Wednesday, June 11

520-52

Session WP3
Room 3
2:30 - 5:30 p.m.

Technology - 2

MONITORING PHYSIOLOGICAL VARIABLES WITH MEMBRANE PROBES

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INTRODUCTION

Successful long-term ventures of humans into space will require a complete understanding of the effects of microgravity on physiological systems and development of effective countermeasures to the deleterious effects of long-term residence under these conditions. Accomplishing this task will require a significant amount of in vivo research. Some of this can be ground-based simulations but much will have to be done in space. We have developed membrane probes and technologies which will facilitate obtaining and processing samples both in ground-based simulations and in on-board studies. Membrane probes also provide a method of studying physiological changes in different tissues simultaneously and therefore provide more complete physiological information than blood sampling alone.

Microdialysis and ultrafiltration probes employ hollow fibers, which can be implanted in living tissue for sample collection. In microdialysis, an isosmotic perfusion fluid is passed through the fiber. Substances in the tissue, with a smaller size than the molecular weight cut off of the membrane, diffuse across the membrane into the perfusion fluid and are collected. In ultrafiltration, a negative pressure is applied to the fiber and interstitial fluid is passed through the membrane, into the lumen and out of the animal.

In this project, we have validated microdialysis and ultrafiltration probes by in vitro recovery tests for electrolytes sodium, potassium, and chloride and for the metabolites glucose and lactate. The use of these probes in simulated microgravity research was demonstrated in the rodent mode.

METHODS

The ultrafiltration probe consisted of three 12-cm hollow fibers in a loop configuration bonded to a fluid conduction tube. The microdialysis probe consisted of a 5-cm membrane in loop configuration, bonded at each end to a fluid conduction tube. In vitro recovery tests were done by placing probes in a stirred solution of the analyte, which was maintained at 37° C. Samples obtained from the probes were compared with samples of the original solution. The range of concentrations investigated included the physiologically normal as well as pathologically high and low concentrations.

Rats were implanted with subcutaneous microdialysis and ultrafiltration probes and jugular catheters. After collecting baseline samples, the rats were placed in a suspension system with heads down and hind legs elevated to simulate the fluid shifts of microgravity. After one to two weeks in the suspension system, the rats were returned to the normal position for one week. Microdialysis samples were collected every two hours; ultrafiltration samples were collected twice a day. Blood samples were collected daily until catheters failed. Samples were analyzed for sodium, potassium, chloride, glucose, and lactate.

RESULTS

In vitro recoveries for each analyte are listed in table I.

Table I. In Vitro Recoveries

Analyte	Ultrafiltration	Microdialysis
Sodium	101% ± 2%	101% ± 2%
Potassium	94% ± 13%	106% ± 4%
Chloride	96% ± 4%	95% ± 7%
Glucose	99% ± 3%	90% ± 10%
Lactate	94% ± 5%	95% ± 7%

The implanted membrane probes provide a method for continuously monitoring changes in body chemistry. Since no cells are removed there is no limit to the number of samples which can be obtained as there is with blood sampling. Figure 1 illustrates the changes in subcutaneous and plasma sodium concentration during a baseline control period, after suspension and during recovery. Sodium levels are stable during the baseline period. After suspension there is an immediate decline in sodium below baseline followed by an elevation above baseline. When suspension is ended, the concentrations return to baseline values during the recovery period.

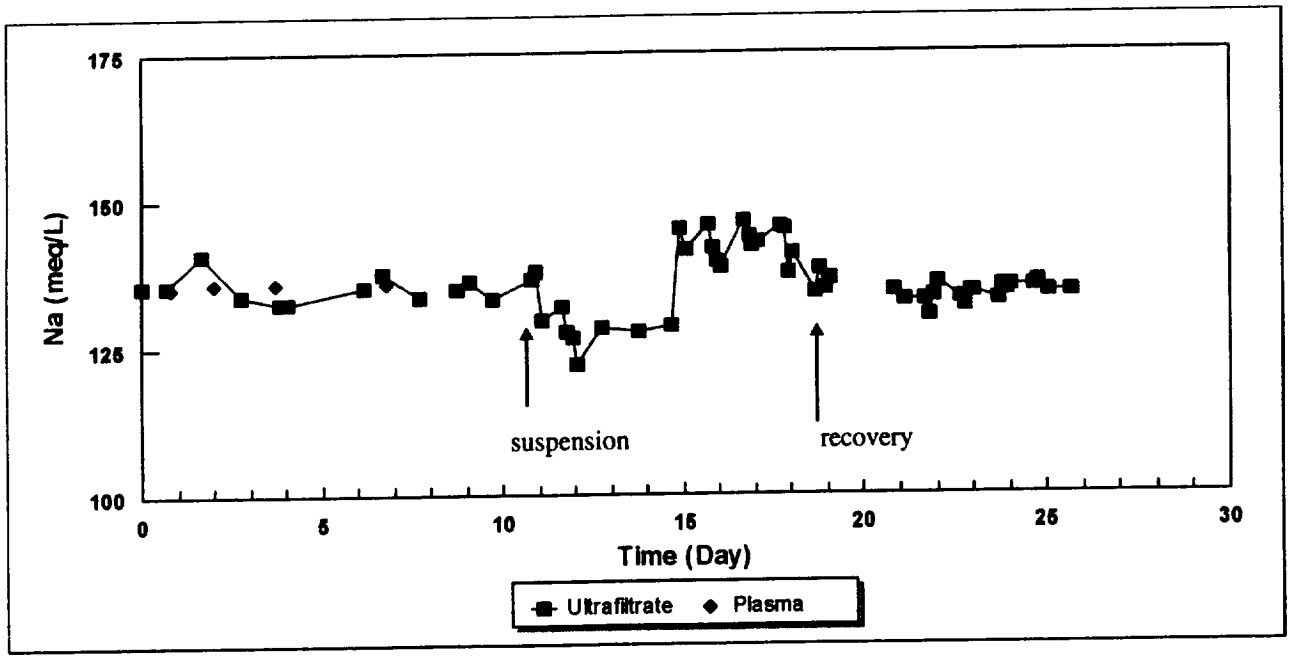

Figure1. Subcutaneous ultrafiltrate and sodium concentrations in the rat during baseline control, head-down suspension, and recovery.

CONCLUSIONS

The in vitro recoveries indicate that the microdialysis and ultrafiltration probes are suitable for use in sampling these analytes.

The in vivo studies have demonstrated the potential of these techniques to obtain physiological data from animal models. These probes have the potential to be coupled with on-line sensors which would make it possible to acquire physiological data from animals in space without astronauts having to collect and store or process samples. This will facilitate the study of the physiological effects of weightlessness and the development of countermeasures.

REAL TIME CONFOCAL LASER SCANNING MICROSCOPY: POTENTIAL APPLICATIONS IN SPACE MEDICINE AND CELL BIOLOGY

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INTRODUCTION

In more recent times technological advances in medicine have tended towards developing non-invasive treatment modalities to replace more conventional invasive surgical procedures. One example of this has been the development of photodynamic therapy for the relatively non-invasive removal of abnormal tissues. This treatment modality involves the systemic administration of a preparation known as a photosensitizer. This material is taken up by abnormal tissues and subsequent irradiation of those tissues using low energy laser radiation results in non-thermal activation of the photosensitizer and resultant cell death at the treated site. In laboratory-based studies on photodynamic therapy (PDT) lasers such as low energy HeNe lasers are used in conjunction with tissue culture systems. One problem associated with this approach is that events occurring in real time at a microscopic level may not be visualized. Here we report on the use of a real-time confocal laser scanning microscope system (CLSM) in conjunction with photosensitized erythrocytes and we discuss its possible applications in space medicine and cell biology.

METHODS

In these studies human erythrocytes were harvested from fresh blood, washed twice in phosphate buffered saline and subsequently exposed to the photosensitizer (HPD) for 2 hours. The cells were then washed and placed on microscope slides together with coverslips. These were placed on the stage of a Nikon Optiphot microscope equipped with a x60 objective lens. This was coupled to an Odyssey confocal laser scanning system (ODYSSEY, Noran Instruments Ltd., UK) with real time imaging facilities in order to facilitate direct examination of the specimen during photodynamic activation. Activation was accomplished during exposure to the visualizing scanning beam emitted by an Argon laser with multi-line emission at 458nm/488nm/514nm/529nm. The microscope and scanning system were controlled by the Odyssey software package loaded into a 486 IBM compatible PC, driven by Microsoft Windows MS-DOS system. Images of events occurring during photoactivation could be captured using a conventional VCR system.

RESULTS

When non-photosensitized samples of erythrocytes were examined using the confocal system it was found that the cells remained unchanged over a period of 1 hour, after which drying of the samples contributed to distortions. However when samples were applied to the system and the emission wavelength of that beam was set at 529nm a very dramatic disruptive event was found to occur within 5 seconds exposure and all cells within the field had disappeared within a 10-second period from the onset of exposure to the scanning beam. This suggested that the system was capable of observing events at a microscopic level during photodynamic activation. These results did not however give any indication at to whether or not the observed events, recorded at a microscopic level, could be quantified. We therefore decided to determine whether the disruptive event could be quantified with respect to photosensitizer concentration and the intensity of the laser scanning beam. It was therefore decided to

expose cells to three different photosensitizer concentrations and to subsequently visualize the samples on the CLSM at various scanning beam intensities. The end point for this study was chosen as the time taken for the onset of the disruptive event to occur once the samples were exposed to the scanning beam. The results demonstrated that increasing the scanning beam intensity decreased the time taken for photoactivation to occur. In addition, when the photosensitizer concentration increased, the time taken for photoactivation to occur also decreased. These results indicated a clear relationship between the events observed in real time using the CLSM and both laser beam intensity and photosensitizer concentration.

In addition to carrying out these studies with erythrocytes, we have also used the CLSM to examine living human HeLa cells which have been exposed to photosensitizers. In these studies cells were also exposed to fluorescent probes which are only taken up by cells with damaged membranes. The results from these studies will also be presented at the Symposium as will potential applications of the system in space medicine and cell biology.

CONCLUSIONS

In ground-based studies, the CLSM system is capable of observing events which occur during photodynamic activation in real time at a cellular level. Those events, in relations to our studies with human erythrocytes may be quantified with respect to scanning beam dose and photosensitizer dose. In the context of long and intermediate duration space flight we envisage that modifications of the existing system offer significant potential both in studying basic cellular function in a microgravity environment and capturing those events in real time for subsequent transmission to ground-based laboratories. Because control of the basic system is computer-based, the degree of expertise required by on-board personnel would be minimal and extensive manipulation of the system could be ground-based. We believe that such a system would have certain attractions for inclusion on-board the International Space Station. In the context of space medicine we believe that the CLSM offers the potential for developing non-invasive, remote medical procedures which would not necessitate return of on-board personnel to Earth. It is also worth noting that the system offers the possibility of carrying our tissue removal at a microscopic level and that removal may be monitored in real time at a microscopic level. The system as outlined above with human erythrocytes has already been suggested to offer potential as a drug delivery system in ground-based medical procedures [Refs. 1 & 2]. We would intend to discuss the above possibilities in more detail at the Symposium.

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OPTIMUM VERSUS UNIVERSAL PLANETARY AND INTERPLANETARY HABITATS

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INTRODUCTION

Habitats designed for interplanetary vehicles and planetary bases pose the challenge of substantial and significant differences in each application. These differences encompass a wide range of functions and accommodations, including radiation shielding, reliability strategy, gravity orientation, EVA airlock, life support system closure, laboratory facilities, countermeasures against weightlessness, pressure ports, and inflatable structures. This comparison, detailed in Table 1, shows that these differences are very substantial and raise the question whether a single habitat design can adaquetely perform the functions of supporting a human crew both in transit to Mars and on the Mars surface.

UNIVERSAL HABITAT PRESSURE VESSEL

Despite these differences in functions and accommodations, it is unlikely that NASA could justify designing and building two separate designs for large, human-rated pressure vessels. Estimates for planetary habitat pressure vessels --conceived as a squat sylinder range from six to ten meters in diameter and from five to twelve meters in height. Estimates for optimized interplanetary habitats -- conceived as a sphere or a nearly spherical ellipsoid -- range from seven to ten meters in diameter and from five to ten meters high. This paper will examine ways in which it may be possible to design a single "universal habitat" pressure vessel module, that is easy to adapt to either interplanetary or planetary use. This study will show the optimized, separate designs for planetary and interplanetary habitat applications. It will propose and examine options for creating a "universal" habitat module that meets the demands of both applications, without forcing unacceptable compromises upon either one.

PRESSURE VESSEL GEOMETRY

One key to successful pressure vessel design for these habitats is careful attention to the ellipsoidal geometry of the end domes. By designing a dome of the most useful and appropriate depth and curvature, it is possible to meet many of the mission demands without compromising essential capabilities. The primary cost comes in sacrificing some modularity and standardization in interior secondary structures, stowage volumes and tankage.

CONCLUSION

This design research suggests that it is possible to create a near-optimized pressure vessel geometry that can support both planetary and interplanetary crewed missions to Mars with minimum compromise to the capabilities of either. The key to implementing this approach will be to treat planned customization as normal use, rather than as an anamoly that requires waivers and special review.

OPTIMUM VERSUS UNIVERSAL PLANETARY AND INTERPLANETARY HABITATS

TABLE 1. INTERPLANETARY VEHICLE AND PLANETARY HABITAT PARAMETERS

MISSION DESIGN IMPLICATIONS

Design Parameter	Interplanetary Vehicle	Planetary Surface Habitat
1. Radiation Shielding	Must launch to LEO, don't want to drag it down to planet surface.	Can extract water from Mars atmosphere or excavate regolith.
2. Reliability Strategy	Propulsive character demands .99999 reliability.	Availablity, resupply & repair complement standard reliability approaches.
3. Gravity Orientation	Optimize for zero-gravity IVA operations.	Optimize for partial-g operations.
4. EVA Airlock	Landing in interplanetary vehicle requires integration of heavy airlock into Habitat.	Separately landed habitat & airlock allows on-surface assembly.
5. Life Support System Closure	Plan for physical / chemical closed-loop regenerative system, with possible plant-growth unit.	Plan for physical /chemical system that includes local resources (atmosphere) with CELSS component.
6. Laboratory Facilities	No use for the Lab Facilities going to Mars, minimal use on return voyage.	Laboratory will provide the center of the Working Environment.
7. Countermeasures Against Weightlessness	Countermeasures such as a small diameter, human-powered centrifuge are essential to maintain crew health.	Zero-gravity countermeasures will be less important in the .38 G gravity field on Mars.
8. Pressure Ports	2 Ports at distal axial ends	4 or more peripheral ports w/ dust control
9. Inflatable Structures	No likely application	Greenhouses, auxiliary and supplementary facilities.

Application of Remote Sensing and Geographic Information System Technologies to the Prevention of Diarrheal Diseases in Nigeria

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Abstract

Among the poor in developing countries up to 20% of an infant life experience may be spent suffering from diarrheal illness, and up to one-third of deaths among children less than 2years of age are due to complications of diarrheal illness. This problem is spatially related to the lack of pure water at different sites. Identification of the areas with poor water facilities and high incidence of diarrhea is crucial to solving this problem. Conventional approaches used in Nigeria do not take into account the spatial relationship between water availability and disease patterns. This project will use remote sensing and geographic information system (GIS) technologies to determine the optimal location for boreholes and other clean water resources to prevent diseases. The initial study will focus on Imo and Anambara States, Nigeria. The RS images of this area will be used to map landcover, landuse, hydrology, towns, villages, and the major transportation networks. The GIS database will also include spatial and quantitative information on diarrheal disease patterns, population data, transportation infrastructure, existing clean water facilities, human waste dumps, industrial pollution sites, and other sources of contamination of water supply locations. The location of potential clean water resources will be determined based on the analysis of the database. Computer modeling will enable determination of the impact of contamination, infrastructure malfunction, population changes, and seasonal fluctuations. The experience gained in this study could be used on a regional scale to guide funding agencies to implement water development schemes. Such an approach could significantly reduce infant mortality due to diarrheal diseases.

A SMALL G LOADING HUMAN CENTRIFUGE FOR SPACE STATION ERA

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INTRODUCTION

Human centrifugations were conducted using a short arm (1.8 m radius) centrifuge (First Medical Co. Japan). Long-duration exposure to the microgravity environment in space would produce various biomedical problems including cardiovascular deconditioning, bone-demineralization, muscle atrophy, etc. Usefulness of a short-radius human centrifuge is expected when it is used in space as a countermeasure against these problems. Especially, centrifugation has been considered as an only solution in a long term micro gravity exposure to prevent a calcium loss from the bone. However almost nothing is well established regarding the most desirable program for artificial G application. Moreover, we definitely need to understand more details about the effects of long duration small +Gz(1-3G) on human. We have studied for many years to solve these points using a short arm centrifuge on the ground. This is an overview of our experiments from the early stage up to the present.

METHODS

Nihon university's short-radius human centrifuge was used for 6 study series. 151 healthy male subjects aged 21 - 39 were informed and chosen for this series of experiments. They received G load along the body's +z axis. The data were collected on sitting position during the load. Electrocardiogram (ECG) was obtained from the third lead and systolic blood pressure (SBP) and diastolic blood pressure (DBP) were obtained with Life Scope 8 (Nihon-Koden). We also observe Arterial Oxygen Saturation by a pulse oximeter since Series B. Sympathetic and parasympathetic activities were evaluated with R-R interval spectral analysis.

In these studies the G load was discontinued when the subject complained of the symptoms by the G load or when the experimenter judged to discontinue based on his evaluation of the subject's physical condition.

RESULTS

The acceleration protocol, G level, and exposure time, the total number of subjects and the number of subjects who completed the exposure time are shown in table I.

The number of subjects who could not tolerate the load, and the causes of discontinue are shown in table II.

A, B, C, D, E and F are the series timely sequenced, and G parameters, such as acceleration protocol, acceleration period, G level and exposure time, have been changed by the previous results, aiming to get the more G and the longer exposure time. By the same reason, the centrifuge itself and its inner devices also have been improved year by year according to the time pass. Then we could gradually neglect the side effects of our short-radius human centrifuge, such as nausea or vertigo.

CONCLUSION

We have studied for many years to understand more details about the effects of long duration small +Gz on human, using short-radius centrifuge on the ground. We have improved our centrifuge and program of artificial G application. Then we could gradually neglect the side effects. However, when we study the usefulness of a short-radius centrifuge, the potential effects of various factors in space need to be considered as well.

USE OF THE BICYCLE ERGOMETER ON THE INTERNATIONAL SPACE STATION AND ITS INFLUENCE ON THE MICROGRAVITY ENVIRONMENT

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INTRODUCTION

A number of exercise techniques have been employed routinely aboard Shuttle and MIR. These same techniques and others are planned for use aboard the International Space Station (ISS) for extended space missions. Peddling on a bicycle ergometer, an endurance exercise, is one exercise technique that will be used to maintain Astronaut respiratory capacity, minimize loss in work capacity, and perhaps increase circulating blood volume.

Operation of the ergometer has however, stimulated some concern for the Space Station Payload Office. Those concerns relate to whether ergometer operation and its location will have an influence on the microgravity payload environment. The microgravity environment generally requires acquiescence. To properly address these concerns, review of isolated and non-isolated ergometer operations are necessary.

METHODS

To assess potential loads (microgravity disturbance) that might be generated for the ergometer aboard the ISS, data from both KC-135 parabolic flights (non-isolated) and two Orbitor flights (isolated) were reviewed. The Orbitor flight tests used both a Passive Cycle Isolation System (PCIS) and an Inertial Vibration Isolation System (IVIS). KC-135 flights to collect microgravity disturbance of an isolated ergometer are under consideration for early spring. The test criteria and data will be compared to the KC-135 non-isolated tests.

RESULTS

KC-135 test data (non-isolated) was assessed by frequency range and amplitude for the MIR ergometer, the Orbitor ergometer, and a proposed ISS ergometer. Disturbances ranged from 0.05 to 5.5 Hz. A wide range of microgravity environment disturbances can also be seen for the two Orbitor flights depending on location and subject peddling technique. These data as well as results of KC-135 isolated ergometer tests, if flown, will be reviewed and presented.

CONCLUSION

Preliminary data analysis from KC-135 non-isolated and Shuttle isolated bicycle ergometer testing suggests potential for microgravity environment disturbance aboard the ISS. These disturbances may be accentuated by location of the ergometer as well as the time period of its use. This type of information will aid ISS research planners in determining the best location of the exercise equipment, methods of its use, and periods of its operation as related to other essential microgravity payloads.

MUNICH SPACE CHAIR (MSC) - A NEXT GENERATION BODY RESTRAINT SYSTEM FOR ASTRONAUTS

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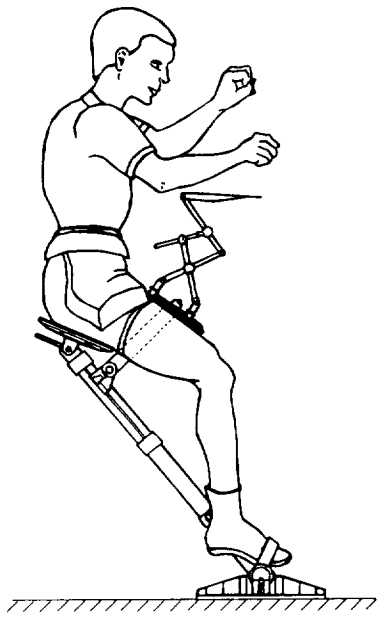
INTRODUCTION

The microgravity environment onboard orbital facilities greatly influences working conditions. On the one hand, the lack of gravitation facilitates the moving from one place to another; on the other hand it makes it more difficult to rest in a stable position. As a prevention from floating away, astronauts have to hold with one hand a grip or handrail, or clamp another part of their body between available facilities. To avoid this and to lower the restrictions due to 0-g, many different body restraint systems have been developed and used onboard spacecrafts and space stations. The most common ones are footloops and handrails. Unlike most of these different restraint systems, the Munich Space Chair (MSC) gives astronauts the possibility to fix their bodies very rigidly while staying relaxed even during work under high muscular strain and long working conditions.



Munich Space Chair with adjustable work table

FIXATION PRINCIPLE

The concept of the MSC is based on ergonomic aspects. It fixes a human body in its neutral 0-g position without the need for additional supports like belts, e.g. The sitting posture of the MSC is combined with a simple fixation principle. As depicted in the figure, the human body is fixed between foot bar, thigh plate and seat plate. The astronaut only has to press his thigh against the thigh plate by stretching his foot and spanning his calf muscles, respectively. Due to the leverage of the thigh plate, the back is pressed onto the seat plate. The whole lower part is fixed while the upper part of the body with the arms keeps its freedom. Depending only on the muscle employment of the astronaut, it is possible to „sit" in the Chair being fixed very tightly or rather loosely or „free floating" within the three fixing points. So the fixation can be easily varied for different tasks. Furthermore the MSC can be adapted to all body sizes.

DEVELOPMENT AND APPLICATION ON MIR

The MSC was tested in three parabolic flight campaigns and optimised according to the results. A detailed load analysis was performed to get the limit loads induced to the MSC by the astronaut. In 1995, more than 10 years after the invention of the space chair, the MSC was launched to Space Station MIR and installed inside the SPEKTR module. In October 1995, an adjustable and foldable work table for the MSC was also sent up to MIR in a PROGRESS cargo spacecraft. During the EUROMIR'95 mission, the MSC was used for experimental activities, writing and typing. Moreover, it was tried to verify an improvement of concentration abilities and precise movements using the MSC for the DLR experiment PSY-15 D, which requires precise work with both hands under high concentration over a long period of time. German Astronaut Thomas Reiter, who spent 6 months onboard MIR, confirmed the expected improvements compared to other restraints for this kind of application. Another MSC main duty onboard MIR, the support of the mechanical PELIKAN manipulator arm operation, has not yet begun.

OUTLOOK

Presently, several components of the MSC are adapted for future use onboard the International Space Station (ISS). Especially, the floor connection unit is redesigned to enable a connection to the seat tracks inside the ISS. The use of the MSC onboard the ISS will complete the required range of restraint systems.

THERMOELECTRIC HUMAN-BODY COOLING UNITS USED BY NASA SPACE SHUTTLE ASTRONAUTS

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INTRODUCTION

The US National Aeronautics and Space Administration (NASA) realized a need for a cooling system that can provide body cooling to the space shuttle astronauts and thus reduce heat stress while they wear the Launch Entry Suit during shuttle launch and reentry. Midwest Research Institute (MRI) developed thermoelectric (TE) cooling units to meet this need. First generation cooling units developed by MRI are being used by the astronauts during the last three years. Second generation cooling units are currently under development and will become available for 1997 missions. The cooling units are used in conjunction with NASA-furnished tube-type cooling garments. The paper will discuss the technical details of body cooling needs of astronauts, second generation TE cooling units, and the performance results.

BODY COOLING NEEDS

The metabolic heat produced by an average astronaut's body is about 100 watts. Since the astronauts wear the Launch Entry Suits for survival reasons during shuttle launch and reentry, the produced heat cannot be rejected to the cabin air. Body cooling is done by wearing a special tubes-sown garment adjacent to the body skin and by circulating a chilled fluid through the garment tubes. A cooling unit is required to rechill the warm liquid returning from the garment.

COOLING UNITS

The second generation TE cooling units are compact, lightweight, and efficient. Each unit weighs about 6.5 lb and has a size of 4 X 5 X 8.5 in. The principal components of a unit are (1) a cooler core, (2) a fan, (3) a fluid pump, (4) an electronic PC board, and (5) an enclosure. The core contains the TE modules, fluid cooling channels, and heat sinks. In operation, power is applied to the TE modules, fan, and pump. The warm fluid returning from the garment is pumped through the cooling channels of the core and thus cooled. The fan circulates cabin air through the heat sinks to remove the heat rejected by the TE modules. A 10-position wired-remote switch is used by each astronaut to regulate the power applied to the TE modules and thus vary the cooling delivered to the body.

PERFORMANCE RESULTS

The cooling unit is capable of delivering up to 150 watts of cooling in a 75° F cabin temperature. The maximum delivered cooling reduces to about 105 watts (and is still sufficient to balance the metabolic heat produced by an average astronaut) when the cabin temperature increases to 90° F. To deliver 100 cooling watts, the electrical power requirements of the cooling unit at 28 VDC are 25 and 60 watts respectively at 75° F and 90° F cabin temperature.