) to fill buffer volume between V1A and V2A. Open V2A briefly (approx.100ms), followed by V3A. Keep V3A open until desired partial pressure of Xe has entered the mixing vessel (D) through the flow restrictor (O1A). Shut off V3A. Repeat procedure CO_2 with branch until desired partial pressure of CO_2 is achieved. .

Transfer Several times per day V5 is opened under computer control to release fresh gas from the mixing vessel (D) into the circulation module BOX C. Transfer is limited to < 7l at 1 atm/day in normal mode.

Before Launch All valves are closed. Mixing Vessel (D) should be at atmospheric pressure. Pressure and temperature monitoring from ground should uninterrupted for as long as possible prior to launch, during flight to ISS and mounting on ISS.



pressures psia **Xe (25^{0}C) 1550 psia** **CF_4(25^{0}C) 1740**

Vessels: psia **Xe (65^{0}C) 3000 psia** **CF_4(65^{0}C) 3200**

Figure 2 - Box - S - TRD gas supplies

Box S Components List

1. Xe Vessel ARDE D4636, 17+109lb Xe, 1680 in^3, MEOP=MDP=3000psig, ISS
2. CF_4 Vessel ARDE D4683, 9.5+18lb CF_4 ,813in^3, MEOP(65^{0}C) = 3200 psig, X33
3. P1a,b and P2a, P2b pressure monitors, GP:50 model 7950, range: 0--3000psi
4. P3a, P3b pressure monitors, GP:50 model 7950, range: 0--300psi
5. RV3 reliefvalves, 300psi
6. V1a,b and V2a,b solenoid valves, Marotta MV100, (current opens valves for typ. 100ms)
7. V17a,b manual valves (Schwer?). After filling the line gets plugged.
8. O1A, O1B, O2; Flow restrictors; The Lee Co; Viscojet model.
9. V3a,b solenoid valves, Marotta MV100, (current opens valves for typ. 5 seconds)
10. D Vessel ARDE SDK 13181, 1liter.
11. V20a,b solenoid valves, Marotta MV100, allows redundancy for V1a, V1b, V2a, V2b
12. V4, V5, solenoid valves, Marotta MV100, V4 allows venting of gas to space if mixture is not correct or if there is overpressure that needs to be relieved.

Box C

The schematic for Box C is shown in Fig. 3. The circulation pumps serve to move the gas through the system to ensure uniform gas properties.

Box C Operations

Normal – gas circulates through the straws, no purification.
Gas cleaning – (on earth) to remove oxygen and water from gas.
Daily filling – replace gas lost in normal operation.
System pressure test – check for loss anywhere in straw system by looking for pressure change when system is closed.
Segment pressure test – isolate single segment and monitor pressure while isolated.
Recovery Xe from AMS – remove Xe from Xe storage tank in Box S on ground if need arises.

Gas composition check – check for contamination of gas with residual gas analyzer (on ground only).

Operations before launch

1. System should be filled and circulating through the purifier well before launch. Circulation should continue until as close to launch time as possible, at which point the pumps are turned off.
2. Before power off for launch, all segment valves should be closed.

Operations after launch at startup

1. Isolate all segments
2. Check for losses in each segment.
3. Open all working segments.
4. Start CP1, begin normal operation.

Operations for return

1. Stop CP1 or CP2.
2. Close all segment valves.

Box C Circulates 3 TRD Volumes Daily

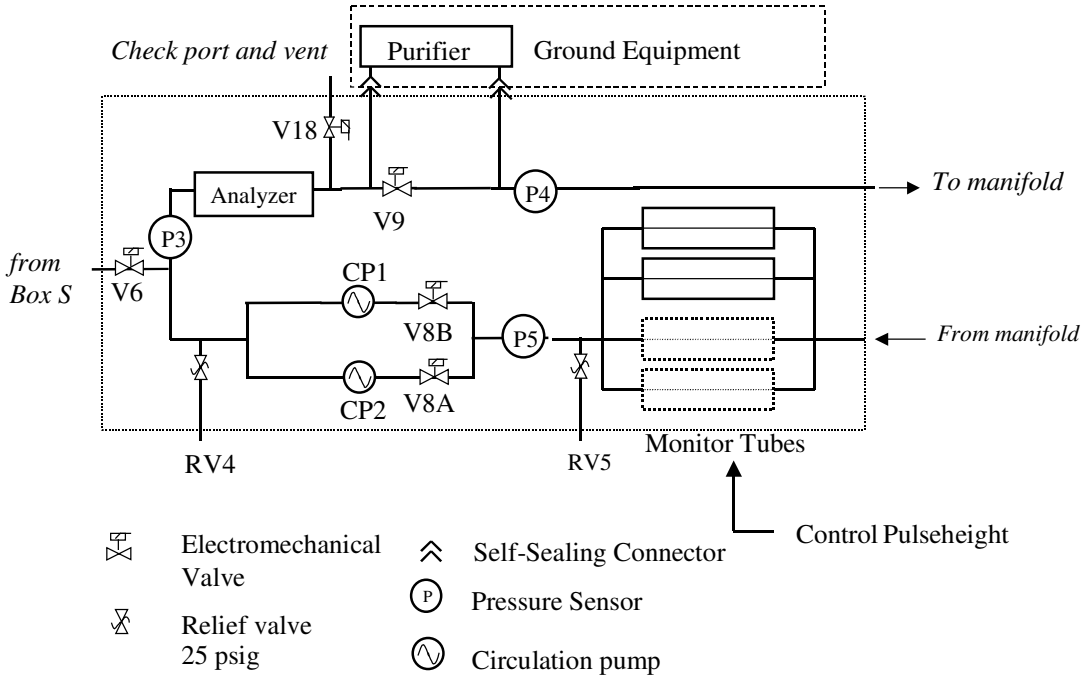


Figure 3. Box C - TRD gas recirculation system

Component List for Box C:

1. V6; electromechanical solenoid valves, Marotta MV100
2. V18, V9, V8A, V8B; electromechanical flipper valves, Burkert, type 6123
3. CP1, CP2; circulation pumps, KNF Neuberger Inc, type UNMP30 KNDC B
4. P3, P4, P5 ; GP :50 pressure sensors, model 7950, range : 0--25psi.
5. RV4, RV5 ; Relief valves; StraVal
6. 4 Monitor tubes; hermitically sealed tubes for measuring gain. Each tube contains a weak (1μCi, 37kBq) Fe^{55} source.
7. Square One Technology model 2115 CO_2 analyzer.

Straw Tube Segments

From the Box C, S assembly, 6mm stainless steel gas lines run to the top rim of the TRD where input and output manifolds are located. The 5248 tubes of the TRD are grouped into 41 separate segments (see Figure 4), each separately attached to the input and output manifolds. Each segment is small enough so as not to be considered a pressure vessel (1bar × 7liters = 0.7kJ). Each manifold is connected to the 41 TRD segments via pressure controlled isolation valves. 3mm steel tubing runs from the isolation valves to the segment inputs and outputs, where it is joined to PEEK tubing via RWTH Aachen designed special connectors. Where other connections need to be made, Cajon VCR fittings are used.

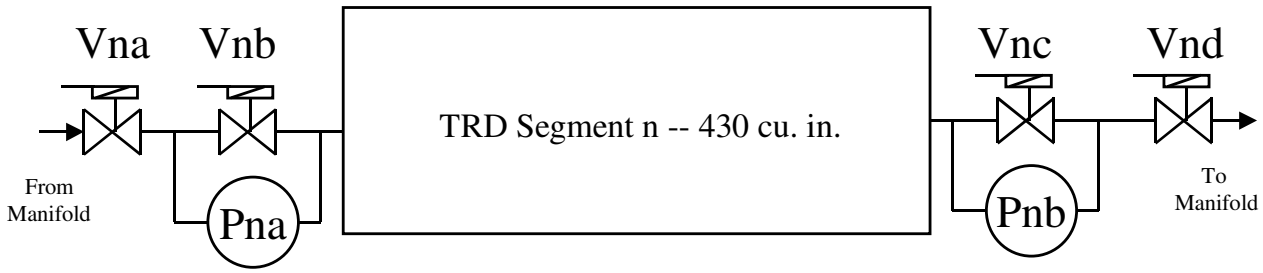
The isolation system works in two modes:

1. In case of a sudden pressure drop in a segment, the control computer will shut all four valves leading to the segment automatically to prevent further gas loss.
2. In case of an increase in gas consumption, or as a periodic check, the computer will close all four valves and monitor the pressure. This will be used to detect slow leaks.

Failure of any of the shutoff valves or pressure sensors cannot cause MDP to be exceeded. The shutoff valve/pressure sensor assembly will be potted inside a magnetic shielding box to preclude any leak from the gas system volume.

The isolation valves will be Burkert Type 6123 2/2 Way Flipper Valves. Closed, they hold 3 bar in either direction and have been leak tested to better than 0.1 ml/day loss, 1 bar to vacuum through a closed valve. They can be flipped from open to closed and vice-versa by a 12V, 100ms pulse, and otherwise consume no power. They are located near the top flange of the TRD in a region of low magnetic field.

The pressure sensors are Honeywell type 24PC.



TRD Segment Gas Circuit

Figure 4. One of 41 TRD straw tube segments.

Monitoring and Control

The electronics that control the gas system will be located in a single crate. The crate will contain a Universal Slow Control Module computer (USCM) that will manage the monitoring and control tasks, as well as maintain communication with the AMS-02 Main Control Computer (MCC). The USCM will be provided with interface electronics to the various gas transducers and actuators scattered throughout the gas system. The USCM and interface electronics will perform the following tasks:

1. Close or open emergency isolation valves in the manifolds.
2. Provide housekeeping data (temperature of valves, pressure vessels, etc.)
3. Store calibration constants.

4. Condition and perform analog to digital conversion for over 100 pressure sensors and approx. 100 temperature sensors distributed around the TRD and gas system.
5. Control two recirculation pumps.
6. Provide logic control for about 200 gas valves.
7. Provide HV for the calibration tubes in Box C. The tubes analyze the pulseheight spectrum from a weak (approximately 1μCi, 37kBq) Fe^{55} source to monitor the quality of the gas with a gain measurement.
8. The interface electronics will provide the power electronics to drive valves, etc.
9. Read out digital signals from the gas analyzer and MCA.
10. Have control logic to switch the gas system to "Safe Mode" in case of communication failure.

The USCM, interface electronics, and gas gain tubes are doubled to provide single fault tolerance.

Gas recovery System

Cryogenic system for recovering the xenon and CO_2 gases is shown in Fig. 5. The purpose of the system is to recover and store the fill gases from the TRD gas system in the event the gas must be removed for safety or repair. The recovery system is not part of the flight hardware. The system also has a controlled leak and residual gas analyzer for checking the composition of the gas to ensure its purity.

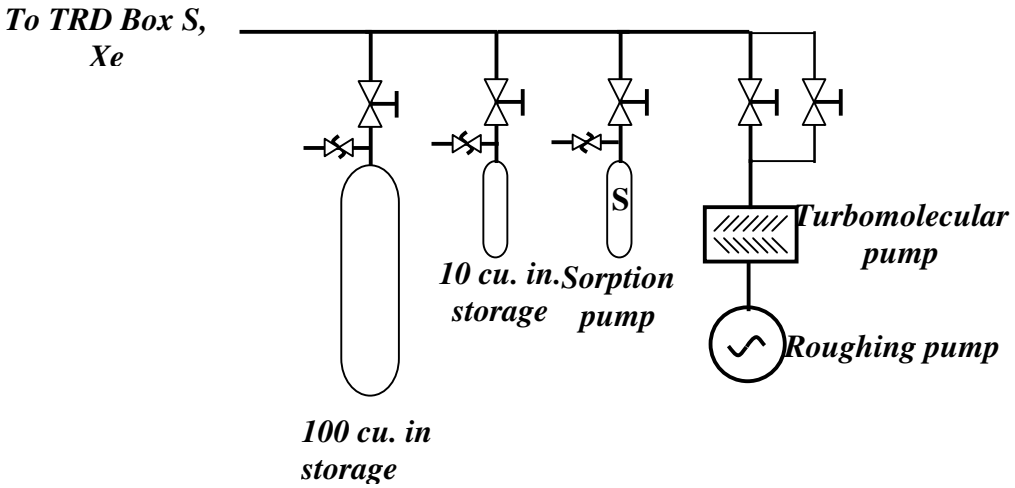


Figure 5. TRD gas recovery and storage system.

Gas system safety

Safety Box S

1. The gas system electronics will be designed so that the gas system is automatically taken to a "Safe Mode" in case of communication failure. For Box S this means all valves closed.
2. Pressure relief valves connected to filling device will add protection against overpressure during ground operations. Indicator P1 gives status. Liquid gas transfer from 109lb prefixed weighted volume excludes overfilling.
3. Computer controlled solenoid valve V4 opens automatically whenever pressure P3 > 00 psig. Relief Valve RV3 adds redundant overpressure protection. V1a, V2a, V3a, V1b, V2b, and V3b are closed when power is off, hence the lower pressure parts are protected. The mixing vessel (D) is protected by three valves and a flow restrictor, as well as relief valve and a venting valve (V4). Box C is protected from the pressure in the mixing vessel (<300psi) by two valves and a flow restrictor.
4. The total transfer of limited 7l into the TRD volume of 350l can at most cause a 2% pressure increase.
5. Relief valve failure: failure of any of the relief valves in Box S will release gas into the surrounding area (into the payload bay of the shuttle for example At STP the entire contents of the mixing bottle only occupies 7l and would not significantly increase the pressure in the shuttle cargo bay.
6. All systems in Box S are two fault tolerant; no part of the system goes above its MOP when any two components fail.
7. Trapped volumes: in the event of closure of all the valves in the Box S, gas would be trapped at high pressure in tubing between the valves. In no case does the trapped volume exceed 0.001 m^3 (0.04 ft^3).

Safety Box C

Box C operates below 1.4b (20.4 psia) and is two fault tolerant. The total gas volume contained in Box C is 0.011 m^3 (0.5 ft^3) (excluding the TRD Straw volume, each segment of which is protected by two valves) and the release of all gas would not cause a substantial change in the press in the shuttle payload bay. Box C is protected from higher pressures in Box S by valves V5 and V6 in series, as well as a flow restrictor.

Safety in Straw System

The straw volume is divided into 41 segments, each one of which is protected by automatic, double redundant valves as described above for mission success reasons. The

rupture on any segment would release about 0.007 m^3 (0.25 ft^3) of gas if the segment is successfully protected by the segment valves. The volume of the entire straw system is 0.3 m^3 (11 ft^3), the release of which would not change the pressure in the payload bay substantially.