International Space Station Ammonia Respirator Kit

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An ammonia release onboard the International Space Station (ISS) could be detrimental to the health and safety of the crew depending on the magnitude of the release. Therefore, crew health and safety must be first and foremost in any scenario to mitigate an ammonia release.

Introduction of ammonia into the cabin atmosphere can occur via the interface heat exchangers (IFHXs) between the external and internal thermal control systems and from the crew. Breach of the water/ammonia barrier of the IFHX can occur through any one of three mechanisms: (1) water freezing in the IFHX core; (2) internal structure failure of the IFHX; or (3) over-pressurization of the IFHX. Water freezing in the IFHX core can happen if ammonia temperatures fall below 32°F or if the internal thermal control system water and the external active thermal control system ammonia become stagnant and the IFHX fails to heat properly (either through a failure of the IFHX heaters or an incorrect ISS attitude). Three levels of redundancy in the ammonia temperature control and operational safeguards exist to minimize this mechanism of IFHX failure. By selection of proper materials, manufacturing process, and testing procedures, materials with adequate strength, stress corrosion characteristics, and compatibilities have been chosen, thus minimizing the probability of an internal structure failure. By employing relief valves, bleed lines, and proper operational procedures, the risk of over-pressurization of the IFHX to the point of failure is also minimized.

Nevertheless, an increase or enhancement of the effective duration of personal protective equipment (PPE) for the crew gives the crew an advantage of being able to remain on the ISS in unaffected modules in the event of a leak. The PPE needs to cover the mouth, nose, and eyes, provide breathing air or filtered cabin air, and allow for the release of exhaled breath into the cabin atmosphere. A full-face mask using interchangeable cartridges was a desirable choice to implement; however, difficulties arose with a simple implementation of a commercial off-the-shelf (COTS) device. The full-face mask is certified by 3M for a maximum ammonia concentration of 300 parts per million (ppm) (National Institute for Occupational Safety and Health [NIOSH] Immediately Dangerous to Life or Health [IDLHs] air concentration values). The IDLHs used by the NIOSH are values established to ensure that the worker can escape from a given contaminated environment in the event of failure of the respiratory protection equipment.

Due to the amount of ammonia on the ISS, the need for protection to higher levels is necessary. Additionally, the crew could not guarantee facial hair and eyeglasses would not interfere with the integrity of the face seal of the mask. A second design of mask was reviewed to eliminate those issues. The second mask reviewed was a chemical/biological-resistant hood with a fixed filter manufactured by Survivair and used by the Supreme Court and the military. Disadvantages of this hood in applications to the event were the inability to change

ISS ammonia respirator and COTS units used.

ISS ammonia respirator during on-orbit training.

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continued

Summary of Results for Tests at 16.0 LPM per Cartridge

Concentration (ppm)		Time to Specified Concentration (min)						
Target	Actual	2.0 ppm	5.0 ppm	8.0 ppm	12.2 ppm	13.0 ppm	15.0 ppm	20.0 ppm
200	194	**1053.1**	1102.8	1128.5	1150.5	1152.4	1161.9	1178.6
500	548	351.3	**367.6**	376.0	383.6	384.8	387.7	393.2
800	798	243.5	252.9	**258.0**	262.7	263.5	265.5	269.3
1220	1223	166.1	172.2	175.6	**178.8**	179.3	180.2	182.4
1300	1302	151.2	157.3	160.9	163.7	**164.3**	165.3	167.7
1500	1507	122.9	127.8	130.5	133.1	133.4	**134.3**	136.2
2000	1991	96.0	99.5	101.6	103.3	103.6	104.3	**105.6**

Summary of Results for Tests at 22.5 LPM per Cartridge

Concentration (ppm)		Time to Specified Concentration (min)						
Target	Actual	2.0 ppm	5.0 ppm	8.0 ppm	12.2 ppm	13.0 ppm	15.0 ppm	20.0 ppm
200	225	**577.5**	610.6	627.6	643.7	646.5	652.9	665.2
500	526	218.1	**230.3**	237.0	243.6	244.8	247.0	251.9
800	799	155.6	163.1	**167.0**	170.8	171.5	172.5	175.1
1220	1218	104.2	109.2	111.7	**114.1**	114.5	115.4	117.2
1300	1306	94.4	99.0	101.5	103.8	**104.2**	105.2	106.9
1500	1501	88.4	92.3	94.4	96.5	96.9	**97.6**	99.1
2000	2040	60.3	63.0	64.6	66.0	66.1	66.7	**67.7**

1% breakthrough shown in bold

Cartridge testing results.

cartridges for extended use and the inability of the nose cone to purge. The hood portion presented a desirable choice for a sealing factor regardless of facial hair or need for eyeglasses.

A hybrid of the full-face 3M masks,with hood, was proposed to create an ammonia respirator with user-interchangeable cartridges. This hood is fabricated from Zytron 300, spun-bonded polyester fiber with a proprietary coating and a silicone rubber neck ring. The hood seals around the neck, providing protection to the entire head with little to no effect on the communicating abilities of the wearer. 3M ammonia cartridges packed with carbon-treated zinc chloride as the active scrubbing medium and a particulate filter can be changed out, as needed. The hooded, full-face ammonia respirator and several ammonia scrubbing cartridge pairs were assembled into an ISS ammonia respirator kit. Additionally, Fresnel lenses, which can be applied to the exterior of the mask, are included in the kit for any crew member needing visual correction. The lenses adhere to the face shield via static cling. Two diopters, which cover the range of all crew members' needs, are included in the kit.

The ammonia respirator is designed to protect the crew for 8 hours in an ammonia environment where ammonia concentration is linearly decreasing from 1,200 ppm to 30 ppm. The respirator scrubs ammonia to an internal concentration of no greater than 20 ppm throughout the duration. The kit contains six pairs of cartridges that can be changed out. The kit has a shelf lifetime of 5 years due to the neck dam that can become brittle over time. The cartridges also have a lifetime of 5 years due to the aging of the active ingredient needed to scrub ammonia from the environment.

When tested in the Johnson Space Center respirator test facility, the ammonia respirator set a fit factor record. A fit factor is the ratio of the test agent concentration outside the respirator to the test agent concentration inside the respirator. The previous fit factor record was 35,000, and the ammonia respirator set a new fit factor record of 55,000. Current requirement is a fit factor of 60. Note that fit factors will vary by wearer. Use of the cartridges in an environment with an ammonia concentration higher than industry necessitated extra testing to ensure the ammonia removal capacity was known at the higher concentrations. Cartridges were tested by an independent third party at 16 and 22.5 liters per minute (LPM) flow rates with concentrations of 200, 500, 800, 1,220, 1,300, 1,500, and 2,000 ppm ammonia. Humidity and temperature were controlled. At 1,220 ppm and a breathing rate of 16 LPM, 96 minutes were required before a 2-ppm breakthrough of ammonia occurred; 106 minutes were required before a 20-ppm breakthrough of ammonia occurred. Vibration testing was also conducted on the cartridges since the various launch vehicles would again be exposing them to environments not typically seen on the ground. The cartridges had no degraded performance after being exposed to the range of vibration environments that various launch vehicles experience.

In an off-nominal situation, extended periods of time on PPE can be expected. Scrubbing calculations have shown that the time required for ammonia concentration to be decreased on the ISS with a crew of three from 10,000 ppm to less than 100 ppm (upper concentration limit at which PPE is optional) is approximately 17 hours. The ammonia respirators provide a commodity typically lacking in an off-nominal situation, time. Through implementation of the ammonia respirators coupled with proper rules and procedures, the inherent dangers of an ammonia release can be managed.