Environmental Controls and Life Support System (ECLSS) Design for a Multi-Mission Space Exploration Vehicle (MMSEV)

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Engineers at Johnson Space Center (JSC) are developing an Environmental Control and Life Support System (ECLSS) design for the Multi-Mission Space Exploration Vehicle (MMSEV). The purpose of the MMSEV is to extend the human exploration envelope for Lunar, Near Earth Object (NEO), or Deep Space missions by using pressurized exploration vehicles. The MMSEV, formerly known as the Space Exploration Vehicle (SEV), employs ground prototype hardware for various systems and tests it in manned and unmanned configurations. Eventually, the system hardware will evolve and become part of a flight vehicle capable of supporting different design reference missions. This paper will discuss the latest MMSEV ECLSS architectures developed for a variety of design reference missions, any work contributed toward the development of the ECLSS design, lessons learned from testing prototype hardware, and the plan to advance the ECLSS toward a flight design.

Nomenclature

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I. Introduction

The MMSEV is a pressurized vehicle to be used for microgravity, planetary or moon based exploration. The MMSEV project produces ground test vehicles which will evolve the vehicle systems toward a flight design. Initially, a rudimentary fluid schematic was developed during the Constellation Lunar Surface Systems Program for a surface rover's flight ECLSS. This schematic was implemented and improved upon for use as the basis for the Lunar Electric Rover (LER), later named the SEV. After an additional review of potential missions the name was replaced with MMSEV. The new name meant the vehicle could support micro gravity, planetary, and lunar missions. Changes were made to the schematic which resulted from integration discussions with other systems which ECLSS supports. This schematic can be seen in Fig 1. (Bagdigian) The latest work has concentrated the design of the Pressure Control System (PCS), Air Revitalization System (ARS), and the cabin ventilation system. In addition, work has continued on the cascade analysis to optimize oxygen consumables and tanks mass for high pressure oxygen use, and on the development of ground prototype, ECLSS hardware for the next generation vehicle called GEN II B.

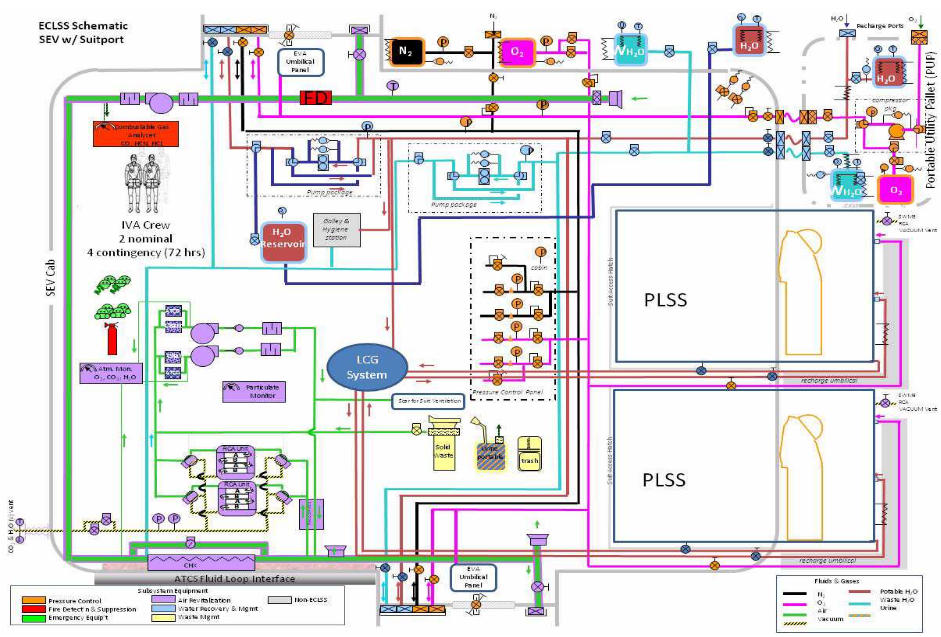

Figure 1: SEV ECLSS Schematic[1]

II. Mission and System Description

The MMSEV ECLSS consumables and hardware support a crew of 2 nominally for 7 days and a crew of 4 off nominally for 72 hours. Contingencies considered during these iterative design cycles are feed the leak and depress/repress cycle of the cabin atmosphere in case of fire, and a rescue of 2 crew with a 72 hour duration to the base/lander. The schematic in Fig 1 highlights four systems essential for life support, the ARS, the PCS, the Potable Water System (PWS) and the Waste Control System (WCS). The ARS provides cabin air circulation and thermal control, trace contaminant control, carbon dioxide scrubbing, recuperates moisture and atmospheric monitoring. The PCS regulates the cabin total pressure and constituent partial pressures. The PWS dispenses both hot and cool potable water for drink and meal preparations and hygiene. This system also provides storage for hygiene and condensate waste water. The WCS collects and stores human metabolic waste and food and packaging waste.

III. Research, Trades and Analysis

A. PCS Gas Introduction Valve Sizing

A model of the PCS was developed to size the nitrogen and oxygen introduction valve needed for the design. EASY 5 modeling software was used to develop the model. Modules were built to represent the cabin, crew, EVA, and the nitrogen and oxygen cabin introduction valves. A bang-bang control scheme was for gas introduction into the vehicle. The control scheme looks at the partial pressure of O2 primarily and total pressure secondarily. The model was run for three cases, nominal 24 hour operations, full repressurization, and feed the leak. The nominal total pressure in the cabin is 8.2 psi and the oxygen concentration is 34%. Issues with the model were encountered during the process. The model was simplified and work continued to run the new model for the three cases. A future publication will report the results with the new model. Reference: T. Hanford MMSEV PCS Analysis Presentation Nov 2012.

B. ARS Design and RCA Sizing for CO_2 and Humidity Control

One aspect of designing the MMSEV ECLSS involved the design and sizing of the ARS. This process involved several design aspects including determining the number of RCA units required to support various crew activities and designing a system that could control cabin humidity without the use of a condensing heat exchanger. Although the entirety of the study involved a large trade space, the important parameters can be summarized as follows:

1. Number of crew members
2. Support of exercise
3. Fan and RCA operational settings
4. Presence of a condensing heat exchanger

Since the ARS design must support a variety of crew activity levels and operating situations, a dynamic simulation tool, developed using the Aspen Custom Modeler chemical process simulation package, was used to simulate operation over a 24-hour day. Fig 2 shows an example of the simulation tool.

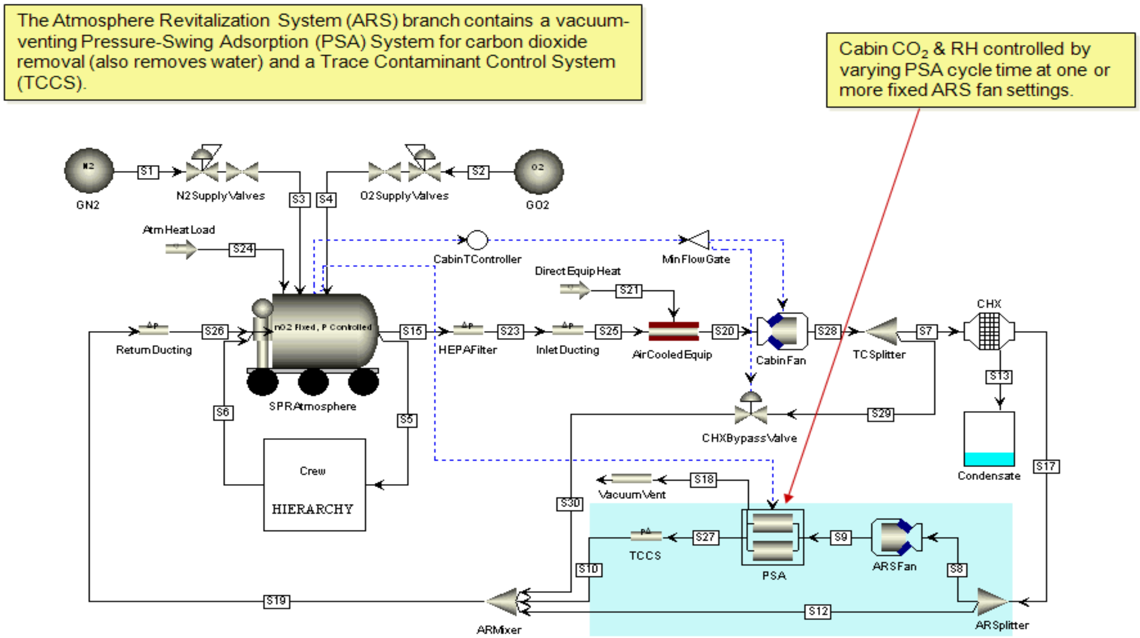

Fig 2. Aspen Custom Modeler flowsheet representation of Air Revitalization System Loop for design and sizing study.

The flowsheet was developed from models of the major components within a typical ARS loop architecture including: fans, heat exchangers (condensing or non-condensing depending on the desired case), control valves, the TCCS (for pressure drop considerations), the RCA units (represented by 'PSA'), and the cabin volume (represented by 'SPRAtmosphere'), and various duct and filter elements to represent sources of pressure drop. The RCA is modeled using empirical correlations for CO_2 and H_2O removal efficiencies based on test data. The crew members are modeled within the 'Hierarchy Block' based on correlations for water and CO_2 production, oxygen consumption and energy balances for generation of heat. The exercise profiles were developed based on recommendations in the current HSIR document (1). Instructions with the models of the crew members specify metabolic events like exercise, nominal activity or sleep. The net effects of crew activity, contributions from powered equipment (heat) and the RCA system (CO_2 and humidity control) manifest themselves within the cabin conditions (temperature and atmospheric composition) and are tracked within the cabin volume model over the 24-hour simulated day. Details of Aspen Custom Modeler and how it is used for simulating spacecraft hardware and systems can be found elsewhere (2, 3).

Table 1. Summary of Cases

Case	**Vehicle**	**Cabin Pressure (psi)**	**Cabin Volume (ft^3)**	**No of Crew**	**Exercise**	**CHX**
1	MMSEV/MPCV	10.2	550	2	Yes	No
2	MMSEV/MPCV	10.2	550	2	Yes	Yes
3	MMSEV/MPCV	8.0	550	2	Yes	No
4	MMSEV/MPCV	8.0	550	2	Yes	Yes

5	MMSEV/MPCV	10.2	550	3	Yes	No
6	MMSEV/MPCV	10.2	550	3	Yes	Yes
7	MMSEV/MPCV	8.0	550	3	Yes	No
8	MMSEV/MPCV	8.0	550	3	No	No
9	MMSEV/MPCV	8.0	550	3	No	Yes
10	MMSEV/MPCV	8.0	550	3	Yes	No
11	MMSEV/MPCV	8.0	550	3	Yes	Yes
12	MMSEV/MPCV	8.0	550	3	Yes	No
13	MMSEV/MPCV	8.0	550	3	Yes	Yes
14	MMSEV/MPCV	8.0	550	2	Yes	No
15	MMSEV/MPCV	8.0	550	2	Yes	Yes
16	MMSEV/MPCV	8.0	550	4	Yes	No
17	MMSEV/MPCV	8.0	550	4	Yes	Yes
18	MMSEV/MPCV	10.2	550	2	No	No
19	MMSEV/MPCV	10.2	550	2	No	Yes
20	MMSEV/MPCV	10.2	550	2	Yes	No
21	MMSEV/MPCV	10.2	550	2	Yes	Yes
22	MMSEV/MPCV	10.2	550	2	Yes	No
23	MMSEV/MPCV	10.2	550	2	Yes	Yes
24	MMSEV/MPCV	10.2	550	3	No	No
25	MMSEV/MPCV	10.2	550	3	No	Yes
26	MMSEV/MPCV	10.2	550	3	Yes	No
27	MMSEV/MPCV	10.2	550	3	Yes	Yes
28	MMSEV/MPCV	10.2	550	3	Yes	No
29	MMSEV/MPCV	10.2	550	3	Yes	Yes
30	MMSEV/MPCV	10.2	550	4	No	No

31	MMSEV/MPCV	10.2	550	4	No	Yes
32	MMSEV/MPCV	10.2	550	4	Yes	No
33	MMSEV/MPCV	10.2	550	4	Yes	Yes
34	MMSEV/MPCV	10.2	550	4	Yes	No
35	MMSEV/MPCV	10.2	550	4	Yes	Yes

The parametric study focused on determining the optimum RCA sizing (number of RCA units) and operating conditions to support various levels of crew activity. Table 1 offers a list of the cases examined. The parameters were varied by adjusting settings within models in the flowsheet. Exercise parameters were varies by commands within the crewmember model, while heat exchanger operation was varied (between condensing and non-condensing), by changing the coolant temperature. Cabin conditions, resulting from the exercise and ARS operating and sizing parameters, were tracked. The object was to maintain a cabin $ppCO_2$ below 5 mmHg, and maintain the cabin %RH between 25 and 75%. When the non-condensing heat exchanger was specified, condensation was tracked by the simulation. Table 2 lists the appropriate ARS parameters to meet the operational requirements.

Table 2. Summary of Results

Case	**No of Crew**	**No of RCA units**	**Exercise**	**CHX**	**Notes**
1	2	2	No	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C
2	2	2	No	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH
3	2	3	Yes	No	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C (73 ml condensate accumulated over 24 hrs)
4	2	2	Yes	Yes	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH; ppCO2 limit is violated twice (during the exercise period) (cumulative 2.5 hours exposure).
5	2	4	Yes	No	Flow rate: 6 CFM/unit. Coolant temp = 18 C (72 ml condensate accumulated over 24 hrs)
6	2	3	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; ppCO2 limit is violated twice (during the 4 hr exercise period) (cumulative 2.25 hours exposure).
7	3	2	No	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C
8	3	2	No	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH
9	3	4	Yes	No	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH; Coolant temp = 17 C (85 ml condensate accumulated over 24 hrs)
10	3	3	Yes	Yes	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH;
11	3	5	Yes	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 17 C (80 ml condensate accumulated over 24 hrs)
12	3	4	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH

13	4	2	No	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 17 C
14	4	2	No	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH
15	4	5	Yes	No	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 16 C (70 ml condensate accumulated over 24 hrs). Cabin temperature reaches 81.2 F during exercise
16	4	4	Yes	Yes	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH
17	4	6	Yes	No	Flow rate: 6 CFM/unit. Coolant temp = 15 C (172 ml condensate accumulated over 24 hrs)
18	4	5	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; Could run with 4 units but you will break the ppCO2 during the exercise period (cumulative 7-8 hrs above 5 mmHg)
19	3	2	No	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH

Table 2 Continued: Summary of Results

20	3	2	No	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH
21	3	4	Yes	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 17 C (90 ml condensate accumulated over 24 hrs) **1/2 hour exercise**
22	3	3	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; ppCO2 limit is violated three times (during the 6 hr exercise period) (cumulative 4 hours exposure). **1/2 hour exercise**
23	3	5	Yes	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 17 C (80 ml condensate accumulated over 24 hrs)
24	3	4	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH
25	2	4	Yes	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C (70 ml condensate accumulated over 24 hrs)
26	2	3	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH;
27	4	6	Yes	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 15 C (170 ml condensate accumulated over 24 hrs)
28	4	4	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; ppCO2 limit is violated 4 times (during the 8 hr exercise period) (cumulative 6 hours exposure). 5 units will put you well below the limit
29	2	2	No	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C
30	2	2	No	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH
31	2	3	Yes	No	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C (73 ml condensate accumulated over 24 hrs)
32	2	2	Yes	Yes	**1/2 hour exercise.** Flow rate: 6 CFM/unit. Control by ppCO2 and RH; ppCO2 limit is violated twice (during the exercise period) (cumulative 2.5 hours exposure).
33	2	4	Yes	No	Flow rate: 6 CFM/unit. Coolant temp = 18 C (72 ml condensate accumulated over 24 hrs)
34	2	3	Yes	Yes	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; ppCO2 limit is violated twice (during the 4 hr exercise period) (cumulative 2.25 hours exposure).
35	3	2	No	No	Flow rate: 6 CFM/unit. Control by ppCO2 and RH; coolant temp = 18 C

In general, lower flowrates (5.2 CFM) of air through the ARS were used during non-exercise scenarios while higher flowrates (6.0 CFM) were required to control CO_2 and humidity during exercise periods. In most cases it was necessary to use cabin $ppCO_2$ and cabin %RH as triggers for cycling the PSA units, so the unit would cycle when either variable reached a specified control limit. For example, the PSA would cycle when the cabin $ppCO_2$ reached 3 mmHg, in order to provide margin to keep the cabin ppCO2 below 5 mmHg. The study also looked at 30 minute vs. 60 minute exercise periods and the half-hour exercise cases are noted in the results table. In the cases without CHX, the results note when small amounts of condensation were observed, and the total condensate (over a 24-hour period) was recorded. Small amounts of condensate formation were tolerated in order to avoid the mass penalty stemming from another RCA unit. Coolant temperature was also noted in some cases where condensation was not allowed. Short periods of high CO_2 levels were recorded in the results and these violations were tolerated per the limits set by the HSIR documentation (1).

In addition to determining ARS sizing parameters, the model was used to develop relationships between the coolant temperature limits and the cabin temperature. The results showed the highest coolant temperature required to maintain a reasonable cabin temperature during exercise (~80F). The data are shown in figure 2.

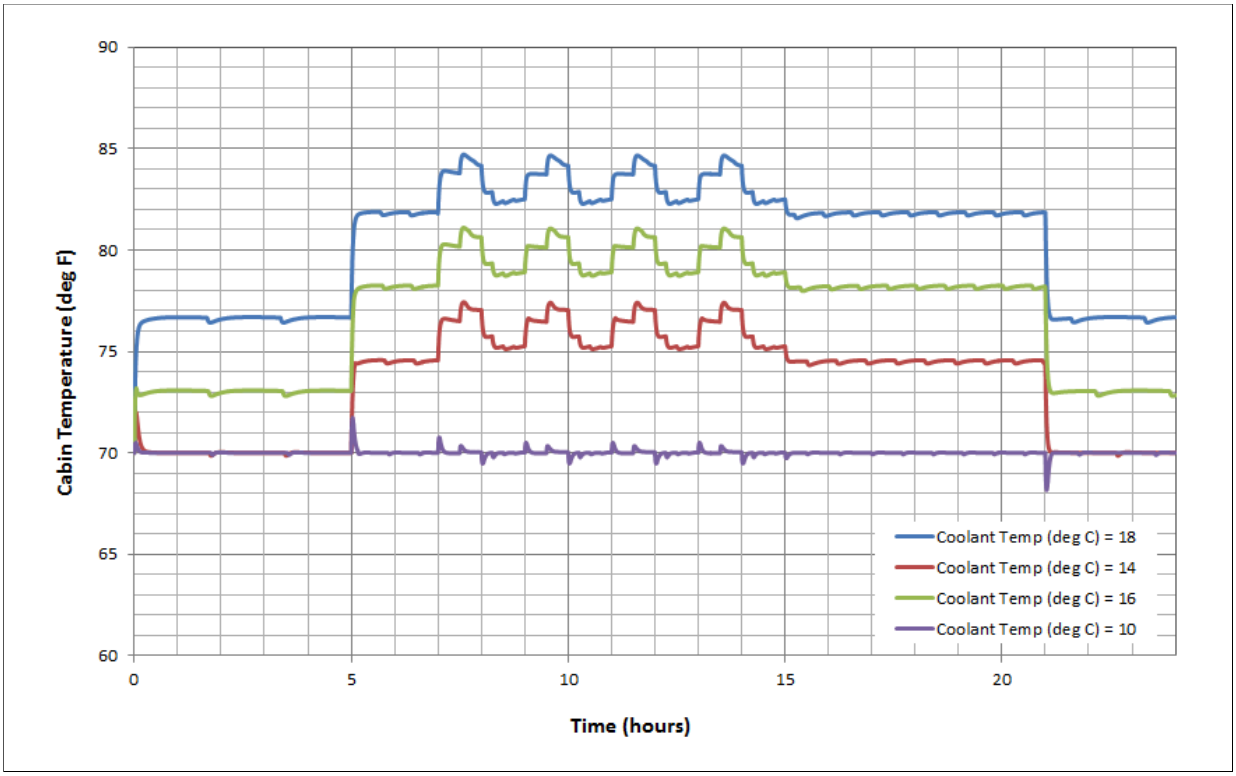

Fig 2. Cabin temperature as a function of heat exchanger coolant temperature.

The heat exchanger operation becomes critical during exercise period since the crew produce significant amounts of heat during exercise. Thus the coolant temperature needs to be low enough to remove heat while not condensing the moisture generated during exercise. The HSIR guideline was used to determine the maximum allowable cabin temperature during the case.

References

1. HSIR document

2. Aspen Technology Inc

3. Allada

C. Cascade Analysis

1. Introduction

An analysis was conducted to trade a high pressure oxygen cascade storage and delivery system with the use of a single tank pressurization system and a dual tank pressurization system with a compressor. The mass, power and volume trade would determine if the cascade system could accommodate the crew during long duration Intra Vehicular Activity (IVA) and be capable of multiple high pressure oxygen fills to the Portable Life Support System (PLSS) worn by the crew during EVAs as compared to the single tank and dual tank/compressor systems. A cascade is a series of high pressure gas cylinders used for the refilling of smaller compressed gas cylinders in the PLSS by equalization of pressure. Each of the high pressure cylinders are filled by a compressor on the ground prior to launch In addition, the cascade system is useful as a "reservoir" to accommodate low pressure needs.

2. Model Development

As part of this analysis, a regression model was developed to provide the mechanism to size the cascade systems subject to constraints such as number of crew, extravehicular activity time and occurrence, and ullage gas requirements under contingency scenarios. The sizing routine employed a numerical integration scheme to determine gas compressibility changes during depressurization and compressibility effects were captured using the Soave-Redlich-Kwong (SRK) equation of state. A multi-dimensional nonlinear optimization routine was used to find the minimum cascade tank system mass that meets the mission requirements. The sizing algorithms developed in this analysis provide a powerful framework to assess cascade filling, compressor, and hybrid systems to design long duration vehicle air systems.

3. *Results*

Reference:

- Evan info…
- Thermal and Environmental Analyst, Energy Systems, 505 King Avenue, Columbus, OH, AIAA Member.
- Imelda and others info…

D. CFD Analysis

1. Introduction

A cabin ventilation model of the MMSEV is being developed using ANSYS/FLUENT ,a Computational Fluid Dynamics (CFD) code. The purpose of this study is to characterize flow behavior in the cabin and its impact on NASA requirements related to specified free stream velocities and species concentrations, such as CO2 levels within the cabin.

2. Model Development

A Computer Aided Design (CAD) model of the MMSEV vehicle was provided by Johnson Space Center's ER Division to Jacobs Technology under the Engineering Support Contract (ESCG). The CAD model was imported into ANSYS Workbench, where the geometry of the interior cabin volume was defined. The cabin geometry included inlet vents for ventilation supply air, a single return outlet, and a simplified geometry (small speheres) representling the source the crew production of CO2 due to breathing for three crewmembers. Additionally selected inlet vents in the vehicle were subdivided into separate surfaces to allow the inlet flow to be directed in multiple directions in the cabin. The geometry of the cabin volume was then meshed with an unstructured grid using tetrahedral elements. The mesh was then imported into FLUENT, where appropriate physical models such as turbulence models were specified, and boundary conditions for the supply air inlets and the crew production of CO2 were established.

3. FLUENT Simulation Results

Two cases have been simulated. In the baseline case, the flow from the inlet vents, which are located in the center of the cabin, is directed downward toward the floor. In the second case the flow has been directed both toward the floor, and also toward the front, sides, and back of the cabin. Results for each case were compared to NASA requirements for percent volume of velocities within a specified range. Methods for evaluating CO2 distribution within the cabin are still being considered.

IV. Hardware Development for GEN II B

A. Potable Water System (PWS)

1. Introduction

Since the MMSEV will be making excursions for days and even weeks at a time, it needs to be able to provide the crew with potable water. This water has two functions: to provide drinking water and to provide heated water to rehydrate the food packets. Multiple secondary capabilities of this critical system were also deemed necessary and will be discussed in detail.

2. Coiled Heater

A MMSEV is a power limited vehicle. Utilizing the power in an efficient way is of great necessity. From past vehicle designs it has been shown that the heating of the water consumes the most power out of any other subsystem. For that reason an efficient way of heating the water was desired.

There are a number of ways to heat water. Some of these include: immersion heaters, gas heaters, and electric heaters. For obvious reasons gas heaters are not plausible in a space vehicle. Immersion heaters, although good at quickly heating water, cannot be used in space either because of bacteria growth concerns. Bacteria can grow on any surface and therefore it is good practice to minimize the amount of surface area touched by the potable water. Using immersion heater adds unwanted surface area to the internal water lines. Electric heaters are the best choice when it comes to heating surfaces in space vehicles. They have been used since the beginning of the space age because they are lightweight and easy to implement and control.

The design of the tank is the next critical part in making the heater system more efficient. In past designs a 3" diameter cylindrical tank was wrapped in Kapton heater strips. This design was successfully implemented but consumed too much power to be viable for an actual space vehicle. The team looked at the water dispenser currently used on the ISS as an example. Their design ¾" tubing coiled around in a helix. By minimizing the tube diameter, the water can be heater more uniformly and efficiently. It was decided that a similar design should be used for the MMSEV.

The tubing was coiled in a manner to fit to the allocated volume and wrapped in Kapton heater strips. To control the heating elements and the water temperature clip-on thermostats were used. To provide redundancy in the system, multiple different circuits of heater strips and thermostats were used. In case a heater strip or thermostat were to fail, there would still be multiple other heating circuits available to do the job. The time to heat the water to its desired temperature would increase, but the capability would still exist.

3. Chiller System

There has never been a water dispenser on a spacecraft that actively cooled water for the crew to drink. Cold water in spaceflight has always been looked at as an extra comfort and not required for crew survival. Saving volume, weight, and power outweighed giving crew a cool drink of water. But as future missions substantially increase in duration from missions of the past, the option of providing cold water to the crew has been reprised. Many astronauts who have visited the ISS have provided commentary that cold water would be greatly appreciated.

4. Filter Cartridge

The water that the crew drinks must be as clean as possible. This minimizes the risk of them getting sick in space. One way to accomplish this is biocide. (more info on biocides)

Additionally a filter is used to remove any impurities in the water supply. Best practice is to place this filter as close to the point of dispense as possible.

These filters have an operational requirement that water flow thru the filter at least once every 48 hours. If water remains stagnant in the filter for longer than that period of time, bacteria can grow and the filter would be useless. The solution to this problem is discussed in the next section. Furthermore, the filters only have a lifetime of 6 months. These two facts make it clear that this filter needs to be removable in space. Having this ability allows the crew to swap out filters whenever necessary. (info on the design of the filter cartridge)

5. Structure

The ability to perform maintenance on the potable water system was deemed critical in a flight vehicle. If there was any issue with the system, you would want the ability for the crew to easily get to the hardware to fix it if possible. For this reason the system was designed so that it could be completely removed in space. In past versions of the water system design, once the system was installed it could not be removed. This showed problematic when issues arose because it was hard to get to many system components.

The design has two different sections that are completely removable. Additionally, if there was a catastrophic issue with the system and in-space maintenance wasn't enough, new components or even a whole new system could be flown to replace the broken one. There is an immense value having a removable system both for ground testing and for flight. This was accomplished by creating to separate entities and attaching guide rails to them. In addition to enabling maintenance, the inclusion of these rails greatly simplifies installation and removal.

6. Telemetry/Commanding

In some of the mission architecture involving an MMSEV, there are periods where the vehicle would be left at a location for an extended period of time. During these quiescent periods it is vital to keep the water system healthy and know if something is not working. For that reason it is vital that an MMSEV PWS have the capability for commanding and telemetry.

Besides the fact that telemetry would allow much desired insight into the system for troubleshooting, commanding is essential to prevent bacterial growth. As previously mentioned, one of the easiest ways to grow bacteria is for the system to remain unused and to have water stagnant in the filter. To prevent this from happening during the quiescent periods, the ground would command the system to run water through a plumbing line that bypasses the dispense point and is closed loop. (The architecture of this 'bypass' line would depend on whether or not the MMSEV has a closed loop ECLSS) The other option to manage this issue is to have an intelligent system. Having a computer that monitors how long it has been since sense this situation on its own

B. Waste Collection System

1. General Functional Description

The WCS is a designated volume for the collection and stowage of human metabolic waste in the SEV. The WCS is located at the aft end of the vehicle aisle way as shown in **Fig. x**. The space allocated for the WCS increased from 21"L x 22.8"W x 15.9"H in the 2A vehicle to 21.5"L x 22.8"W x 22"H in the MMSEV 2B.
The MMSEV WCS collects urine and fecal waste separately within the system. WAG bags are used to collect and dispose of fecal waste. Urine is collected and stored in a 4 gallon urine tank via a urinal funnel and hose. The tank is holds approximately 3 days of urine for a crew of 2. Both the wag bags and the urine tank contain Poo Powder® to alleviate odors and solidify liquids.

2. Design changes implemented after the MMSEV 2A testing

There were many crew comments that provided beneficial feedback during the MMSEV 2A test in August 2012. These comments helped the design team consider changes to alleviate problems or potential issues with the vehicle. The comments also helped to guide general design improvements for crew comfort and efficiency.

Some crew members commented that they would like the WCS to be deeper for defecation. With a deeper depth allocation, 2B design has allowed the WCS to go below the floor of the vehicle, allowing a deeper deployment of the WAG bag for defecation.

When asked about access to hygiene items while using the WCS, crew members suggested adding a wipes holder just aft of the urine hose assembly, which is an unused space in 2A. The wipes storage box has been added to the 2B design.

A fan is used for odor control in the WCS, pulling air from the toilet seat area, the urine tank, and the solid waste bin. While adequate from an odor perspective, crew members asked for a louder fan for additional camouflage sound.

One of the least favorable aspects of the MMSEV 2A WCS is the waste bin with saloon-style doors that have very strong hinges. Crews see it as an easy pinch point and difficult to operate. The waste bin lid on 2B has been completely redesigned remove the doors altogether, but still allow for airflow through carbon filters in the fore and aft portions of the bin. The size of the waste bin was also an issue on 2A and has been dramatically increased for 2B.

Other issues that were noted by the Crew Accommodations team included the urine hose receptacle and the WCS lid structural soundness. The urine hose receptacle had not originally been designed to accommodate the proper cap, but for 2B will be deep enough for the cap. The lid of the WCS on 2A has experienced some warping, likely due to structural cycling during crew exercise or if crew members were to stand on the lid while entering the suit ports. For the 2B design, supports will be added to the forward corners of the structure under the lid to provide additional strength and better distribute the load.

C. Trash Compartment

1. General Functional Description

The volume allocated for the MMSEV trash compartment changed little from the 2A allocation of 0.036 m^3 (~22 in. x 8 in. x 12.5 in.) and the 2B allocation of xxx m. (22 in. x 9 in. x 14 in.). The trash compartment is used to collect and store wet and dry trash. Wet trash includes such items as food packaging, wet wipes, and drink bottles. Dry trash includes such things as plastic packaging, cardboard, and paper items. The bin is located on the port side of the SEV behind the crewmember's seat (**see Fig. 10**).

2. Design changes implemented after the MMSEV 2A testing

The location of the MMSEV 2A trash in the vehicle was deemed good for meal prep, but substandard when moving about the cabin and inaccessible when a crew member is exercising. Relocating the trash was not considered for the 2B vehicle. The vehicle team is partial to the symmetry of having the same space allocated on each side of the vehicle for the potable water system and the trash directly opposite.
One crew comment stated that the lid of the bin sometimes would get stuck making it difficult to slide the trash drawer into the closed position. The 2B design takes this into consideration, adding a latch to secure each lid in place for ease of use.

V. Conclusion

Trade studies, analyses, and prototype designs have been accomplished between 2011 and 2012 to aid with the development of the ECLSS design and evolve it toward a final flight design. The PCS Valve Sizing Analysis model development continues. Simplification of the model was needed to get efficient model runs. Case runs will be completed and reported in a future paper. The ARS d**esign and RCA sizing for CO_2 and humidity control analysis conclusion is still needed.** The cascade analysis compared a cascade system, conventional high pressure/low pressure tank system, and dual tank compressor system. The Cascade system traded well for missions less than 14 days but for a 28 day mission duration, a dual tank/compressor system traded slightly better. ECLSS hardware was designed for the GEN IIB version of the MMSEV. The work started on the MMSEV CFD model will be aid in the development of the vehicle ventilation design by studying the flow behavior and potential for localization of CO2 in the cabin. Results from the model show [TBD]. The PWS, WCS, and Trash designs will be completed in FY 13 with manufacturing of this designs in FY14 for a future DRATS test. These prototypes will evolve the systems with the end goal of developing the flight design.

V. Forward Work

Several system upgrades are still being considered for future years work. This includes continued work on CFD analysis, air monitor, PCS breadboard test, changes to the PWS, and upgrades to WCS.

V. References

1.
2.
3.
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VI. Acknowledgments