Title of Research: Design of Test Support Equipment for Advanced Space Suits
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Research Focus

As a member of the Space Suit Assembly Development Engineering Team, I designed and built test equipment systems to support the development of the next generation of advanced space suits. During space suit testing it is critical to supply the subject with two functions: (1) cooling to remove metabolic heat, and (2) breathing air to pressurize the space suit.

The objective of my first project was to design, build, and certify an improved Space Suit Cooling System for manned testing in a 1-G environment. This design had to be portable and supply a minimum cooling rate of 2500 BTU/hr. It needed to supply cooling water at a variable temperature and flowrate. My next project was to design and build a Breathing Air System that was capable of supply facility air to subjects wearing the Z-2 space suit. The system needed to intake 150 PSIG air and regulate it to two operating pressures. It also had to provide structural capabilities at 1.5x operating pressure.

Research Methods

Both projects followed a similar design methodology. The first task was to perform research on existing concepts to develop a sufficient background knowledge. Then mathematical models were developed to size components and simulate system performance. Next, mechanical and electrical schematics were generated and presented at Design Reviews. After the systems were approved by the suit team, all the hardware components were specified and procured. The systems were then packaged, fabricated, and thoroughly tested. The next step was to certify the equipment for manned used, which included generating a Hazard Analysis and giving a presentation to the Test Readiness Review Board.

Results

The Space Suit Cooling System is a robust, portable system that supports very high metabolic rates. It has a highly adjustable cool rate and is equipped with digital instrumentation to monitor the flowrate and critical temperatures. It can supply a variable water temperature down to 34°F, and it can generate a maximum water flowrate of 2.5 LPM.
The Breathing Air System is capable of supplying air at both 4.3 and 8.3 PSIG operations. It has instrumentation to monitor flowrate, as well as inlet and outlet pressures. The system has a series of relief valves to fully protect itself in case of regulator failure.

**Main Conclusions**

Both of these test support systems will perform critical roles in the development of next-generation space suits. They will be used on a regular basis to test the NASA’s new Z-2 Space Suit. The Space Suit Cooling System is now the primary cooling system for all advanced suit tests.

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**Abstract (400 words)**

As a member of the Space Suit Assembly Development Engineering Team, I designed and built test equipment systems to support the development of the next generation of advanced space suits. During space suit testing it is critical to supply the subject with two functions: (1) cooling to remove metabolic heat, and (2) breathing air to pressurize the space suit.

The objective of my first project was to design, build, and certify an improved Space Suit Cooling System for manned testing in a 1-G environment. This design had to be portable and supply a minimum cooling rate of 2500 BTU/hr. The Space Suit Cooling System is a robust, portable system that supports very high metabolic rates. It has a highly adjustable cool rate and is equipped with digital instrumentation to monitor the flowrate and critical temperatures. It can supply a variable water temperature down to 34°F, and it can generate a maximum water flowrate of 2.5 LPM.

My next project was to design and build a Breathing Air System that was capable of supply facility air to subjects wearing the Z-2 space suit. The system intakes 150 PSIG breathing air and regulates it to two operating pressures: 4.3 and 8.3 PSIG. It can also provide structural capabilities at 1.5x operating pressure: 6.6 and 13.2 PSIG, respectively. It has instrumentation to monitor flowrate, as well as inlet and outlet pressures. The system has a series of relief valves to fully protect itself in case of regulator failure.

Both projects followed a similar design methodology. The first task was to perform research on existing concepts to develop a sufficient background knowledge. Then mathematical models were developed to size components and simulate system performance. Next, mechanical and electrical schematics were generated and presented at Design Reviews. After the systems were approved by the suit team, all the hardware components were specified and procured. The systems were then packaged, fabricated, and
thoroughly tested. The next step was to certify the equipment for manned use, which included generating a Hazard Analysis and giving a presentation to the Test Readiness Review Board.

Both of these test support systems will perform critical roles in the development of next-generation space suits. They will used on a regular basis to test the NASA’s new Z-2 Space Suit. The Space Suit Cooling System is now the primary cooling system for all advanced suit tests.
**Team Role**

Design and build space suit test equipment to support the development of the next generation of advanced space suits.

**Personal Responsibilities:**
- Design, build, and certify a space suit cooling system for thermal testing, in a 60°C environment.
- Engage systems to supply breathing air to isolated subjects.
- Conduct automatic and manual testing of equipment in a lab.
- Utilize AutoCAD for design and model-based assessment.
- Specify and procure component hardware.
- Lead professional development
- Design Reviews
- Technical Analyses

**Professional Training**

- Space Vehicle Mechanisms (34 hrs)
  - Science of working knowledge of sliding, mechanical, and high-performance materials used in the space environment.
  - Ice core study and use for simple design manipulation.
  - Learned valuable fixtures that will greatly benefit my future academic and professional endeavors.

- Detailing in Creo Parametric 2.0 (26 hrs)
  - Learned how to easily create detailed drawings using information acquired in the design courses.
  - Learned how to create production drawings suitable for manufacturing.

**Task Objective**

Design and build a functional EMU port that will be used in the development of a new EMU design.

**Design Features:**
- FLX3000 fuel cell mounted to a carbon fiber body.
- Customized cooling system.
- Custom assembly supplies the test article with a combination of water and gas.
- Valved flow loop.
- Coolant is allowed to exit the system and return to the test article.
- Ensure that the system is capable of handling water and gas.
- Ensure that the system is capable of cooling for greater efficiency.

**Technical Schematic:**

**Space Suit Cooling System**

**Disadvantages of the PCBs:**
- No ballast required if water is used as a secondary cooling method.
- Insulation method of cooling.
- Expensive and low-frequency on heat source.
- No flow rate control. Off-the-shelf only.
- Cannot handle water or oil at high MPA.
- No water temperature control.
- Expensive cost of water leads to recycling costs.
- High air conditioning costs and less heat.
- Ordinary control, reducing blood flow.
- Body retains heat and subject can actually overheat.

**Design Features:**
- Adjustable fluid temperature: up to 60°C water. (60°F)
- Adjustable flow rate: up to 4 LPM (24.4 CFM).
- Custom front panel control box.
- Color-scaled flow lines to indicate water level and supply.
- Short circuit protection (SAC)

**Design Overview:**

- Adjustable fluid temperature: up to 60°C water. (60°F)
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**Process Diagram: Instrumentation**

- Water flow controller
- Water flow to cooling water loop
- Water return to flow controller
- Water filter
- Flow controller
- Water flow meter
- Flow meter
- Differential pressure
- Dual water temperature
- Cooling water inlet
- Cooling water outlet

**Design Objective:**

- 500 PSIG, full-automated pump.
- Available computer control.
- Remote control is automated to simulate operational mode.
- Comfort Front End.
- System instrumentation:
  - Analog flow pressure gauge (PSIG)
  - Analog outlet pressure gauge (PSIG)
  - Digital outlet pressure monitor (PDP)
  - Digital flow meter (ACM)
- Using an filter to protect flow meter.

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**Crew and Thermal Systems Division**

**Advanced Space Suit Test Support Equipment**

**Jeffrey A. Watters**

B.S. Mechanical Engineering, University of Wyoming: August 2013

Space Suit Assembly Development Engineering | ECS: Space Suit and Crew Survival Systems Branch