NASA/TM—2002–211465

Materials Science Research Rack–1 Fire Suppressant Distribution Test Report

P.O. Wieland
Marshall Space Flight Center, Marshall Space Flight Center, Alabama

January 2002

The NASA STI Program Office…in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results…even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at (301) 621–0134

- Telephone the NASA Access Help Desk at (301) 621–0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076–1320

NASA/TM—2002–211465

Materials Science Research Rack–1 Fire Suppressant Distribution Test Report

P.O. Wieland
Marshall Space Flight Center, Marshall Space Flight Center, Alabama

National Aeronautics and
Space Administration

Marshall Space Flight Center • MSFC, Alabama 35812

January 2002

Acknowledgments

A fire suppressant distribution test is considered relatively simple. However, to perform the test properly and obtain valid, usable data many details need careful attention. The following people were instrumental in planning, preparing, and performing the Materials Science Research Rack–1 fire suppressant distribution test and evaluating the obtained data:

Joseph McConnell	Thermal and Environmental Control System team lead
Wade Short	Design engineer
Jim Hester	Simulator fabrication
Chris Delano	Safety engineer
Andre Miller	Structures engineer, provided rack faceplate
Doug Counter	Acoustic engineer, provided information on acoustic insulation
Fred Long (Boeing, KSC)	Provided portable fire extinguisher (PFE) for test use
Kevin Alexandre (Boeing)	Provided information on filling the PFE
Roger VonJouanne (Boeing)	Provided carbon dioxide (CO_2) monitors
Will Downs (Sverdrup)	Venting analysis support
Dave McIntosh	Test engineer, test procedure developer and test conductor
David Johnston	Test engineer, PFE filling
Steve Kennemer	Technician, rack preparation and test operations
Bill Major	Technician, rack preparation
Jeff Dysart	Technician, rack preparation
Kevin Burks	Test engineer, data system and CO_2 monitor field calibration setup
Phillip Bryant	Technician, CO_2 monitor field calibration setup
Terry Holcomb	Quality engineer, rack preparation quality assurance (QA) supervision
Lisa Miller	Quality engineer, PFE fill and test QA supervision
Al Jones	Data systems engineer, data system setup and data reduction

TRADEMARKS

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076–1320
(301) 621–0390

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487–4650

EXECUTIVE SUMMARY

The Materials Science Research Rack–1 (MSRR–1) is a furnace facility payload for performing crystal growth and related experiments that will be installed in the lab module of the *International Space Station* by 2003. The MSRR–1 uses the Active Rack Isolation System (ARIS) to minimize vibrational accelerations on the experiment modules. The ARIS requires additional holes through the rack shell for the control rods. Without the ARIS, the area of holes and gaps in the rack shell is 129 cm^2 (20 in^2). The ARIS adds 148 cm^2 (23 in^2), more than doubling the area of holes and gaps. Previous fire suppressant distribution testing was performed on non-ARIS configured racks; e.g., Space Station Furnace Facility (SSFF) and Expedite the Processing of Experiments to the Space Station (EXPRESS), so, the effects of the ARIS on fire suppressant distribution had not been tested.

To verify the fire suppression scheme for the MSRR–1, two tests were performed to map the distribution of carbon dioxide (CO_2) fire suppressant throughout a mockup of the MSRR–1 when discharged from a flightlike portable fire extinguisher. The components of the MSRR–1 were simulated with metal mockups having the same volumes, and insulation was installed in the side panels where it will be installed in the flight rack, to provide the same air volume and flowpath restrictions. An array of nine CO_2 monitors was installed, evenly distributed throughout the rack including locations expected to be difficult for CO_2 to reach.

The test requirement states that CO_2 concentrations throughout the rack must reach at least 50 percent within 1 min of beginning of discharge. To address gravitational effects, the rack was rotated to a back-down orientation and the readings from all sensors were averaged to provide a more representative comparison with the on-orbit condition.

The results show that the requirement was met. The first test was performed on February 6, 2001. The lowest maximum concentration was 59 percent and the average for the rack was 60 percent, achieved within 45 s of discharge initiation. It is anticipated that experiment furnaces will be replaced over the lifetime of the MSRR–1, but the future designs are not yet known. To ensure that future experiments will meet the CO_2 concentration requirement, the Space Products Development experiment mockup was removed, thereby increasing the free air volume in the rack and providing a worst-case configuration. The test was repeated on February 7. The lowest maximum concentration was 49 percent at one location, due to gravitational effects and dilution with the additional air volume. The average for the rack was 58 percent, comfortably exceeding the required minimum. Therefore, even with the ARIS, the MSRR–1 meets the requirements for fire suppression.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF ACRONYMS AND SYMBOLS

AAA	Avionics Air Assembly
AR	atmosphere revitalization
ARIS	Active Rack Isolation System
CO_2	carbon dioxide
EM	experiment module
ESA	European Space Agency
EXPRESS	Expedite the Processing of Experiments to the Space Station
FDA	Fire Detection Assembly
ISPR	International Standard Payload Rack
KSC	Kennedy Space Center
MDL	Microgravity Development Laboratory; mid-deck locker
MSFC	Marshall Space Flight Center
MSL	Materials Science Laboratory (from ESA)
MSRR–1	Materials Science Research Rack One
PFE	portable fire extinguisher
RSS	Rack Support System
SPD	Space Products Development
SSFF	Space Station Furnace Facility
SSPCM	solid state power control module

LIST OF ACRONYMS AND SYMBOLS (Continued)

TECS	Thermal and Environmental Control System
THC	temperature and humidity control
UAH	The University of Alabama in Huntsville
UIP	utility interface panel
VAS	vacuum access system

TECHNICAL MEMORANDUM

MATERIALS SCIENCE RESEARCH RACK–1 FIRE SUPRESSANT DISTRIBUTION TEST REPORT

1. INTRODUCTION

The Materials Science Research Rack–1 (MSRR–1) is a furnace facility that will be installed in the U.S. Lab module of the *International Space Station* in 2003. The MSRR–1 will enable a variety of crystal growth and related experiments to be performed. The rack is designed to allow experiment modules to be replaced. The initial configuration includes two furnaces that may operate simultaneously.

Fire safety, a key requirement for all powered racks, must be verified prior to acceptance for flight.[1] To suppress a fire, the free-volume oxygen level in the rack must be reduced to ≤10.5 percent by volume.[2] The test requirement for distribution of carbon dioxide (CO_2) is 50-percent CO_2 concentrations throughout the rack within 1 min of initiation of discharge of the portable fire extinguisher (PFE). Suppressant distribution depends on the nozzle design and rack packaging. The MSRR–1 has two key differences from racks previously tested for fire suppressant distribution that may affect the required CO_2 concentrations:

(1) MSRR–1 includes the Active Rack Isolation System (ARIS) that requires additional penetrations of the rack shell, increasing the vent area by ≈148 cm^2 (23 in^2) (more than doubling the amount of vent area without the ARIS).

(2) MSRR–1 does not include an Avionics Air Assembly (AAA) or the associated ducting, which reduces the free air volume significantly.

No previous fire suppressant distribution testing on an International Station Payload Rack (ISPR) with this configuration has been identified, so testing on the MSRR–1 was indicated. Mockups of the MSRR–1 components were fabricated of metal and installed in a flight-qualified ISPR for testing (see fig. 1). Faceplates similar to the flight design were installed with the fire suppressant access port, located as shown in figure 2, below the Thermal and Environmental Control System (TECS) shelf, near the center post.

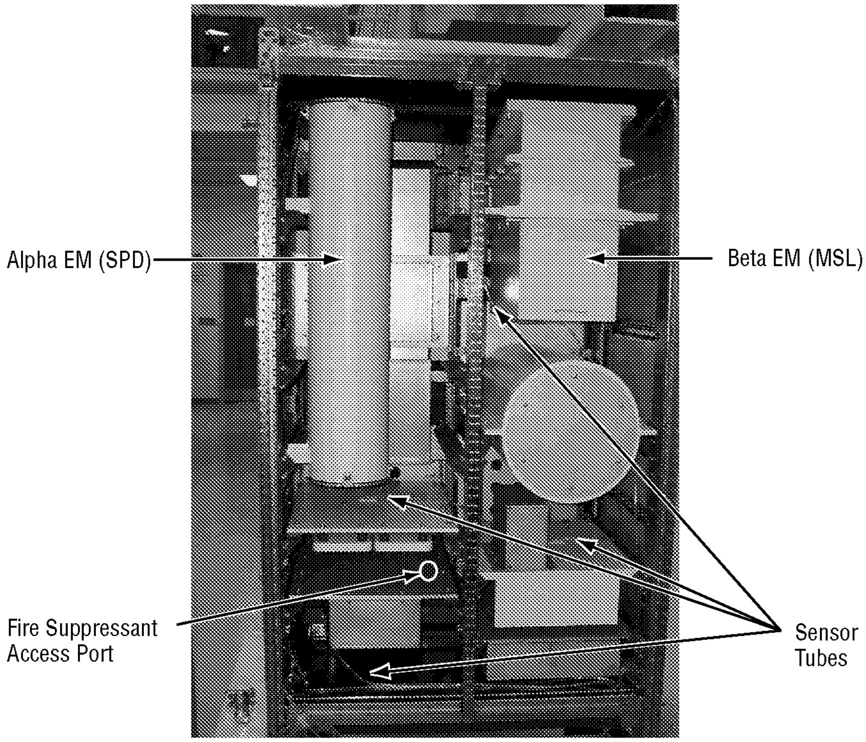

Figure 1. MSRR–1 simulator for fire suppressant distribution testing.

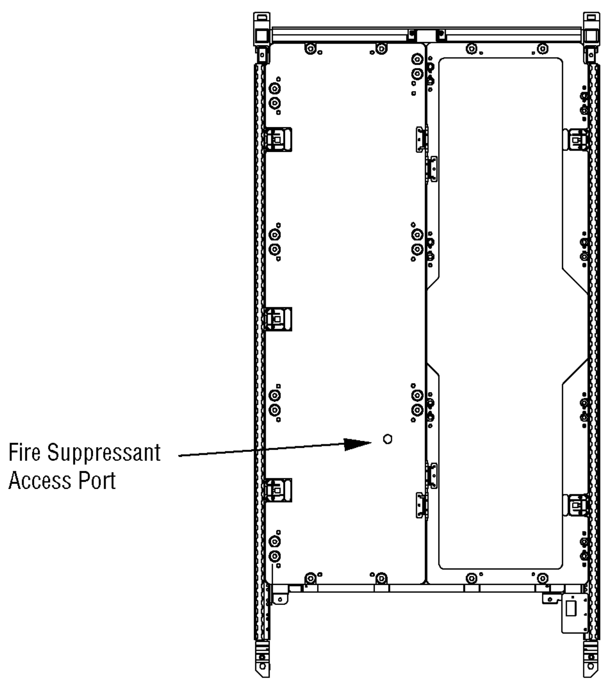

Figure 2. Location of fire suppressant access port on faceplate.

2. TEST REQUIREMENTS

In order for this test to serve as validation of the final flight configuration, the volumes of the components, the distribution of the volumes, and the flowpaths for the CO_2 fire suppressant must closely simulate the flight configuration. Any differences must be conservative. Two tests were performed—one with the Space Product Development (SPD) simulators and one without the SPD simulators. The second case is more conservative and is intended as a worst-case scenario to accommodate future SPD experiment modules. (The initial SPD furnace is from The University of Alabama in Huntsville.)

The various test requirements are explained in sections 2.1–2.6.

2.1 Rack Requirements

A high-fidelity mockup of the MSRR–1 was installed in an ISPR. The mockup mirrored the volumes and positions of components, placement of thermal/acoustic insulation, wiring and tubing, faceplate, and sealing of the rack. Simulators for the SPD and Materials Science Laboratory (MSL) experiment modules were fabricated, as well as simulators of the Rack Support System (RSS), TECS, and the ARIS.

The rack was oriented horizontally, back down, to minimize gravitational effects that cause settling of the CO_2.

2.2 Safety Requirements

Since during discharge the PFE gets very cold due to expansion of the CO_2, gloves and other protective measures; e.g., goggles, were provided for the operator. An oxygen monitor was also provided for the PFE operator.

2.3 Facility Requirements

The test required a high bay facility with the capability of rack rotation, since the MSRR–1 must be oriented horizontally, with the back down.[3] The Microgravity Development Laboratory (MDL) was selected for performing this testing.

Charging the PFE requires a CO_2 supply sufficient to fill the PFE with 2.7 kg (6 lb_m) CO_2 to 5.9 MPa (853 psia) at 21 °C (70 °F) with a regulator to control the fill rate. During the PFE charging process, as shown in figure 3, it is necessary to monitor the PFE temperature and measure the mass of CO_2 entering the PFE using an electronic scale.

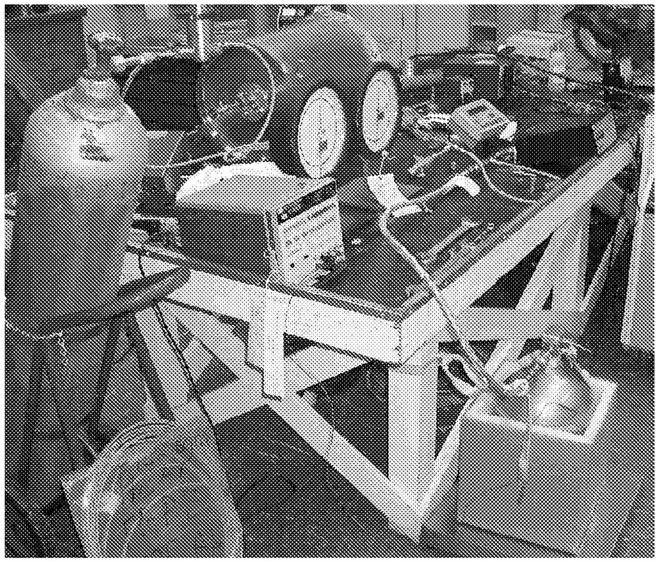

Figure 3. Setup for charging the PFE.

2.4 Support Equipment Requirements

The qualification PFE, shown in figure 4, was obtained from Kennedy Space Center. This PFE was recertified in 2000 for an additional 50 cycles and was filled according to the PFE fill procedure.[4] Equipment needed to fill the PFE includes a flow meter, a scale to weigh the PFE during filling, and a temperature sensor to monitor the temperature of the PFE during filling, as well as the fittings and hoses delivered with the PFE.

The PFE nozzle has eight radial holes and one axial (in the tip) hole, so most of the CO_2 is dispersed nonpropulsively in a 360° pattern.

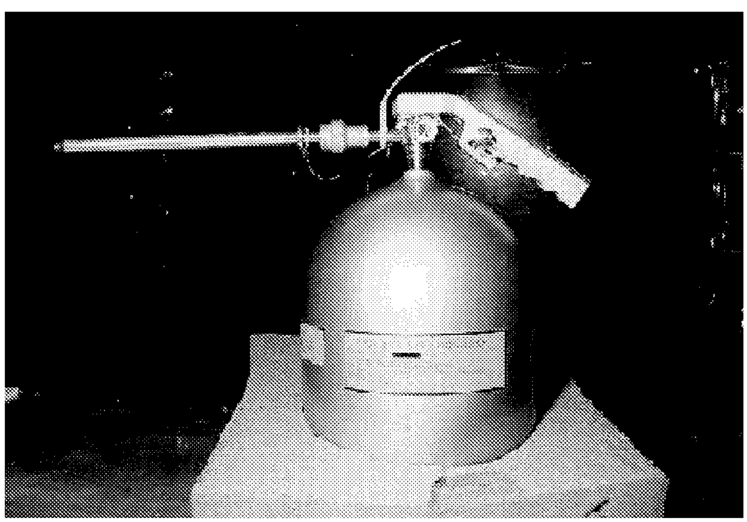

Figure 4. Portable fire extinguisher.

2.5 Carbon Dioxide Monitoring

The CO_2 monitors used for this testing, shown in figure 5, are the same monitors that were used for previous fire suppression testing for the Space Station Furnace Facility (SSFF), standoffs, end cones, etc. These monitors are packaged in three suitcase-type cases, three to a case, totaling nine sensors. Tygon®-type tubing is used to draw air from the locations being monitored to the monitors (see fig. 1). Tubes are the same length for each monitor to ensure simultaneous readings. The monitors include pumps to draw the air at 1.5 L/min, so there is minimal time lag for the measurements. Data are recorded every 5 s on strip charts for each monitor. The monitors were calibrated at zero-, 50-, and 100-percent CO_2 and certified for use. Each monitor was also field checked using ambient air as "zero" and bottled CO_2 as "100 percent" to ensure that the chart paper was properly aligned. The accuracy of the CO_2 monitors is ±2 percent.

The sampling points were distributed throughout the rack, attached at locations where CO_2 will have difficulty reaching; i.e., behind boxes or plates and at the furthest possible distances from the access port, in order to provide a conservative test.

Figure 5. Setup of the CO_2 monitors.

2.6 Other Test Requirements

To obtain information needed for structural design evaluation, temperatures and pressures in the rack were also measured. Temperatures were measured at six locations and pressures were measured at four locations (as listed in table 1).

Table 1. Location of sensors (T, P).

Sensor	Location	Coordinates, cm (in)					
		x		*y*		*z*	
T1	Near the top left rack front	19.0	(7.5)	185.4	(73.0)	12.7	(5.0)
T2	Near the top right rack rear	83.8	(33.0)	180.3	(71.0)	67.3	(26.5)
T3	Near the bottom left rack front	6.4	(2.5)	43.2	(17.0)	18.3	(7.2)
T4	Near the bottom right rack rear	95.3	(37.5)	63.5	(25.0)	67.3	(26.5)
T5	Near the PFE access port where the thermocouple will be in or near the CO_2 flow	36.8	(14.5)	76.2	(30.0)	15.7	(6.2)
T6	On external PFE tank	–	–	–	–	–	–
P1	Same as T1	19.0	(7.5)	185.4	(73.0)	12.7	(5.0)
P2	Same as T2	83.8	(33.0)	180.3	(71.0)	67.3	(26.5)
P3	Same as T3	6.4	(2.5)	43.2	(17.0)	18.3	(7.2)
P4	Same as T4	95.3	(37.5)	63.5	(25.0)	67.3	(26.5)

3. DESCRIPTION OF THE TEST ARTICLE AND SETUP

The test article was prepared by modifying a mockup prepared for vibration testing. The mass simulators for the internal components were modified, where feasible, to provide volumes similar to the flight design. In some cases new volume simulators were fabricated, and plates with holes were fabricated to simulate wiring and plumbing. Acoustic insulation was installed where it may affect the flow of CO_2 fire suppressant, on the side panels where the gap between the shelf rails and the shell of the rack is partly filled by the insulation. The dimensions, volumes, and locations of the simulators are listed in table 2. The coordinates are measured from the lower left front corner where the side, bottom, and front post planes intersect, as indicated on figure 6

Table 2. MSRR–1 volume simulators.

Description	Dimensions (cm)	Dimensions (in)	Volume (liter)	Volume (in^3)	Coordinates to Center of Item cm (in) *x*	*y*	*z*
SPD furnace	94 L × 21 D	37 L × 8.25 D	32.4	1,978.0	22.0 (8.5)	133.0 (52.5)	15.2 (6.0)
SPD plate	1.3 × 76 × 33	0.5 × 30 × 13	3.2	195.0	28.0 (11.0)	131.0 (51.5)	53.3 (21.0)
SPD video box	5 × 29 × 13	2 × 11.5 × 5	1.9	115.0	38.0 (15.0)	100.0 (39.5)	39.4 (15.5)
SPD box	33 × 22 × 13	13 × 8.5 × 5	9.1	552.5	28.0 (11.0)	131.0 (51.5)	45.7 (18.0)
TECS shelf	0.64 × 61 × 44	0.25 × 24 × 17.25	1.7	103.5	28.0 (11.0)	81.0 (32.0)	40.0 (15.7)
TECS boxes	4 * 15 × 25 × 2.5	4 * 6 × 10 × 1	3.3	240.0	28.0 (11.0)	76.0 (30.0)	34.3 (13.5)
RSS shelf	0.64 × 61 × 44	0.25 × 24 × 17.25	1.7	103.5	28.0 (11.0)	63.5 (25.0)	40.0 (15.7)
RSS box	53 × 24 × 15	21 × 9.5 × 6	19.6	1,197.0	28.0 (11.0)	55.0 (22.0)	39.4 (15.5)
SPD routing	0.64 × (46 × 66 – 25.4 D – 9*3.8 D)	0.25 × (18 × 26 – 10 D – 9*1.5 D)	1.8	111.0	28.0 (11.0)	61.0 (24.0)	76.2 (30.0)
MSL furnace	75 L × 36 D	29.5 L × 14 D	74.4	4,541.0	77.5 (30.5)	108.0 (42.5)	39.4 (15.5)
MSL box	56 × 25.4 × 41	22 × 10 × 16	57.7	3,520.0	76.0 (30.0)	155.0 (61.0)	38.1 (15.0)
MSL box	56 × 25.4 × 15 (in front) × 8 (in rear)	22 × 10 × 6 (in front) × 3 (in rear)	16.2	990.0	76.0 (30.0)	180.0 (71.0)	33.0 (13.0)
MSL plate	1.9 × 56 × 43	0.75 × 22 × 17	4.6	280.5	76.0 (30.0)	69.0 (27.0)	39.4 (15.5)
MSL box	27 × 11 × 18	10.5 × 4.25 × 7	5.1	312.0	67.0 (26.5)	76.0 (30.0)	24.1 (9.5)
MSL box	34 × 37 × 11	13.5 × 14.5 × 4.5	14.4	881.0	76.0 (30.0)	46.0 (18.0)	27.9 (11.0)
MSL box	8 × 10 × 33	3 × 4 × 13	2.6	156.0	74.0 (29.0)	63.5 (25.0)	49.5 (19.5)
MSL routing	0.64 × (41 × 91 – 24*3.8 D holes)	0.25 × (16 × 36 – 24*1.5 D holes)	2.2	133.0	78.0 (30.5)	89.0 (35.0)	76.2 (30.0)
MSL routing	0.64 × (27 × 46 – 9* 3.8 D holes)	0.25 × (10.5 × 18 – 9*1.5 D holes)	0.7	43.0	67.0 (26.5)	76.0 (30.0)	24.1 (9.5)
		Subtotal for boxes	253.2	15,452 in^3 = 8.9 ft^3			
		Add 19% for rails and brackets	48.1	2,936 in^3 = 1.7 ft^3			
		TOTAL VOLUME of simulators	301.3	18,388 in^3 = 10.6 ft^3			

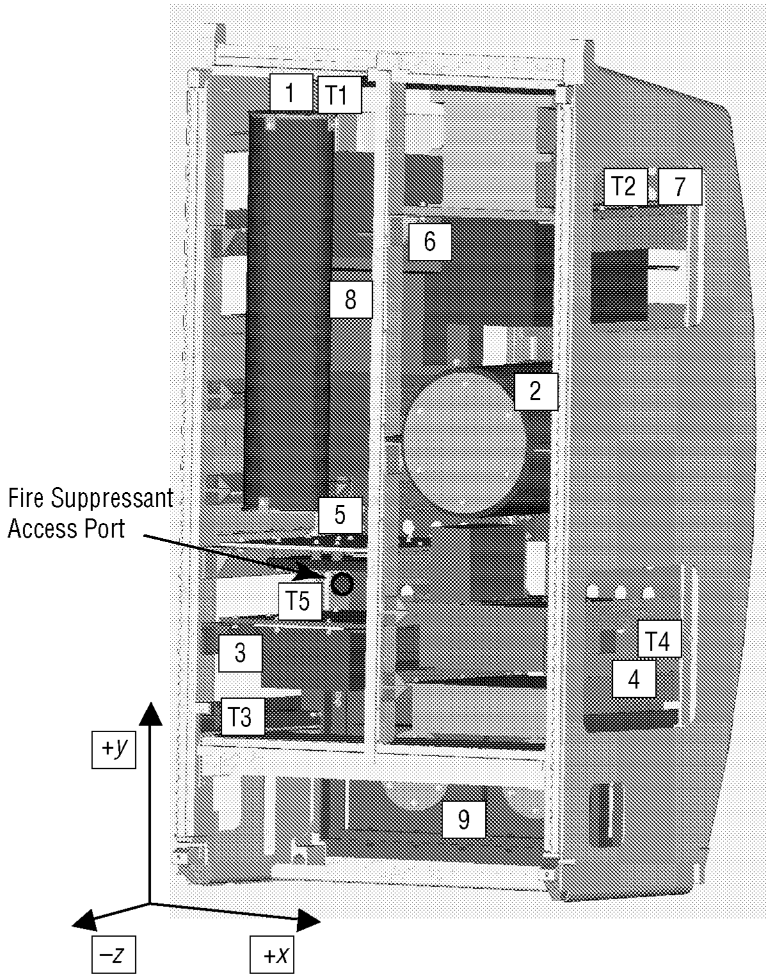

Figure 6. CAD model of the MSRR–1 mockup showing sensor locations.

The volume of an empty ISPR (six-post configuration with side and center posts) is 1.51 m^3 (53.3 ft^3). The volume of the MSRR–1 component simulators, including rails and brackets, is 0.30 m^3 (301.3 L) (10.6 ft^3). The free air volume in the initial MSRR–1 configuration is therefore 1.21 m^3 (42.7 ft^3). With the SPD simulators removed, the component volume is 0.25 m^3 (9.0 ft^3), and the free air volume is 1.26 m^3 (44.3 ft^3). The ISPR has numerous leak paths that allow air to escape while CO_2 is injected. The holes and gaps in the ISPR shell are listed in table 3. Figures 7–13 show examples of the holes and gaps. The inclusion of the ARIS adds several holes, primarily in the utility interface panel (UIP), as shown in figure 10.

Table 3. Holes and gaps in the ISPR.

Description	Dimensions (mm)		Dimensions (in)		Area (in²)	No. Places	Total Area (cm²)	Total Area (in²)	Approximate Leak Locations (Measurements Taken From Lower Left Front Rack Post When Facing Front of Rack) Left-Hand Side Coordinates, cm (in) x	y	z	Right-Hand Side Coordinates, cm (in) x	y	z
Round hole in top of rack—7- to 8-mm diameter	8	–	0.31	–	0.08	2	1.0	0.16	36.00 (14.00)	193.0 (76.00)	41.0 (16.00)	69.0 (27.00)	193.0 (76.0)	41.0 (16.00)
Leaks around lower support posts	9	21	0.35	0.83	0.29	2	3.8	0.59	3.20 (1.25)	5.0 (2.00)	76.0 (30.00)	101.0 (39.75)	5.0 (2.0)	76.0 (30.00)
	9	20	0.35	0.79	0.28	2	3.6	0.56	–	–	–	–	–	–
	–	–	0.50	1.25	0.63	2	8.1	1.25	–	–	–	–	–	–
Gap between center post and upper faceplate Z-beam	47	26	1.85	1.02	1.89	2	24.4	3.79	50.00 (19.50)	193.0 (76.00)	2.5 (1.00)	57.0 (22.50)	193.0 (76.0)	2.5 (1.00)
	46	8	1.81	0.31	0.57	2	7.4	1.14	–	–	–	–	–	–
Slot through rack shell top in front corner	6	11	0.24	0.43	0.10	2	1.3	0.21	5.00 (2.00)	198.0 (78.00)	11.0 (4.50)	100.0 (39.50)	198.0 (78.0)	11.0 (4.50)
Gap between upper Z-beam and rack side	20	40	0.79	1.57	1.24	2	16.0	2.48	5.00 (2.00)	191.0 (75.00)	3.2 (1.25)	100.0 (39.50)	191.0 (75.0)	3.2 (1.25)
	11	59	0.43	2.32	1.01	2	13.0	2.01	–	–	–	–	–	–
Gap between rack front side and rack top corner	12	10	0.47	0.39	0.19	2	2.4	0.37	–	–	–	–	–	–
Corner gap between lower faceplate Z-beam and rack structure	5	21	0.20	0.83	0.16	2	2.1	0.33	8.00 (3.00)	33.0 (13.00)	3.2 (1.25)	97.0 (38.00)	33.0 (13.0)	3.2 (1.25)
	4	51	0.16	2.01	0.32	2	4.1	0.63	–	–	–	–	–	–
Gap between center post and lower Z-beam	34	27	1.34	1.06	1.42	1	9.2	1.42	52.00 (20.50)	33.0 (13.00)	3.2 (1.25)	–	–	–
Gap on top front corner of ortho-grid	23	58	0.91	2.28	2.07	2	26.7	4.14	5.00 (2.00)	31.0 (12.00)	9.0 (3.50)	99.0 (39.00)	31.0 (12.0)	9.0 (3.50)
Gap between front side post and rack shell	10	25	0.39	0.98	0.39	2	5.0	0.78	–	–	–	–	–	–
	10	15	0.39	0.59	0.23	2	3.0	0.47	–	–	–	–	–	–
Gap through lower corner of UIP	30	52	1.18	2.05	2.42	2	31.2	4.84	2.50 (1.00)	2.5 (1.00)	42.0 (16.50)	102.0 (40.00)	2.5 (1.0)	42.0 (16.50)
Rod passing through gap in UIP	18	–	0.71	–	0.39	2	–5.1	–0.79	–	–	–	–	–	–
Radius of rack shell (right triangle w/legs 20 mm)	–	–	–	–	0.31	2	–4.0	–0.62	–	–	–	–	–	–
Round hole in bottom of rack—7- to 8-mm diameter	8	–	0.31	–	0.08	2	1.0	0.16	36.00 (14.00)	0	45.0 (17.50)	69.0 (27.00)	0 (0)	45.0 (17.50)
Leaks around 10 small bolts on back of rack	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Slot in UIP for ARIS	46	130	1.81	5.12	9.27	2	119.6	18.54	10.00 (4.00)	6.0 (2.50)	43.0 (16.75)	94.0 (37.00)	6.4 (2.5)	43.0 (16.75)
Slot in upper corners of UIP	4	13	0.16	0.51	0.08	2	1.0	0.16	0.64 (0.25)	31.0 (12.00)	43.0 (16.75)	104.0 (40.75)	31.0 (12.0)	43.0 (16.75)
TOTAL AREA from enclosed rack volume =							274.7	42.59						
Area related to ARIS =							151.8	23.54						
TOTAL AREA not related to ARIS =							122.9	19.05						

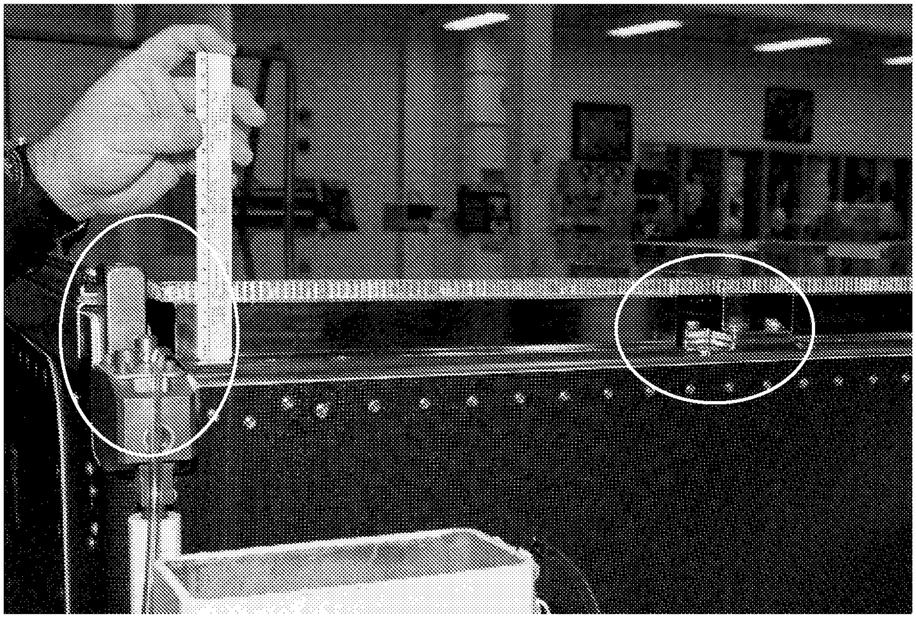

Figure 7. Gaps at the top of the rack near the side post (left) and center post (right).

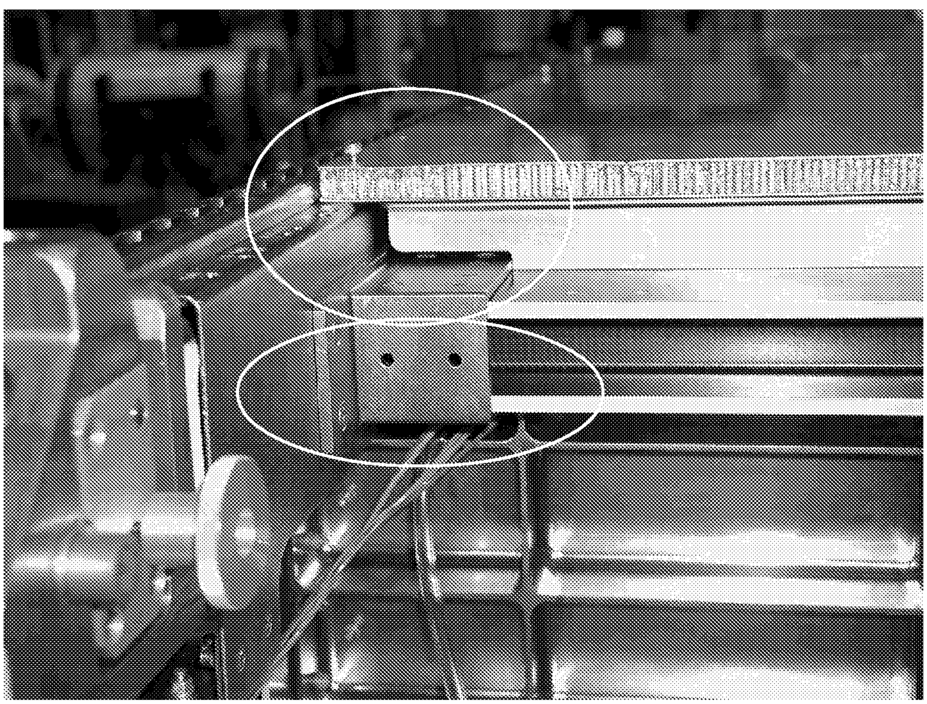

Figure 8. Gaps at the bottom of the faceplate.

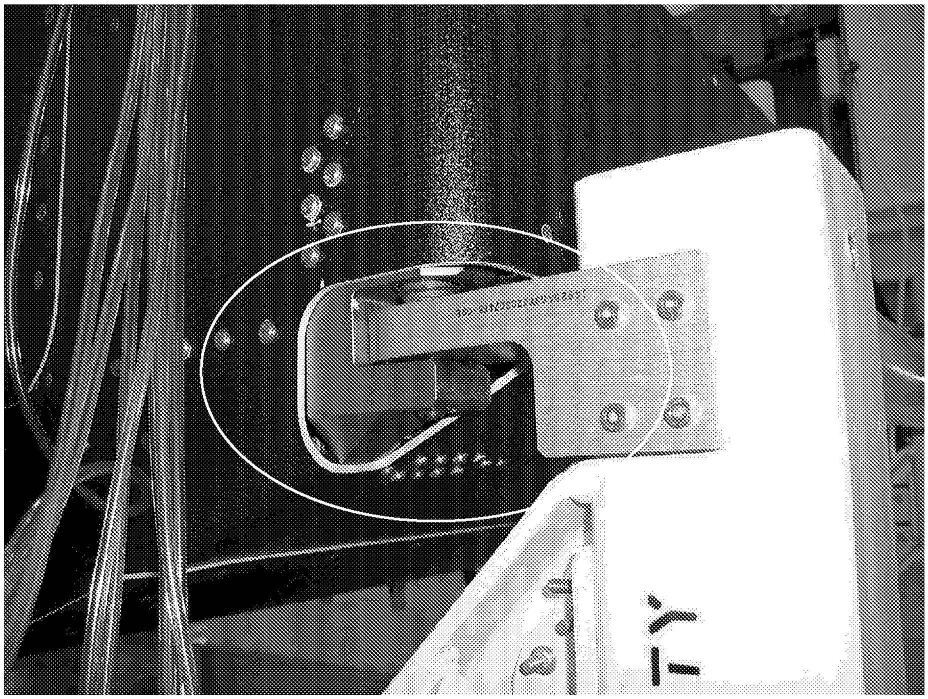

Figure 9. Gaps at the bottom rear of the rack.

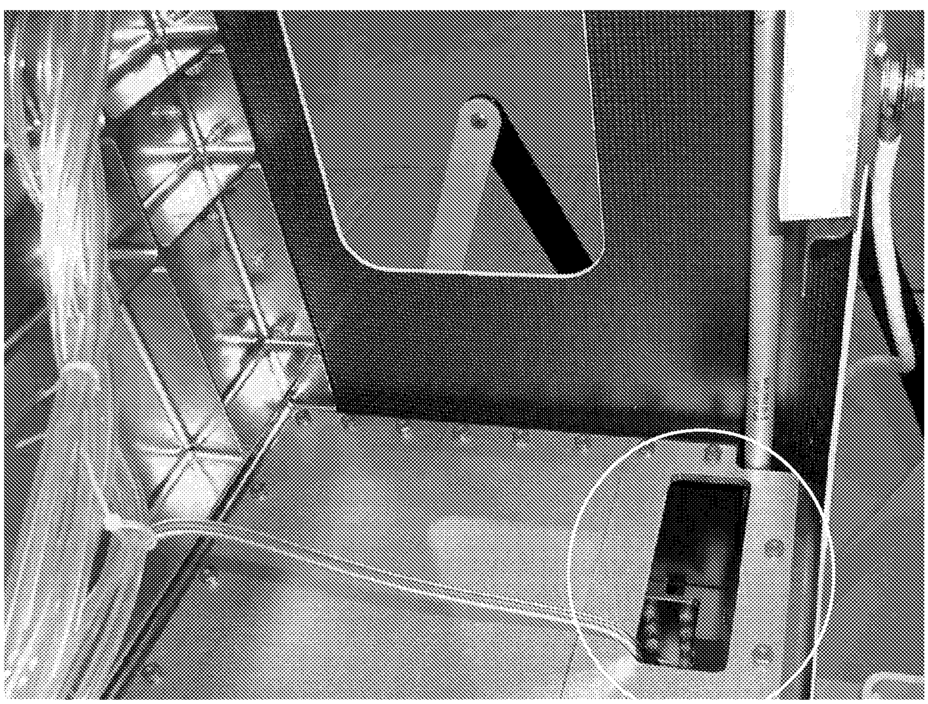

Figure 10. One of two holes for the ARIS in the UIP.

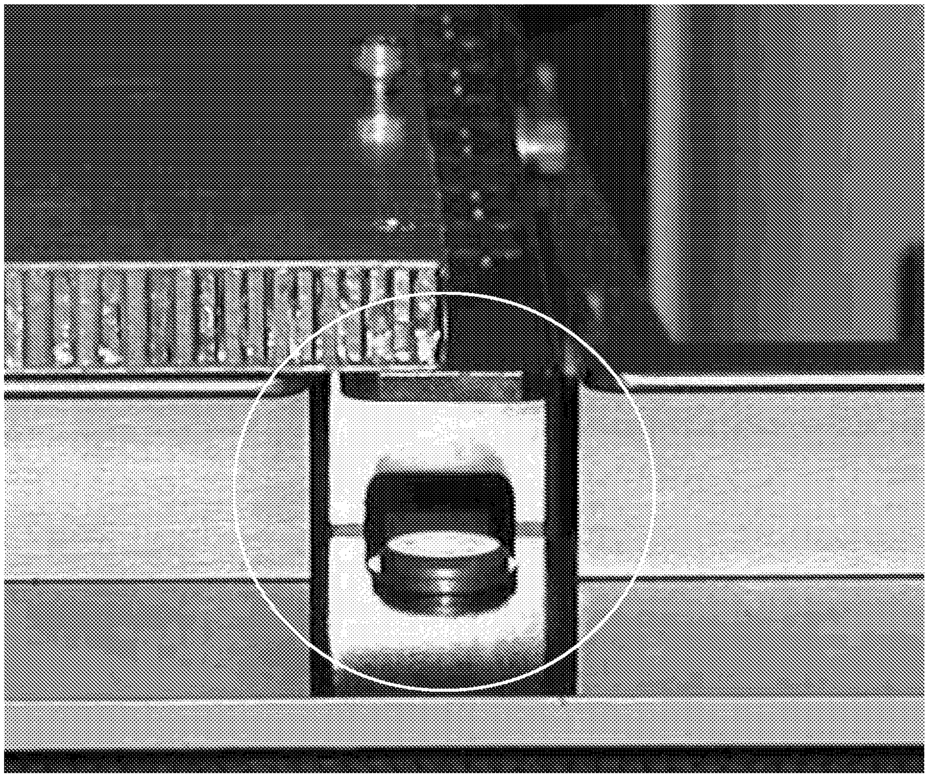

Figure 11. Gaps at the bottom of the center post.

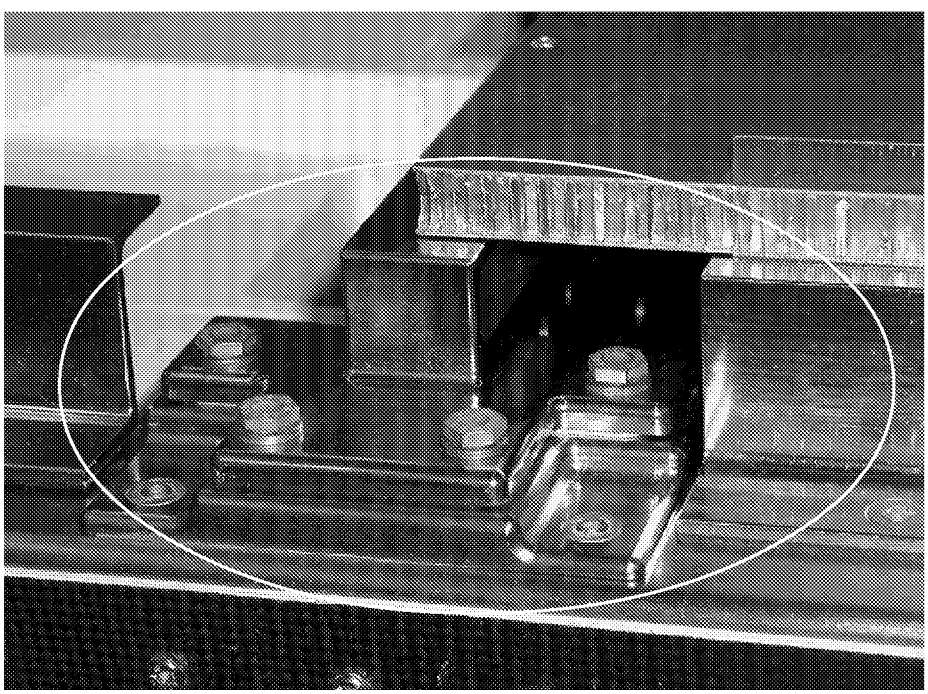

Figure 12. Gaps at the top of the center post.

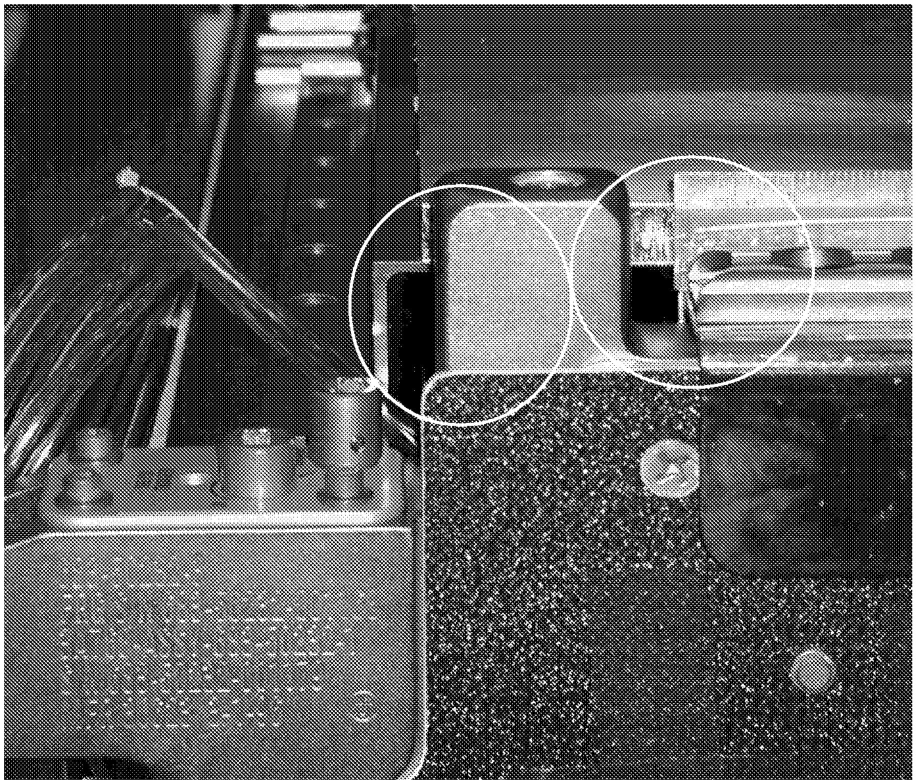

Figure 13. Gaps at the top left corner of the faceplate.

The results of these tests are very conservative for the following reasons:

- The TECS shelf mockup is a solid plate (fig. 14) that obstructs the flow of CO_2, while the flight TECS shelf has numerous holes, allowing CO_2 to disperse more broadly. (See fig. 15 of the MSRR–1 half-scale model.)

- Settling of CO_2 due to gravity is minimized by testing the rack horizontally, but is still a factor. To correct for this effect, the measurements from the distributed monitoring locations were averaged to provide a more realistic concentration value.

- More free air volume is present in the tested units than in the final flight configuration, especially for the second test case.

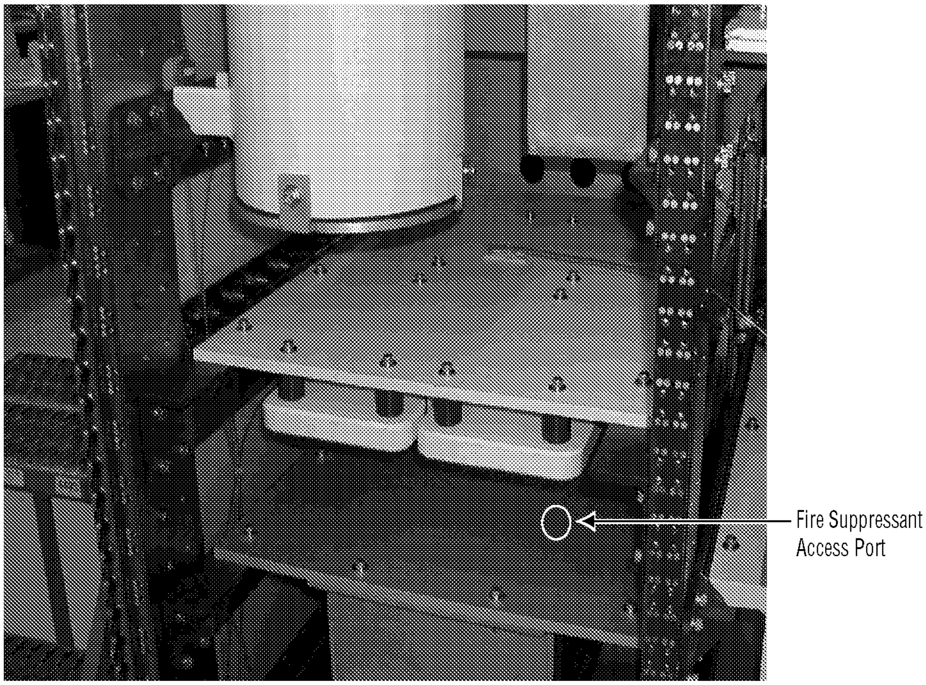

Figure 14. TECS shelf simulator.

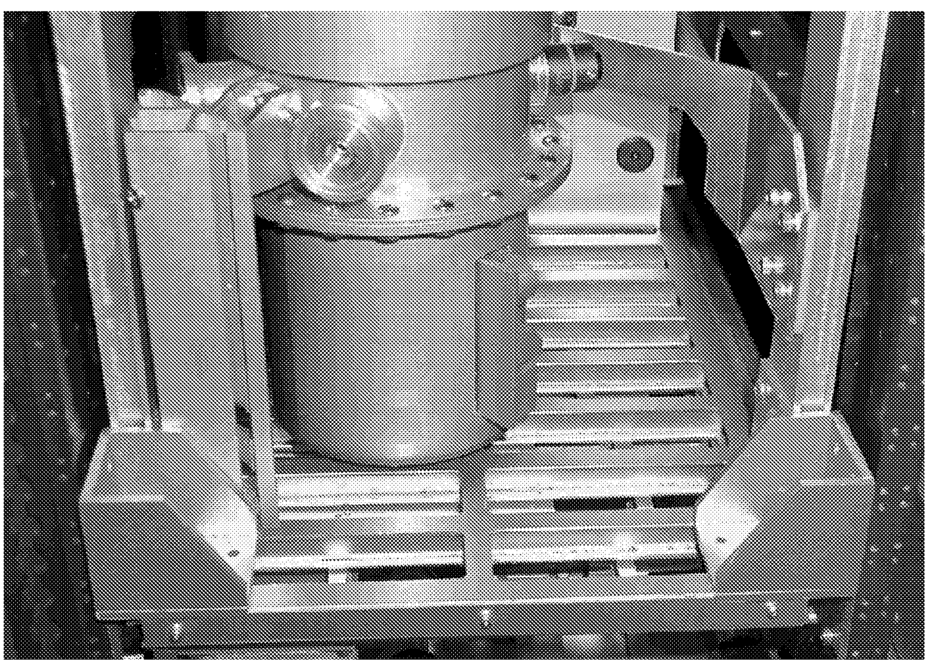

Figure 15. TECS shelf model.

4. PERFORMING THE TESTS

The tests were performed in the MDL with the rack in a horizontal, backdown orientation.[5] The following steps were performed:

1. Field check the calibration using ambient air (approximately zero percent) and bottled CO_2 (≈100 percent).

2. Check tubing installation and connections.

3. Activate monitors, if not already activated.

4. Ensure monitors are stable and recording properly.

5. Insert the PFE nozzle into the access port 8 to 10 cm (3 to 4 in).

6. Discharge the PFE until the full charge of CO_2 is injected into the rack.

7. Mark the times on the paper strips when CO_2 discharge begins and when it concludes.

8. Determine the peak CO_2 levels, based on the pretest calibration, at each monitoring location.

Two cases were tested. The first case included the SPD simulators, and for the second case the SPD simulators were removed, leaving an open space in the upper Alpha side of the rack.

5. TEST RESULTS

The measured CO_2 concentrations are shown in tables 4 and 5 and plotted in figures 16 and 17. The CO_2 concentrations throughout the rack reached 59 percent or higher for the first test, with a maximum average of 61 percent for the rack. For the second, more conservative test, maximum concentrations reached 58 percent or higher, except for one location where the increased free volume of air diluted the CO_2 to 49 percent maximum. The average maximum CO_2 concentration for the rack was 58 percent for the second test.

Table 4. CO_2 instrumentation and measurements for case 1.

Test Article: MSRR–1 Rack		Test Date: 2/6/01								Test Case: 1 (SPD Mockup In Place)			
Test Engineer: Dave McIntosh, 544–1314										Test Requester: Paul Wieland, 544–7215			
Safety Representative: Lisa Miller										Notes:			
Test Data													
		CO_2 Concentrations (% At Time After Test Start)											
Sensor No.	CO_2 Sensor Location	10 s	20 s	30 s	40 s	50 s	60 s	90 s	120 s	180 s	240 s	Max. Conc.	Coordinates, cm (in) *x, y, z*
1	Front plane above SPD	38	55	60	57	32	12	4	0	0	0	60	20, 185, 14 (8, 73, 5.5)
2	Front plane to right of MSL furnace	28	50	58	60	60	50	10	5	2	1	61 (at 45 s)	94, 113, 25 (37, 44.5, 10)
3	Front plane below VAS shelf	38	55	61	60	58	54	30	8	2	1	61	6, 43, 19 (2.5, 17, 7.5)
4	Center plane below MSL	26	50	58	59	59	58	54	35	8	4	59	94, 66, 37 (37, 26, 14.5)
5	Center plane above TECS shelf	30	51	58	60	59	59	50	31	10	5	60	25, 81, 43 (9.75, 32, 17)
6	Center plane to left of MSL box above furnace	35	54	60	60	60	59	47	22	7	4	60	56, 154, 42 (22, 60.5, 16.5)
7	Back plane between routing simulator and MSL box	30	50	58	61	62	61	62	62	61	59	62	86, 182, 66 (34, 71.5, 26)
8	Back plane behind SPD	33	53	60	61	60	60	59	56	48	30	61	30, 137, 52 (12, 54, 20.5)
9	Back plane behind lower interface panel	38	55	60	61	58	57	54	38	12	6	61	47, 10, 44 (18.5, 4, 17.5)
											Average for Rack	61	

Table 5. CO_2 instrumentation and measurements for case 2.

Test Article: MSRR–1 Rack	Test Date:											Test Case: 2 (SPD Mockup Removed)	
Test Engineer: Dave McIntosh, 544–1314												Test Requester: Paul Wieland, 544–7215	
Safety Representative:												Notes:	
Test Data													
		CO_2 Concentrations (% At Time After Test Start)											
Sensor No.	CO_2 Sensor Location	10 s	20 s	30 s	40 s	50 s	60 s	90 s	120 s	180 s	240 s	Max. Conc.	Coordinates, cm (in) *x, y, z*
1	Front plane near top of rack on left side	7.0	21.0	35.0	45.0	48.0	41.0	13.0	5.0	1.0	0.0	49.0 (at 45 s)	20, 185, 14 (8, 73, 5.5)
2	Front plane to right of MSL furnace	30.0	49.0	56.0	59.0	59.0	52.0	11.5	5.0	2.5	0.0	59.0	94, 113, 25 (37, 44.5, 10)
3	Front plane below VAS shelf	38.5	55.5	59.0	57.0	55.5	55.0	31.0	8.5	2.0	0.0	59.0	6, 43, 19 (2.5, 17, 7.5)
4	Center plane below MSL	27.0	48.5	56.5	58.0	57.5	57.0	49.5	26.0	8.0	4.0	58.0	94, 66, 37 (37, 26, 14.5)
5	Center plane above TECS shelf	20.0	47.5	57.0	59.5	58.5	59.0	54.5	36.5	11.5	4.0	59.5	25, 81, 43 (9.75, 32, 17)
6	Center plane to left of MSL box above furnace	24.0	45.0	54.5	58.0	58.5	58.5	51.0	27.0	7.5	4.0	58.5	56, 154, 42 (22, 60.5, 16.5)
7	Back plane between routing simulator and MSL box	19.0	42.0	53.0	58.0	59.0	59.5	60.0	60.0	59.5	58.5	60.0	86, 182, 66 (34, 71.5, 26)
8	Back plane at rear of experiment space on the left	37.0	54.0	59.0	60.0	59.0	59.0	56.5	51.0	30.0	15.0	60.0	30, 137, 52 (12, 54, 20.5)
9	Back plane behind lower interface panel	30.0	51.5	58.5	59.0	57.0	56.0	53.5	36.0	15.0	7.0	59.0	47, 10, 44 (18.5, 4, 17.5)
											Average for Rack	58.0	

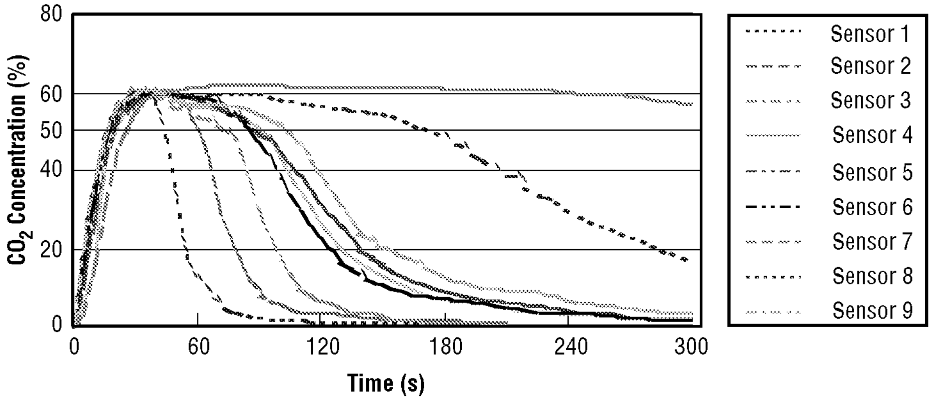

Figure 16. CO_2 concentrations for case 1 with SPD simulators.

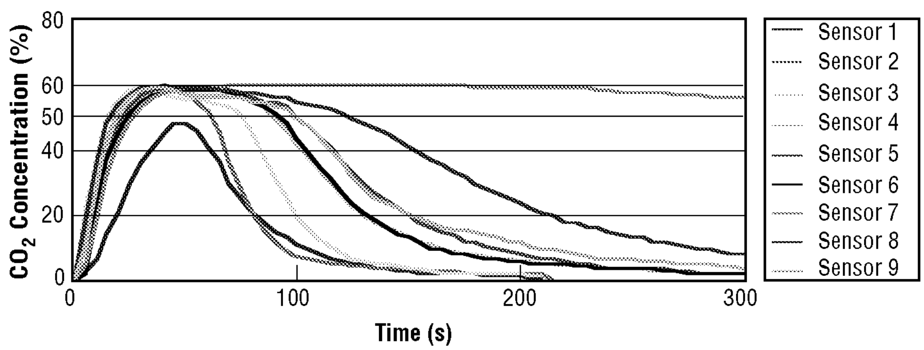

Figure 17. CO_2 concentrations for case 2 without SPD simulators.

The correlation of the flowpath lengths and tortuousness with the maximum CO_2 concentrations at each sensor location were also investigated. As shown in table 6, there is no distinguishing effect due to path length or the bends in the flowpath. Sensor location No. 4 is located 65 cm (26 in) from the PFE nozzle tip during discharge with a relatively straight flowpath, yet has the lowest maximum CO_2 concentration. Conversely, sensor location No. 7 is located 130 cm (51 in) from the PFE nozzle tip with a moderately tortuous flowpath, yet has the highest maximum CO_2 concentration. This indicates that other factors are much more important than flowpath length and form.

Table 6. Correlation of flowpath length and tortuousness with maximum CO_2 concentration.

Sensor No.	Straight Line Distance From Access Port		Path Description	Maximum CO_2 Concentration (%)	
	cm	in		Case 1	Case 2
1	111	44	Sharp bends (60° to >90°)	60	49.0
2	70	28	Shallow bends (0° to 30°)	61	59.0
3	47	18	Sharp bends (60° to >90°)	61	59.0
4	65	26	Shallow bends (0° to 30°)	59	58.0
5	38	15	Sharp bends (60° to >90°)	60	59.5
6	87	34	Sharp bends (60° to >90°)	60	58.5
7	130	51	Moderate bends (30° to 60°)	62	60.0
8	76	30	Sharp bends (60° to >90°)	61	60.0
9	76	30	Shallow bends (0° to 30°)	61	59.0

The temperature and pressure data are plotted in figures 18–20. The PFE gets very cold, with temperatures dropping to <0 °C (32 °F) during discharge. The temperature of the TECS shelf dropped to near 0 °C (32 °F). The pressure in the rack changed very little during discharge of the PFE, due to the relatively large area of openings in the rack shell. Pressure data for the second test is not plotted because it is virtually indistinguishable from the pressure plots for the first test (for more information see ref. 6).

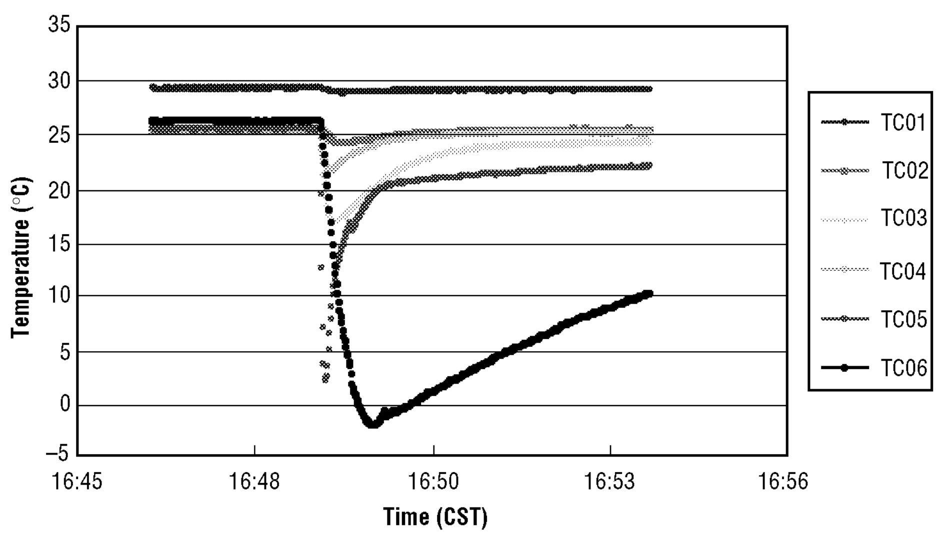

Figure 18. Temperatures measured for case 1.

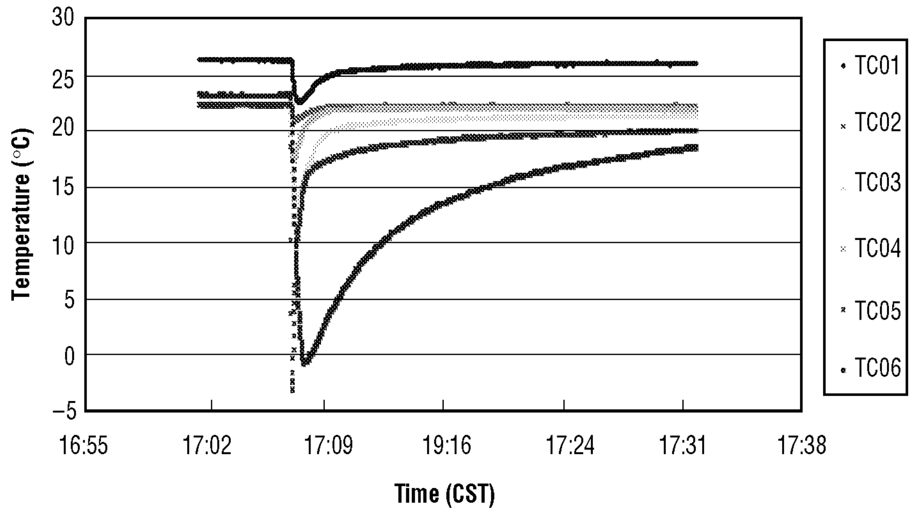

Figure 19. Temperatures measured for case 2.

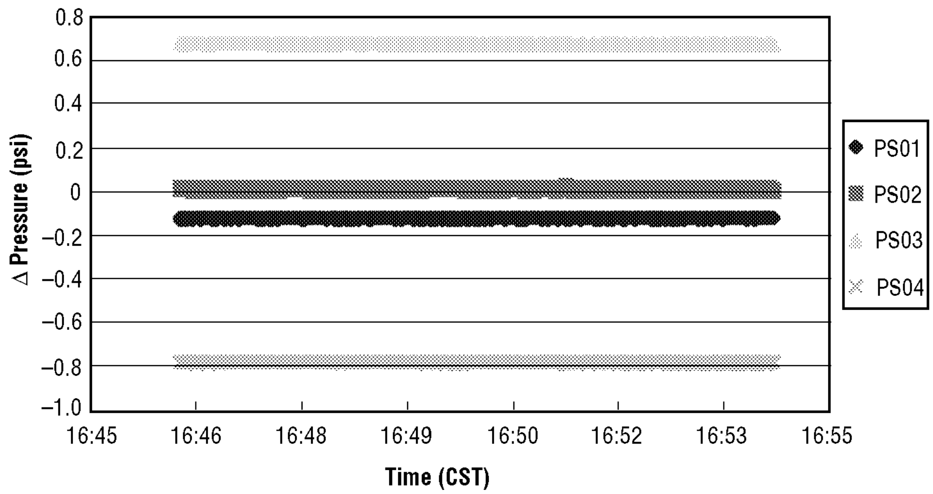

Figure 20. Pressures measured for case 1.

6. CONCLUSIONS AND BENEFITS FOR FUTURE PAYLOAD OR SYSTEM RACKS

Several conclusions can be reached based on the results of the MSRR-1 testing, and by comparing these results with results from previous fire suppression testing. The following conclusions can be used with future payload or system racks to determine, without additional testing, whether fire suppressant distribution requirements can be met:

- The MSRR–1 will meet the requirements for fire suppressant distribution.
- Primary factors that affect the ability to meet the CO_2 distribution requirements are:
  - The free air volume in the rack
  - The total area and distribution of openings in the rack shell.
- The length and degree of tortuousness of the suppressant flowpath have little correlation with CO_2 concentration.

By comparing the results of this MSRR–1 testing with the results of previous testing on non-ARIS racks such as the SSFF, it can be deduced that a variety of rack configurations with more free air volume or greater area of holes in the rack shell than MSRR–1 will meet the requirements for CO_2 dispersal and concentration. Such comparison leads to the following conclusions that can be useful in evaluating future ISPR configurations:

- The total area of holes and gaps in the rack shell could be significantly increased.

For non-ARIS racks with holes totaling 123 cm^2 (19 in^2), the average maximum CO_2 concentration was 63.8 percent, whereas an ARIS rack has holes totaling 275 cm^2 (43 in^2) and an average maximum CO_2 concentration of 61 percent. A conservative extrapolation indicates that a hole area of 400 cm^2 (62 in^2) could be accommodated, providing that the free air volume is no more than 1.26 m^3 (44.3 ft^3), and still achieve a maximum CO_2 concentration of at least 50 percent.

- The free air volume could be significantly increased.

For MSRR–1 test case 1, the free air volume was 1.21 m^3 (42.7 ft^3) and the average maximum CO_2 concentration was 61 percent; whereas for test case 2, the free air volume was 1.26 m^3 (44.3 ft^3) and the average maximum CO_2 concentration was 58 percent. A conservative extrapolation indicates that a free air volume of 1.4 m^3 (49.4 ft^3) could be accommodated, providing that the total area of holes and gaps is no more than 275 cm^2 (43 in^2), and still achieve a maximum CO_2 concentration of at least 50 percent.

- Longer or more tortuous flowpaths have little impact on the average maximum CO_2 concentration.

No significant correlation could be made between flowpath characteristics and average maximum CO_2 concentration, implying that path length and severity of bends can be increased considerably and still meet the requirement, so long as flow is not completely blocked.

- The PFE nozzle should be inserted to the stop on the nozzle, which helps seal the gap around the nozzle in the access port, to ensure the highest maximum CO_2 concentration.

Testing on the SSFF indicates that inserting the PFE nozzle completely to the stop results in a 1.4 percent higher average maximum CO_2 concentration.

While additional testing would be required to establish statistical validity of these conclusions, they can serve as guidelines for evaluating future racks to determine whether testing is warranted for verifying compliance with fire suppressant distribution requirements. For any future testing of ISPR configurations, it is recommended that quantitative information be collected on the volumes and locations of components, the free air volume in the rack, the areas and locations of gaps and holes in the rack shell and their total area, the CO_2 monitoring locations, and flowpath length and characteristics from the fire suppressant access port to the monitoring locations.

APPENDIX A—FIRE SUPPRESSANT DISTRIBUTION TESTS ON OTHER RACKS

Numerous fire suppressant distribution tests have been performed for the Space Station program by Boeing and NASA, including tests on system racks, payload racks, module standoffs, and module end cones. The available information on the rack tests is described below. The rack tested that is most similar to the MSRR–1 is the SSFF.[7] Additional racks that were tested include the Atmosphere Revitalization (AR) rack, the Avionics rack, the Expedite the Processing of Experiments to the Space Station (EXPRESS) rack, and the Temperature and Humidity Control (THC) rack.

Limited quantitative information is available on the configurations of these racks during fire suppressant distribution testing. The total area and distribution of holes and gaps in the rack shells as well as the volumes of the component simulators and their distributions are not known quantitatively. Therefore, it is necessary to make some assumptions in order to compare results with the MSRR–1. The validity of the comparisons thus depends on the accuracy of the assumptions. It can be assumed that the free volume of the other racks is similar to the MSRR–1 with the SPD EM, and that the area and distribution of gaps and holes in the rack shell is similar to that of a standard non-ARIS rack.

A.1 Space Station Furnace Facility Fire Suppressant Distribution Test Results (1996)[7]

The SSFF rack (fig. 21) was a standard ISPR (non-ARIS); however, an aluminum version was used rather than a composite version. The total area of holes and gaps may therefore differ somewhat from a standard composite ISPR. The distribution of the holes and gaps is unknown quantitatively. The locations and distribution of the CO_2 sensor tubes are known.

The locations of the CO_2 sensors are listed in table 7, and the maximum CO_2 concentrations for each of two test runs are listed in table 8. To compare these results with the MSRR test results, several assumptions can be made:

- The area of holes and gaps in the rack shell is similar to that of a non-ARIS rack.
- The total volume of component simulators appears to be somewhat greater than for the MSRR–1. Therefore, there is somewhat less free air volume.
- There are numerous flowpaths for rapid dispersion of CO_2 throughout the rack.

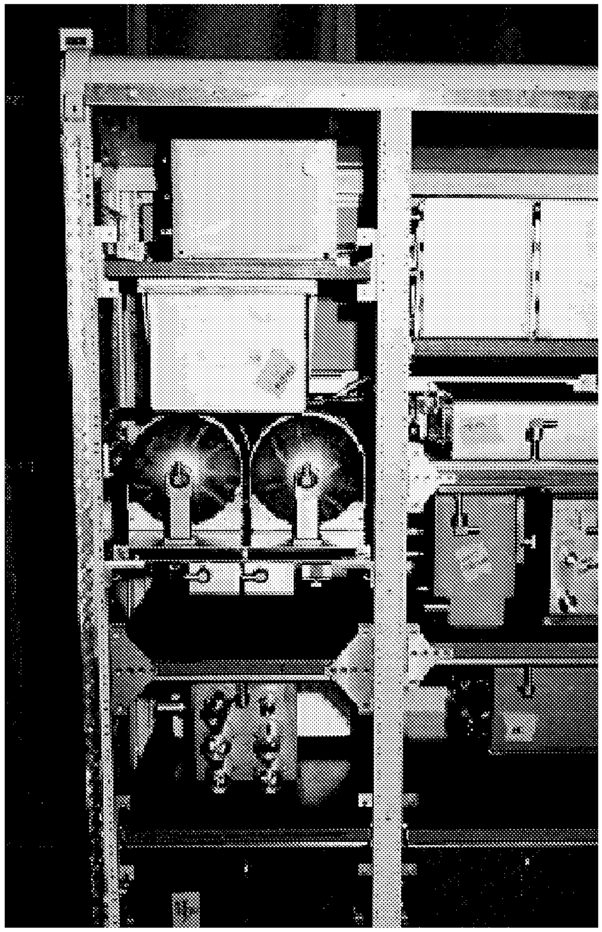

Figure 21. SSFF core rack mockup.

Table 7. SSFF CO_2 sensor locations.

Sensor No.*	*x* (cm)	*y* (cm)	*z* (cm)	*x* (in)	*y* (in)	*z* (in)
1	88.0	30.5	34.0	34.5	12.0	13.5
2	24.0	41.0	90.0	9.5	16.0	35.5
3	77.5	109.0	32.0	30.5	43.0	12.5
4	94.0	188.0	19.0	37.0	74.0	7.5
6	16.5	133.0	89.0	6.5	52.5	35.0
7	25.0	140.0	43.0	10.0	55.0	17.0
8	95.0	27.0	8.0	37.5	10.5	3.0
9	0	99.0	37.0	0	39.0	14.5
10	9.0	76.0	65.0	3.5	30.0	25.5
11	96.5	80.0	16.5	38.0	31.5	6.5
12	4.0	175.0	7.5	1.5	69.0	3.0

*Sensor No. 5 not working

Table 8. SSFF maximum CO_2 concentrations (percentage).

Sensor No.	Test Run No. 1	Test Run No. 2
1	68.0	63.5
2	68.0	66.0
3	67.0	64.0
4	55.0	62.25
6	68.0	65.0
7	65.0	63.0
8	66.0	63.0
9	67.5	64.5
10	66.0	65.0
11	66.5	65.0
12	60.25	60.5
Average	65.2	63.8

The SSFF test was performed twice, first by inserting the PFE nozzle to the stop, which seals the access port, and then by inserting the PFE nozzle ≈8 cm (3 in). The average maximum CO_2 concentration was 65.2 percent for the first case and 63.8 percent for the second case. This decrease of 1.4 percent may be due to measurement uncertainty, or due to CO_2 escaping through the access port, or both. Since the PFE nozzle was inserted ≈8 cm (3 in) for the MSRR–1 test, the second SSFF test is a better comparison. The average maximum CO_2 concentration for MSRR–1 with the SPD EM was 61 percent, ≈2.8 percent less than for the SSFF. Assuming that the primary difference between the SSFF and MSRR–1 is the increased area of holes due to the ARIS, the results indicate that even though doubling the area of holes has a noticeable effect, the requirement would be met even if the area was considerably more. This is comparable to the effects of removing the SPD EM simulators, which increased the free air volume by 0.045 m^3 (1.6 ft^3). Though the sensor located in the open volume only reached 49 percent CO_2, the rack average was 58 percent, indicating that even with additional free volume the requirement would be met. This result also indicates the importance of flowpaths, since the TECS shelf simulator blocked direct flow of CO_2 to the Alpha EM volume. If the TECS shelf simulator had been more accurate, with holes, then that location would likely have exceeded 50 percent CO_2 concentration as well.

A.2 Atmosphere Revitalization Rack Fire Suppressant Distribution Test Results (6/24/96)

Limited information is available on the configuration of the AR rack during fire suppression testing. Table 9 lists the locations of the CO_2 sensors and table 10 lists the maximum CO_2 concentration. Figures 22–24 show the results of the three test runs.

Table 9. Atmosphere revitalization rack CO_2 sensor locations.

Sensor No.	*x* (cm)	*y* (cm)	*z* (cm)	*x* (in)	*y* (in)	*z* (in)
1	87.5	156.0	21.5	34.4	61.4	8.4
2	33.0	158.0	8.0	12.9	62.2	3.1
3	31.0	159.5	56.5	12.2	62.8	22.3
4	12.5	121.5	61.0	5.0	47.8	24.0
6	25.0	86.5	40.5	9.9	34.0	15.9
7	73.5	39.5	22.0	29.0	15.6	8.6
8	68.5	78.5	54.0	27.0	30.9	21.2
9	69.5	148.5	46.5	27.4	58.5	18.4
10	73.5	138.0	75.0	29.0	54.3	29.5
11	43.0	138.0	24.5	16.9	54.3	9.6
12	30.5	37.5	48.5	12.0	14.8	19.0

Table 10. Atmosphere revitalization rack test maximum CO_2 concentration (percentage).

Sensor No.	Test Case No. 3a Test Run No. 1 (7/2/96)	Test Case No. 3b Test Run No. 2 (7/3/96)
1	59	60
2	59	62
3	58	62
4	58	62
5	61	64
6	60	61
7	60	63
8	61	61
9	61	64
10	59	60
11	NA	NA
12	60	64
Average	59.6	62.1

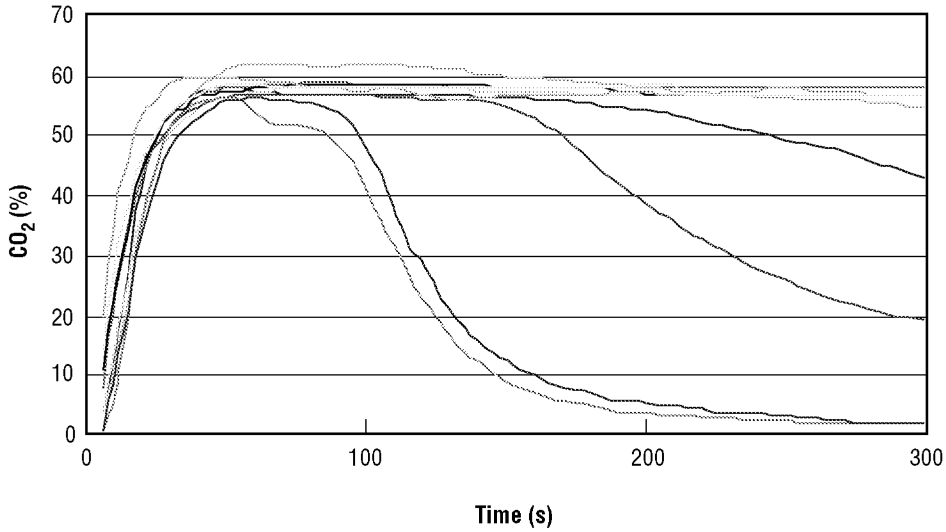

Figure 22. CO_2 concentrations for the AR rack pretest.

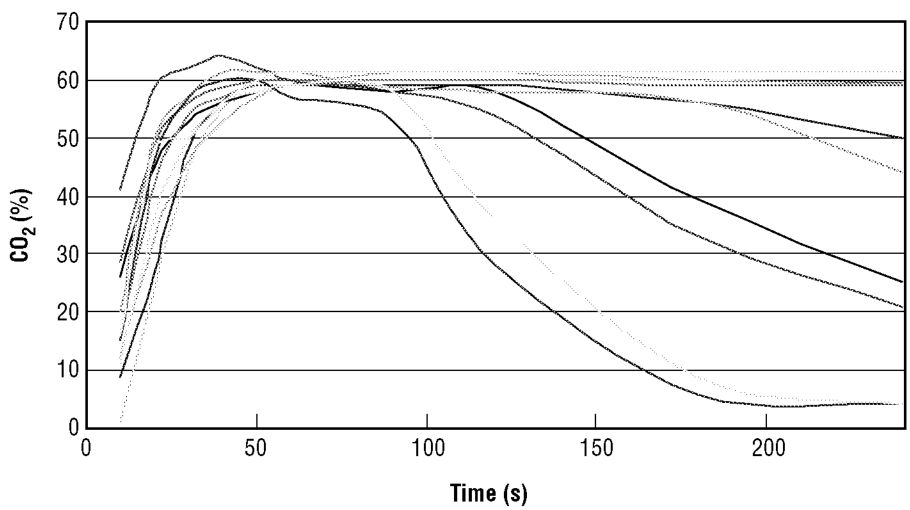

Figure 23. CO_2 concentrations for the AR rack test case No. 3b, test run No. 1.

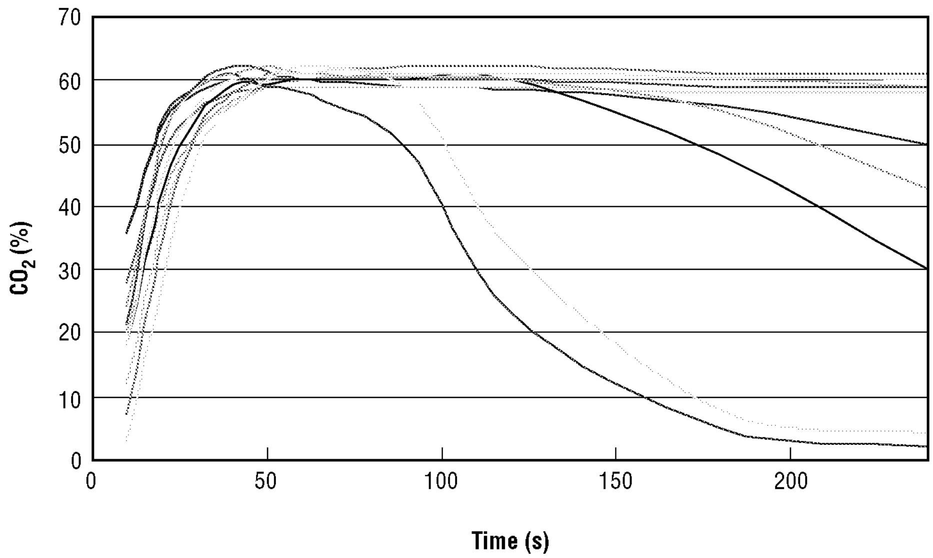

Figure 24. CO_2 concentrations for the AR rack test case No. 3b, test run No. 2.

A.3 Avionics Rack Fire Suppressant Distribution Test Results

Several fire suppression tests were performed on the avionics rack. Unfortunately, information on the configuration of the avionics rack (volumes and distribution of volume simulators, areas of gaps and holes, flowpath limitations) for these tests is not currently available. The locations of the CO_2 sensors are listed in table 11. Results of four tests are listed in table 12. The two runs of test case No. 5a show good repeatability, with <1 percent difference in the average maximum concentration for the rack. The second run of test case No. 5b is also within this difference, though sensor 12 apparently stopped functioning. The first run of test case No. 5b showed significantly lower concentrations, possibly due to insufficient filling of the PFE or some undescribed malfunction.

Table 11. Avionics rack CO_2 sensor locations.

Sensor No.	*x* cm (in)	*y* cm (in)	*z* cm (in)
1	74.0 (29.0)	34.0 (13.5)	34.3 (13.5)
2	97.0 (38.0)	163.0 (64.0)	27.3 (10.7)
3	46.0 (18.0)	105.0 (41.5)	50.8 (20.0)
4	67.0 (26.3)	57.0 (22.5)	14.6 (5.7)
6	23.0 (9.3)	41.0 (16.0)	29.2 (11.5)
7	50.0 (19.7)	178.0 (70.0)	30.5 (12.0)
8	41.0 (16.0)	124.0 (48.7)	77.5 (30.5)
9	28.0 (11.0)	81.0 (32.0)	58.4 (23.0)
10	83.0 (32.5)	94.0 (37.0)	67.3 (26.5)
11	51.0 (20.0)	48.0 (19.0)	85.1 (33.5)
12	53.0 (21.0)	16.5 (6.5)	34.3 (13.5)

Table 12. Avionics rack maximum CO_2 concentration (percentage).

Sensor No.	Test Case No. 5a Test Run No. 1 (7/19/96)	Test Case No. 5a Test Run No. 2 (7/19/96)	Test Case No. 5b Test Run No. 1 (7/19/96)	Test Case No. 5b Test Run No. 2 (7/19/96)
1	56	55	50	57
2	56	58	52	58
3	56	55	50	57
4	52	52	51	57
6	56	56	52	56
7	55	54	50	56
8	57	56	52	57
9	56	54	46	52
10	58	56	50	57
11	57	55	49	55
12	58	56	48	NA
Average	56.1	55.2	50	56.2

A.4 EXPRESS Rack Fire Suppressant Distribution Test Results

The EXPRESS rack (shown in fig. 25) is designed to accommodate different payload configurations, allowing a variety of payload experiments to be installed in drawers or Shuttle “middeck-type” lockers to accommodate payloads designed for the Shuttle. The test configuration included eight middeck lockers and two drawers (8/2 configuration). Volume simulators of the AAA and major rack subsystems were installed and a Plexiglas® sheet covered the rear access opening. Nine CO_2 sensors were installed as shown in figure 25 and as described in table 13. During testing, the rack was laid on its starboard (right) side. This is a departure from the usual practice of laying a rack on its back for fire suppressant distribution testing. The fire suppressant access port is located on the lower connector panel, across the middle of the rack face, below the middeck lockers and above the drawers.

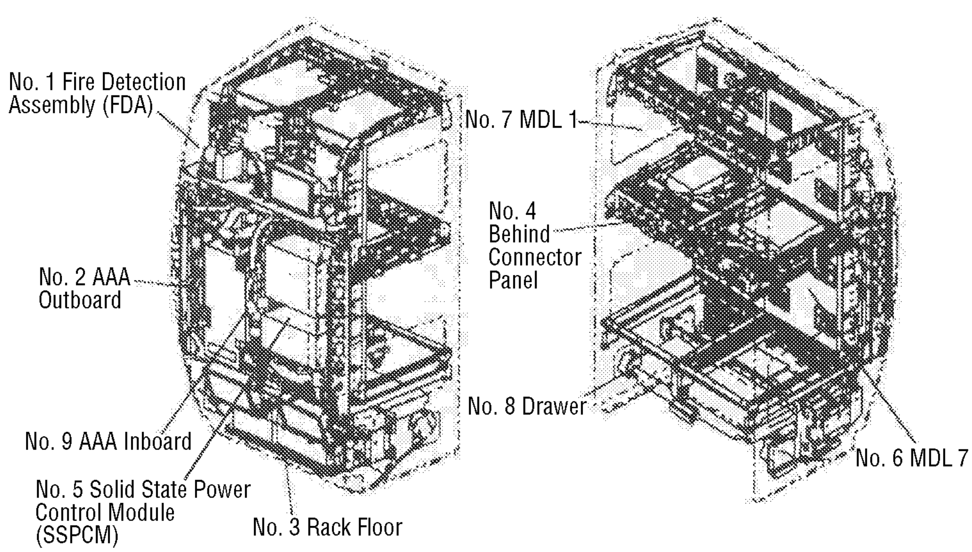

Figure 25. EXPRESS rack configuration during testing.

Table 13. EXPRESS rack CO_2 sensor locations.

Sensor No.	Sensor Location
1	FDA—10 cm (4 in) above intercostal
2	AAA—midpoint of outboard side
3	Rack floor—midpoint
4	Behind lower connector panel between Payload Ethernet Hub Bridge and Express Memory Unit
5	SSPCM—midpoint of upper side
6	MDL No. 7—inside at front of locker
7	MDL No. 1—inside at front of locker
8	Drawer No. 1—inside at front of drawer
9	AAA—midpoint of inboard side

Results of the testing are shown in table 14. Two runs were performed to evaluate the repeatability of the discharge effects. The average maximum CO_2 concentration for the first run was 75.8 percent and 74.7 percent for the second run.

Table 14. EXPRESS rack maximum CO_2 concentrations.

Sensor No.	Run No. 1	Run No. 2
1	75.5	76.0
2	84.0	83.0
3	77.0	77.5
4	80.0	78.0
5	79.0	68.5
6	76.0	75.5
7	67.5	68.0
8	67.0	68.0
9	76.5	78.0
Average	75.8	74.7
Mass Discharged, kg (lb)	2.61 (5.76)	2.54 (5.59)
Comments	None	Nozzle pointed slightly down

A.5 Temperature and Humidity Control Rack Fire Suppressant Distribution Test Results

Details of the configuration of the THC test rack are not available; however, reviewing the results provides some useful information. Table 15 summarizes the results of testing the THC rack with two cases. Repeated runs of the same case condition show repeatability within 2 percent. Sensor No. 5 was not functioning and for the third run of test case No. 4a, readings from three additional sensors were not available. Two of the three sensors that were not available were probably low in the rack and therefore gave higher than average readings. The differences between test case Nos. 4a and 4b are not known (they may be related to the depth of nozzle insertion), but the average maximum CO_2 concentration is 2.5 to 3 percent less for test case No. 4b, but still well over the 50-percent requirement.

Table 15. Temperature humidity control rack test results.

Sensor No.	Maximum CO_2 Concentrations (%)				
	Test Case No. 4a, Test Run No. 1	Test Case No. 4a, Test Run No. 2	Test Case No. 4a, Test Run No. 3	Test Case No. 4b, Test Run No. 1	Test Case No. 4b, Test Run No. 2
	7/11/96	7/11/96	7/15/96	7/15/96	7/15/96
1	57	50	52	52	53
2	56	58	58	58	58
3	63	64	62	61	59
4	75	74	68	64	62
5	NA	NA	NA	NA	NA
6	64	64	64	62	60
7	57	52	54	56	54
8	61	62	62	60	59
9	62	64	64	62	60
10	65	64	NA	62	60
11	62	62	NA	60	59
12	65	64	NA	62	60
Average	62.5	61.6	60.5	59.9	58.5

REFERENCES

1. “Materials Science Research Rack–1 (MSRR–1) Thermal and Environmental Control Systems Data Book,” *MSRR1–DOC–0018*, Marshall Space Flight Center, AL, February 14, 2001.

2. “Pressurized Payloads Interface Requirements Document,” *SSP57000RE*, Rev. E, NASA, November 1, 2000.

3. McIntosh, D.: “First Materials Science Research Rack (MSRR–1) Rack Handling Procedure,” *MTCP–TH–MSRR1–300A*, Marshall Space Flight Center, AL, January 31, 2001.

4. “Hazardous Operation and Maintenance Instruction Portable Fire Extinguisher (PFE) Fill Procedure,” *OMI R1540,* Rev. A, Kennedy Space Center, FL, January 21, 2000.

5. McIntosh, D.: “First Materials Science Research Rack (MSRR–1) Fire Suppressant Distribution Test Procedure,” *MTCP–QS–MSRR1–300*, Marshall Space Flight Center, AL, February 5, 2001.

6. Downs, W.: “MSRR–1 IPL Rack Venting Analysis with Rack Pressurization from a PFE,” Sverdrup Report to Marshall Space Flight Center, 2001.

7. Gard, M.Y.: “*International Space Station,* Space Station Furnace Facility Rack Fire Suppression Test Report,” unnumbered report, Marshall Space Flight Center, AL, May 1997.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 2002	Technical Memorandum

4. TITLE AND SUBTITLE

Materials Science Research Rack–1 Fire Suppressant Distribution Test Report

5. FUNDING NUMBERS

6. AUTHORS

P.O. Wieland

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)

George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

8. PERFORMING ORGANIZATION REPORT NUMBER

M–1038

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA/TM—2002–211465

11. SUPPLEMENTARY NOTES

Prepared by the Flight Projects Directorate

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified-Unlimited
Subject Category 54
Nonstandard Distribution

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Fire suppressant distribution testing was performed on the Materials Science Research Rack–1 (MSRR–1), a furnace facility payload that will be installed in the U.S. Lab module of the *International Space Station*. Unlike racks that were tested previously, the MSRR–1 uses the Active Rack Isolation System (ARIS) to reduce vibration on experiments, so the effects of ARIS on fire suppressant distribution were unknown. Two tests were performed to map the distribution of CO_2 fire suppressant throughout a mockup of the MSRR–1 designed to have the same component volumes and flowpath restrictions as the flight rack. For the first test, the average maximum CO_2 concentration for the rack was 60 percent, achieved within 45 s of discharge initiation, meeting the requirement to reach 50 percent throughout the rack within 1 min. For the second test, one of the experiment mockups was removed to provide a worst-case configuration, and the average maximum CO_2 concentration for the rack was 58 percent. Comparing the results of this testing with results from previous testing leads to several general conclusions that can be used to evaluate future racks. The MSRR–1 will meet the requirements for fire suppressant distribution. Primary factors that affect the ability to meet the CO_2 distribution requirements are the free air volume in the rack and the total area and distribution of openings in the rack shell. The length of the suppressant flowpath and degree of tortuousness has little correlation with CO_2 concentration. The total area of holes in the rack shell could be significantly increased. The free air volume could be significantly increased. To ensure the highest maximum CO_2 concentration, the PFE nozzle should be inserted to the stop on the nozzle.

14. SUBJECT TERMS

MSRR, Materials Science Research Rack, FDS, *ISS*, payload, furnace facility, fire protection

15. NUMBER OF PAGES

44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102