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INTEGRATED SUPPORT STRUCTURE FOR GASCAN II

WORCESTER POLYTECHNIC INSTITUTE N91-18159

The focus of the WPI Advanced Space Design Program was the preliminary design of the Integrated Support Structure for GASCAN II, a Get Away Special canister donated to WPI by the MITRE Corporation. Two teams of three students each worked on the support structure: the structural design team and the thermal design team. The structure will carry three experiments also undergoing preliminary design this year: the μ-g Ignition Experiment, the Rotational Flow in Low Gravity Experiment, and the Ionospheric Properties and Propagation Experiment. The structural design team was responsible for the layout of the GASCAN and the preliminary design of the structure itself. They produced the physical interface specifications defining the baseline weights and volumes for the equipment and produced layout drawings of the system. The team performed static and modal finite-element analysis of the structure using ANSYS. The thermal design team was responsible for the power and timing requirements of the payload and for identification and preliminary analysis of potential thermal problems. The team produced the power, timing and energy interface specifications and assisted in the development of the specification of the battery pack. The thermal parameters for each experiment were cataloged and the experiments were subjected to "worst case" heat transfer scenarios. These analyses will be integrated by next year's thermal design team to model the overall performance of the system.

INTRODUCTION

WPI's Get Away Special Canister (GASCAN) Program is now in its eighth year. This program is the result of a cooperative effort by WPI and the MITRE Corporation of Bedford, Mass. MITRE purchased and donated two GASCANs to WPI. The first of these canisters is now scheduled for launch in August of 1990. The second canister, GASCAN II is now undergoing preliminary design. Since 1986, the design of GASCAN II has also been part of the NASA/USRA Advanced Space Design Program.

The task of designing this payload has been divided into the two groups: experiment design and support structure design. The experiments are described in the Payload Description Section. The focus of the AY1989-90 program is the thermal and structural design of the integrated support structure of the GASCAN.

PAYLOAD DESCRIPTION

Size and Weight

The maximum volume of our payload will be 5.0 ft^3. The maximum weight will be 200 lb.

Experiment Descriptions

We are developing four experiment packages. Each experiment will operate in a stand-alone mode as completely as possible. A brief description of each experiment is presented below. The experiments are as follows:

1. Ionospheric Properties and Propagation Experiment
2. Microgravity Ignition Experiment
3. Rotational Fluid Flow in Microgravity Experiment
4. Environmental Data Acquisition System

Ionospheric Properties and Propagation Experiment (IPPE)

The purpose of the IPPE is to correlate the occurrence of radio wave ducting with electron density. This will be accomplished by measuring the electron density in the ionosphere and the signal strength of a 15 MHz signal (radio station WWV in Colorado and Hawaii). Electron density will be determined using an Electrostatic Analyzer (ESA). A radio receiver tuned to 15 MHz will provide the signal strength data.

Radio wave ducting occurs when a high frequency signal is trapped between two ionospheric layers. Theory predicts that ionospheric layers with high electron density will reflect radio waves. If a radio wave is trapped in a layer with a low electron density between two layers with a higher electron density, then that wave will be "ducted." A ducted radio signal will experience less attenuation than a non-ducted signal. The data from the IPPE radio receiver will be analyzed in order to find changes in signal strength attenuation. These changes will indicate ducting of the radio signal.

The basic IPPE system is shown in Fig. 1. The system has four main components: radio receiver, radio antenna, Electrostatic Analyzer (ESA), and a control assembly. Both the ESA probe and the radio antenna will be mounted external to the canister lid (Fig. 2).
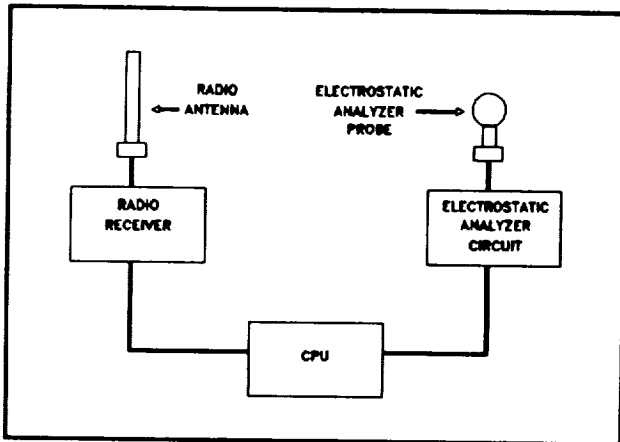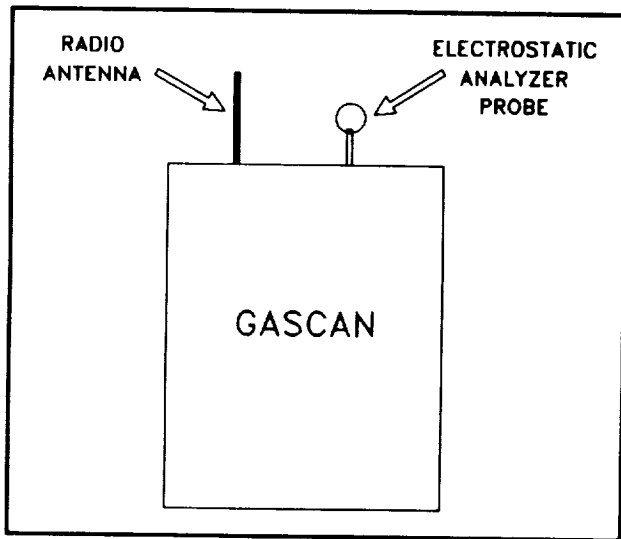
Fig. 1. Schematic of the IPPE

Fig. 2. External View of the Canister

The ESA probe consists of two concentric spheres; the outer sphere is constructed of gold-plated steel mesh, and the inner sphere is a gold-plated hollow aluminum ball. For the experiment to function properly, a voltage potential is maintained between the two spheres. When electrons are drawn onto the inner sphere, a negative current in the range of 10^{-10} to 10^{-5} amperes will be produced. The radio antenna is composed of spring steel. Both the ESA probe and the radio antenna will be mounted to the GASCAN endcap using surface mounts and high impedance vacuum feedthroughs.

The Electrostatic Analyzer circuit inputs the signal from the ESA probe and uses a log electrometer to convert the currents into a 0-5 V range. The control assembly then takes this information, processes the signal as required by the experiment, and stores the necessary information onto an Erasable Programmable Read Only Memory (EPROM).

The unit will be turned on by a shuttle crewmember following the completion of the Rotational Fluid Flow Experiment. At this point the experiment will begin sampling WWV signal strength and ion density at regular intervals.

In order for this experiment to be able to take proper readings within the ionosphere, it must be flown on a high-inclination shuttle flight.

Microgravity Ignition Experiment

The initiation of combustion on Earth is largely controlled by the presence of gravity since natural convection and buoyancy are functions of gravity. By neutralizing the effects of gravity, other mechanisms should become dominant factors in the ignition process. The purpose of this experiment is to compare the ignition characteristics of a material in a microgravity experiment with ignition characteristics established from laboratory experimentation in a 1-g environment.

The experiment has two major subsystems: the combustion chambers and the control system, as shown in Fig. 3. There will be four airtight combustion canisters capable of withstanding five atmospheres of internal pressure. Each of the four containers will have an identical paper target (alpha cellulose) that will be ignited using a high-intensity lamp. Data will be collected from the chambers using temperature, pressure, and heat flux sensors. In addition, an ion sensor will be located above the target to serve as a flame detector.

The control system will contain a microprocessor and an EPROM card for data storage. This system will be responsible for monitoring the experiments and taking appropriate action to shut down a canister if a hazardous condition arises.

This experiment should be turned on by a shuttle crewmember during a period of relative inactivity. Upon activation, this experiment will enter a "sleep mode" for a predetermined time period. At the end of this "sleep phase," the microprocessor will begin the ignition experiments.
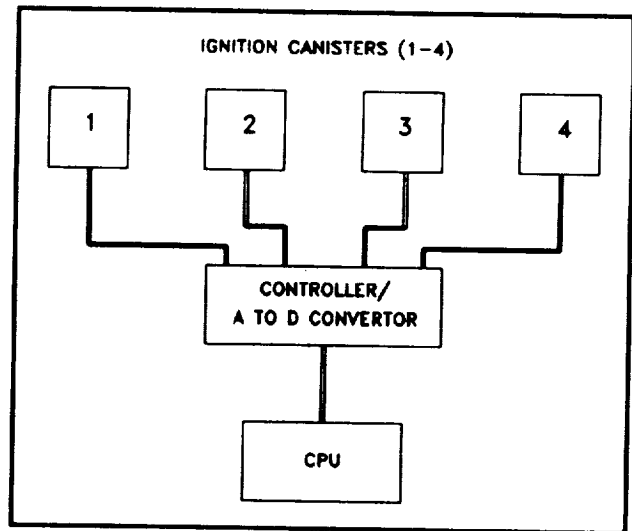

Fig. 3. Schematic of the Microgravity Ignition Experiment

Rotational Fluid Flow in Microgravity Experiment

When a fluid rotates with the axis of rotation normal to a gravitational field, the rotation is accompanied by a decrease in the surface elevation of the fluid at the center of rotation. This phenomenon is referred to as a vortex. Vortex formation is governed by the fluid's angular velocity, viscosity and surface tension. The objective of this experiment is to examine the behavior of a free surface vortex in a microgravity environment.

This experiment has four main components: the rotating platform, the fluid system, the data acquisition assembly, and the control assembly (Figs. 4 and 5). A rotating platform will allow the experiment to utilize its microgravity environment to simulate other gravities, within the range of 10^{-6} to $2.0\ g$'s.

The fluid system will be composed of a tank, connecting tubes, and a pump. The working fluid will either be a silicon-based oil or a water/glycerol mixture that will not freeze in the cold of the GASCAN. The fluid will be injected tangentially into the upper end of the cylinder and drained from the bottom of the tank. This process will induce an angular velocity into the fluid and create the vortex.

The data acquisition assembly will collect data using a camera, an ultrasonic device, and temperature sensors. The ultrasonic sensors will be used for measuring the velocity, and hence circulation, of the fluid within the tank. The camera will be used to measure the actual size of the vortex and will function as a second measure of vortex strength. Not shown in the figures is the gas entrainment detector, which will be located along the piping between the tank outlet and the pump. This device examines the fluid for gas bubbles. If gas is detected within the tubing, the control system stops data collection for that trial.

The control system will use a set of accelerometers to monitor and control the platform's angular velocity. The accelerometers will be aligned to measure the platform's centripetal acceleration.

This experiment will be turned on by a shuttle crewmember by the same switch as the microgravity ignition experiment. Upon activation, this experiment will enter a "sleep mode" until the ignition experiment is finished.
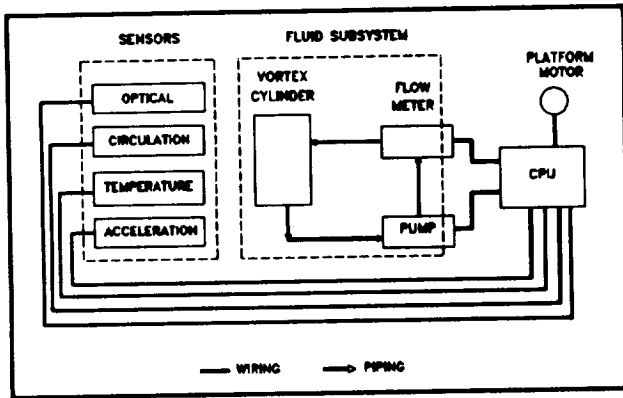
Environmental Data Acquisition System

The Environmental Data Acquisition System (EDAS) collects data describing the environment internal to the canister from just after launch until all of the experiments are turned off. The system will be activated by the baroswitch as the shuttle passes through an altitude of 70,000 ft. The system will then begin to sample data for the entire time that experiments are running in the canister. These data will be available for postflight analysis of the experimental data.

Fig. 4. Schematic of the Rotational Fluid Flow Experiment

STRUCTURAL DESIGN

The objective of the payload structural design group is to integrate all the experiments into a complete package inside the GASCAN II canister while conforming to all NASA structural design requirements. The project is in the preliminary design phase. Emphasis is on adequate structural support of the payload to ensure reliability and safety during flight operation.

General Requirements

Container construction. The standard GAS canister is made of aluminum. There is thermal insulation on the exterior. The top may or may not be insulated depending on the particular shuttle mission and needs of the experimenter. The standard circular endplates are 5/8-in-thick aluminum. The bottom 3 in of the container are reserved for NASA interface equipment such as command decoders and pressure regulating systems. This volume is not included in the space available to the experimenter.

Container size. The container has a volume of 5 ft³. The user size is 28.25 in in height and 19.75 in in diameter. The maximum user weight is 200 lb.

Fig. 5. Rotational Fluid Flow Experiment Layout

Experiment mounting plate. The experiment mounting plate serves three purposes: it seals the upper end of the standard GAS container, provides a mounting surface for the experimental equipment, and acts as a thermal absorption and radiation surface. The inner mounting plate is fitted with 45 holes to accept 10-32 UNF stainless steel screws to a depth of 0.31 in. There are two purge ports for venting gases from the battery pack.

Venting. Batteries, which can produce a combustible mixture of gases, must be housed in a sealed, corrosion proof, vented battery box. Plumbing for the venting of the battery box is to be supplied by the experimenter. The battery box must be vented through the mounting plate and through two 15-psi differential pressure relief valves provided by NASA. All plumbing should be stainless steel.

Lateral load support. Because the experiment structure will be cantilevered from the experiment mounting plate, radial support of the free end of the experiment structure must be provided by at least three equally spaced bumpers between the experiment structure and the standard GAS container.

Load Specifications

Launch:	normal:	3 g RMS, 20-2000 Hz
	adverse:	12 g RMS, 20-1000 Hz
Orbit:	normal:	negligible vibration, 0.1 g with thrusters
Landing:	normal:	negligible vibration, 5 g static along can axis

Payload Integration

Each experiment has characteristics that affect the design. This section will address these design issues and describe the payload layout that will give a structural integrity that meets NASA specifications.

IPPE Experiment. This experiment has some unique requirements that must be adapted into the support structure. Two components, an ion collector and an antenna, are to be protruding out of the experiment mounting plate. These components will be located at a yet to be determined position on the mounting plate and could be anywhere on the diameter. Thus, these components must have access to the entire diameter and must be closely coupled to the IPPE controller box. With these considerations, it is necessary to place the IPPE controller box at the top of the GASCAN II support structure.

Rotational flow vortex experiment. The experiment is completely enclosed within a rotating section of the GASCAN assembly. The experimenters have requested the maximum diameter available in the GASCAN (19.75 in). This will necessitate the placement of support bumpers both above and below the experiment.

Battery and battery box. The battery weight is currently estimated at 79 lb. The battery box must be removable from the structure for installation, checkout, and repair. Vent lines and electrical leads must be accommodated.

Microgravity ignition. The four ignition chambers must be removable and their installation must allow connection of electrical and data lines to the experiment controller.

Initial Design and Design Changes

This design team inherited a design by the previous payload integration structural team which was a year out of date. There were many details that needed to be changed as quickly as possible to allow the other Advanced Space Design project teams to progress with their parts of the design.

The first team had incorrectly allocated the space for the experiment mounting plate within the user interface space. The plate is 5/8-in thick and, therefore, detracted from the amount of space available for the experiments. Also, the previous team had not fully specified how the flange/centerpost assembly would be attached to the mounting plate.

In order to redesign the top of the support structure, the major concern was to do so without altering the space already designated for the IPPE and microgravity combustion experiments. Since it was established that the experiment mounting plate should not have been included in the design, this gave the height of the usable space an additional 5/8 in. Clearance for both the IPPE and microgravity combustion was already sufficient and could only benefit from the additional height. With the exterior components of the IPPE, it was decided that the flanges could be altered such that the IPPE team could have access to the entire diameter to allow them to run their electrical leads to the ion collector and antenna. As this idea developed, it was also discovered that the previous group had not finished the design of the venting mechanism for the battery. From the outset, it was assumed that the venting would be done through the centerpost; however, the routing and connection to the mounting plate had not been established.

Further review of the NASA specifications showed that the battery vent had to be lead to a location within a plumbing circle section of the mounting plate. The mounting plate did not have to be oriented at any particular angle around the diameter; therefore, the team specified that it be oriented above one of the three compartments of the top section of the payload. The next concern was route of the venting line from the centerpost to the plumbing circle.

Taking both the venting and mounting to the mounting plate into account, the top of the support structure was then redesigned. The flanges and centerpost were reduced by 3 in. This 3-in clearance would allow vent lines to exit the centerpost and be directed to the venting apparatus inside the plumbing circle. It would also allow IPPE wiring access anywhere on the plate with the exception of the plumbing circle. The next design change was the mounting of the support structure. Since GASCAN II utilized the same three-flange design as GASCAN I, it was decided to use the same type of mounting brackets.

The next design consideration was the supports around the rotational flow experiment. The earlier design used braces to support the shelves above and below the experiment. The experiment group requested access to the entire diameter of the canister. Therefore, it was decided that the supports of the old design could be removed and replaced by bumpers above or below the rotational area which would give the same support that the previous design would give.

As energy and power requirements for the experiment were developed, it was estimated that 99 lb of batteries and battery box would be required. This weight was much greater than the earlier estimate of 42.6 lb. This discovery caused an immediate review of many of the design aspects. The original design located the battery box as far as possible from the mounting plate. This resulted in a substantial amount of weight supported solely by the centerpost. With this weight so far from the fixed end, the natural frequency of the entire structure would be low, possibly below the minimum requirement of 51 Hz. To help alleviate this problem, the battery box was switched with the rotational flow experiment. This would move the bulk of the weight up the cantilevered structure, increasing the frequency and giving a firmer mounting orientation. This orientation also simplified the installation of the rotational flow device, since the platform will be supported by bearings above and below the system.

The battery box can be slotted to slip over the centerpost and be bolted around the entire diameter of the centerplate. To give the battery box some support at the centerpost, a support ring with a set screw will be welded into place. This ring will also serve as a rigid support for the rotational flow bearing mounts.

Bumpers to stabilize the support structure were the next concern. It was decided that the bumpers could be positioned above the battery box at the ends of the flanges and an additional set could be installed beneath the rotational flow platform and above the bottom plate.
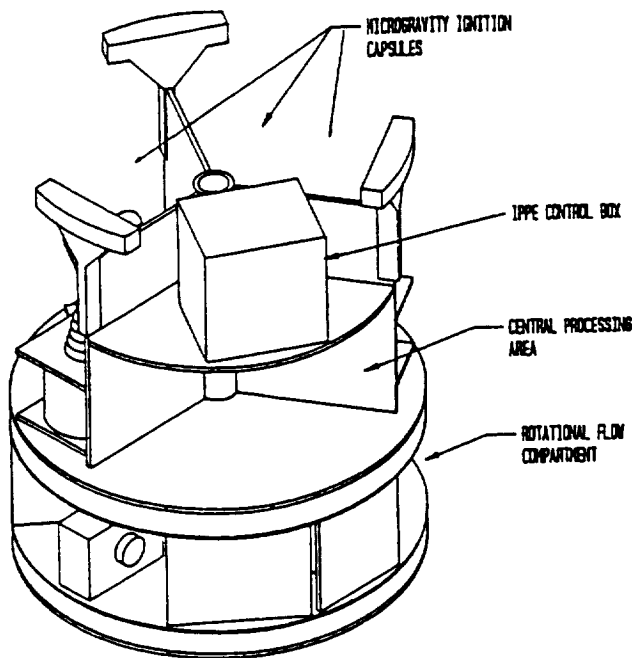
The final layout is shown in Fig. 6.

Fig. 6. GASCAN II Layout

ANSYS Introduction

To insure structural integrity of GASCAN II, finite-element analysis was performed using ANSYS. The analysis begins with the orientation of the can with respect to the space shuttle coordinate system. It is along these axes that the loadings are defined.

The most important factor for design purposes is the loadings. These loadings are split into three categories, limit, yield, and ultimate loads. The limit loads are the worst possible yield, and ultimate loads. The limit loads are the worst possible loadings that actually may occur. The yield loads are used to insure that the design, within a specified margin of safety, will not undergo plastic deformations. The ultimate loadings are used to insure that the design will be safe when comparing actual loads with the ultimate allowable loads for the materials of the can.

For GASCAN II to become space-qualified, certain safety requirements must be met. The factor of safety is the allowable stress divided by the applied stress. NASA requires that the GASCAN II to meet a Yield F.S. = 1.5 and an Ultimate F.S. = 2.0.

Results and Conclusions

Several structural questions, which would have been difficult or impossible with hand calculations, were addressed using ANSYS. The final models were made using the beam element, the plate element, and the mass element. These elements modeled the experiments and other parts of the can with a minimum amount of input. This was necessary since the ANSYS programs on the WPI campus had a limitation on the size of the model that could be analyzed, and also there was a limit on the time and space available to us on the larger ANSYS program at the MITRE Corporation.

The beam element was used in three places on the can. The first was the center shaft. This element was ideal for the analysis since it gave moments and deflections at the two plates and between the two plates. It also reduced the number of elements necessary to model the center shaft, allowing us to use WPI's computer facilities. The second use of beam elements was in the modeling of the experiments. The element was given a density of near zero and stiffness large enough to eliminate internal deflections in the beam which allowed us to translate the acceleration of a mass into moments and forces at the fastening locations. This provided stresses and deflections in the plates at the experiment locations. The last place the beam element was used was for the mounting brackets, which allowed any forces and moments induced within the beams to be transferred to the plate elements of the flanges.

The plate element was used to model the plates and flanges of GASCAN II. Mass elements were used to represent the masses of the experiments and were attached to the beams as mentioned above. All the elements were then compatible with each other and the model was analyzed.

The first model developed of the can, Model I, consisted of the plates, flanges and center post. To develop forces on GASCAN II, we calculated the force that would be required to accelerate the mass of each experiment at 6 g's. These forces were then applied to GASCAN II at appropriate

locations. The largest deflection that occurred was at node 45, on the outer edge of the bottom plate, and occurred in the z direction. The largest stress in a component direction was at node 140, on the upper corner of a flange, and occurred in the y direction. This was also the location of the highest principal stress. All other high stresses occurred at the bumpers and upper flange locations, the points where the degrees of freedom were fixed. We were not able to determine stresses in the center shaft, but deflections were low, which indicated low stresses. All the stresses that occurred were low in comparison to yield stress and ultimate stress limits, but a more accurate model of the system was required.

The second and third models were identical in structure with the exception of the location of the battery box. The second had the battery box underneath the bottom plate and the third had the battery box above the rotational fluid flow experiment. Additional elements were added to represent the experiments and the mounting brackets, since the first model neglected moments induced by the acceleration of the experiments. These moments added to the stresses in the structure. Another improvement was to accelerate the whole model to take into account the body forces that occur in the parts of the structure.

A further reason for the two models was to compare structural rigidity and vibrational stability. For design reasons, mainly the fastening arrangement of the battery box, the battery box was positioned above the rotational fluid flow experiment. Both designs were analyzed to see if moving the battery box affected the structural integrity of GASCAN II.

As expected, the stresses that occurred in these improved models were much higher than in the simple one. The highest stresses that resulted in both cases were in the direction of the principal stresses for all acceleration directions.

The highest stresses occurred where the nodes were fixed, due to the fact that stress is generally inversely proportional to area. At these points the area is reduced to almost zero and the stresses increase.

The stresses also depended on direction of acceleration and the type of model. The first type was with the battery box on the bottom and the bumpers fixed in all directions. The second type was with the battery box on the bottom and the bumpers free in the z direction. The third was with the battery box above the rotational fluid flow experiment and the bumpers fixed in all directions and the fourth was with the battery box above the rotational fluid flow experiment and the bumpers free in the z direction. The models were each accelerated in the x, y, and z directions.

The lowest stresses occurred when GASCAN II was accelerated in the y direction. Away from the areas around the fixed points, the stresses are in the range of 2000 psi to 5000 psi which is well within the acceptable range for aluminum. The maximum allowable stress for aluminum is 37,000 psi in tension and compression. At the bumpers and mounting brackets, where GASCAN II is fixed, the stresses are in the range of 15,000 psi to 20,000 psi, which is still in the acceptable range. For accelerations in the y direction, the stresses are all within the acceptable range for all four conditions mentioned.

The accelerations in the x direction yielded high stresses at the bumper locations and the mounting brackets. Away from the areas that were fixed, the stresses ranged from 10,000 psi to 13,000 psi. At the bumper locations, the stresses were in the 60,000 psi to 90,000 psi range. In one model the stresses were considerably lower. This was the condition with the battery box above the rotational fluid flow experiment and the bumpers fixed in all directions. The stresses in this model ranged from 2000 psi away from the bumpers to 33,000 psi at the bumper locations. This result was good because it justified moving the battery box above the rotational flow platform.

The accelerations in the z direction were the most important because this is the direction of maximum acceleration requirement. This is also the direction that the bumpers were free to slide. Any movement in the x and y directions would only be from torque. The main concern was the location of the battery box above the rotational fluid flow experiment. In our worst case, where the bumpers would fail and slip, stresses were low in the plates. They were below 7000 psi in the bottom plate, and between 7000 psi and 14,000 psi in the middle plate. The high stresses occurred at the mounting brackets. These were the only three points keeping the entire can from moving and stresses reached the 60,000 psi range, again because of small areas. These stresses carried into the flanges and the shelf and ranged between 25,000 psi and 48,000 psi. Some of these numbers were above the allowed maximums, but might be lower with improved modeling of the bumpers. We found that moving the battery box would not disrupt the structural integrity of GASCAN II. Under certain conditions the stresses were slightly higher, on the order of 1000 psi to 2000 psi, but in others it was considerably lower. To sum up the results, the design with the battery box above the rotational flow platform should meet NASA safety specifications, but must be further analyzed with a finer mesh. Further detailed design of the can should proceed from this design taking into account the problem areas specified above.

THERMAL DESIGN

Introduction

The purpose of the thermal portion of the preliminary design is to identify potential thermal problems and to suggest possible solutions to these problems. In order to identify potential thermal problems, we looked at the thermal energy balance of each experiment and the interaction of each experiment with the surrounding hardware. Through this analysis, we determined if the experiments might fail due to temperature extremes. As a secondary task, this project team was responsible for coordinating and documenting electrical interfaces for GASCAN II, including power requirements, timing of that power, and the subsequent energy requirements. The preliminary electrical interface specification is also part of this project.

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Systems Configuration Diagram

Systems Configuration Diagram, shown in Fig. 7, illustrates all three experiments contained within the GASCAN II. The relationships between each experiment, the GASCAN/NASA Interfaces and the battery pack are also included to give a simplified diagram of all of the systems in the GASCAN II.

Heat Transfer Analysis

Using basic heat transfer theory, often simplified, the thermal analysis of GASCAN II was developed. In the following sections, the methods of analysis, possible thermal design problem areas and recommendations to future groups are presented for each experiment. In addition to the analysis of the experiments, bulk temperature considerations of the GASCAN are discussed in the IPPE section.

*IPPE/canister top.*The Ionospheric Propagation Properties Experiment (IPPE) consists of a radio receiver, an electrostatic analyzer and the necessary electronics required for the control of the experiment and the storage of data. One of the requirements for this experiment is the external mounting of an ion sensor and an antenna for the radio receiver. Because of this requirement, the insulating cap, which is usually placed on top of the canister, cannot be used.

While the IPPE experiment does not adversely affect the thermal environment in itself, the external mounting of the antenna and the ion probe along with the leads to them does affect the thermal environment when one looks at the temperature extremes the canister must endure without the insulating cap. While the temperature of deep space has been approximated at 3 K (-270°C), because of the complex radiation that occurs in shuttle bay, the "effective" external temperature experienced by a payload is significantly higher and is directly dependant on the shuttle bay orientation. When the shuttle bay is oriented so that it faces space, as when a satellite is deployed, a heat sink of 173 K (-100°C) should be assumed and, generally, heat will be conducted out of the canister which could result in exceedingly cold temperatures. Similarly, should the shuttle bay face the sun for an extended period of time, the possibility of thermal problems exists because the effective external heat sink temperature is 313 K (+40°C)

There are always potential problems with electronics. If heat generating components are not properly mounted to a conducting surface, they can burn up. It is important to note that while these two scenarios present the extremes that will be encountered, the information gathered from these two situations will provide us with an estimate of the thermal characteristics of the canister and the experiments at any time during the mission.

The following is the methodology for the calculation of the temperatures that will be experienced by GASCAN II as a function of time, shuttle bay orientation, and presence of an insulating cap.
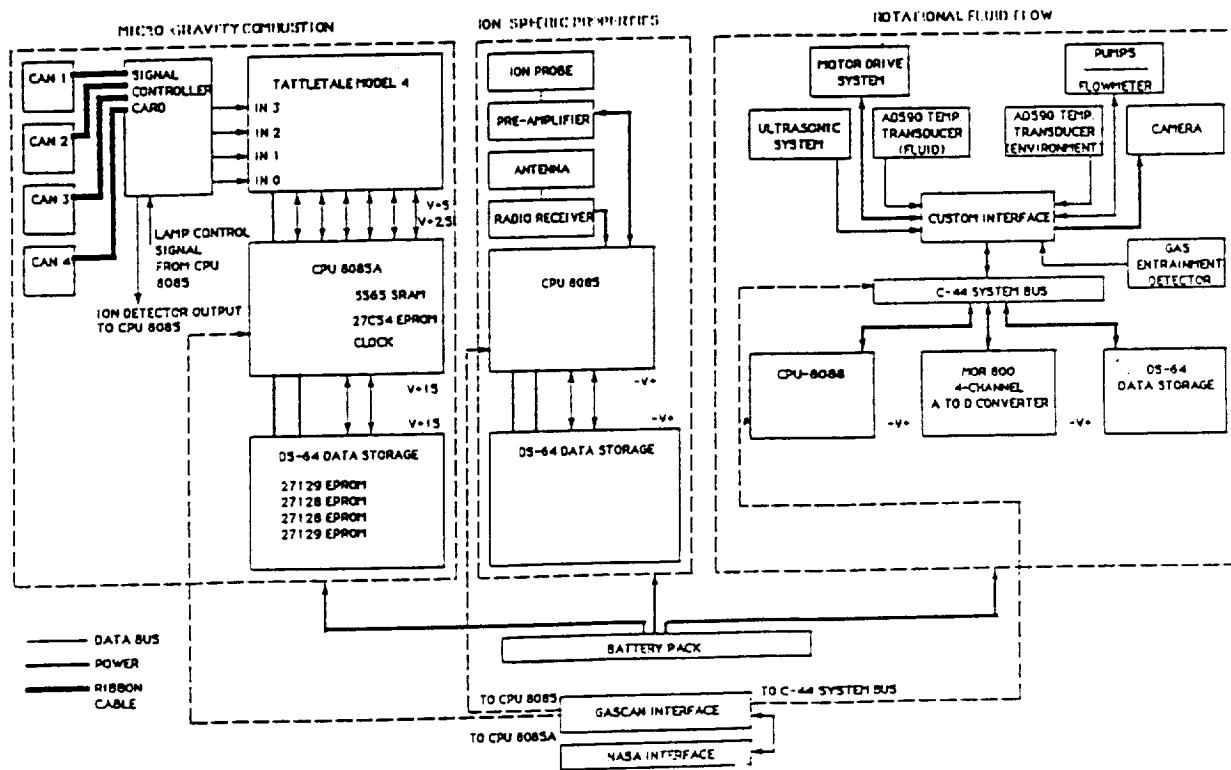

Fig. 7. System Configuration Diagram

Bulk GASCAN II Temperature Calculations

In order to determine the temperature of GASCAN II as a function of time and shuttle bay orientation, the following model was taken from Appendix A of the Get Away Special (GAS) Thermal Design Summary. The following information represents the internal temperature of GASCAN II as a function of time for different shuttle bay orientations for an insulated and uninsulated GASCAN II. It is important to note these temperatures are bulk temperatures for GASCAN II and do not represent the temperature of any individual component. The basic assumption of this analysis is the entire GAS canister is considered to be one thermal mass with the same temperature at any spot in the canister. Obviously temperature variations will exist both from the outside to the inside of the canister as well as the areas around heat generating components.

The resulting differential equations were solved using the ASDEQ, a user friendly, differential equation solver from the Engineering Department of USMA, West Point. The equations are modeled with block diagrams similar to analog computer wiring diagrams. The equation and the resulting ASDEQ block diagram are shown in Fig. 8. After input of the blocks into the program, ASDEQ solves the equations using a fourth order Runge-Kutta scheme and presents data in column or plot formats. Plots of the average GASCAN temperature for three orientations using insulated and uninsulated configurations are shown in Figs. 9, 10, and 11.

For an Earth orientation, the uninsulated GASCAN reaches an equilibrium temperature of -15°C in 70 hr. In comparison, the insulated model does not reach its equilibrium temperature of -5°C even after 150 hr. Similarly, in the sun orientation the uninsulated GASCAN reaches equilibrium with the environment after 60 hr at a temperature of 30°C. The insulated canister approaches its equilibrium temperature of 40°C after 120 hr. Finally in analyzing the space orientation, one sees even after 150 hr neither the uninsulated nor the insulated GASCAN reach their respective equilibrium temperatures of -110°C and -100°C. The uninsulated canister does, however, cool off much more rapidly and a long duration in this orientation will pose problems for GASCAN II.

In all sets of data, there is a "hump" which exists from T+15 until T+30. This increase in temperature is due to the operation of the experiments. One can see a direct correlation between this "hump" and the power requirements for the canister.

It is important to note these calculations assume a shuttle liftoff and subsequent bay orientation immediately after the shuttle is in space. Combinations of these orientations will exist in reality; therefore, the GASCAN may already be at equilibrium in, say, the Earth orientation and then change to a space orientation. This would lead to an initial temperature of 5°C instead of the 27°C modeled here, therefore, reducing the time necessary for the GASCAN to reach critical temperatures. These represent extremes of what could happen to the payload during the shuttle flight.

Thermal Analysis: Microgravity Ignition Experiment

The Microgravity Ignition Experiment consists of four cylindrical canisters each containing a heat lamp, ion detector,

$$\frac{dT_2}{dt} = \frac{1}{C_v M}[\dot{Q}_{int} - \epsilon \sigma A(T_2^4 - T_1^4)]$$

where:

A	Surface Area
C_v	Average Specific Heat
M	Total Mass
$\dot{Q}_{int}$	Internal Heat Generation
T_1	Environmental Temperature
T_2	Mean GASCAN Temperature
t	Time
ϵ	Effective Emittance
σ	Stephan-Boltzmann Constant

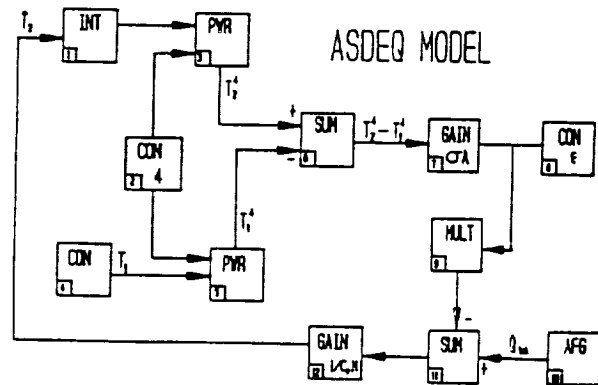| Values of Environmental Temperature, T_1		
Viewing	Insulated	Uninsulated
Space	173K	163K
Earth	268K	258K
Sun	313K	303K
Values of Effective Emittance, ϵ		
	0.065	0.16

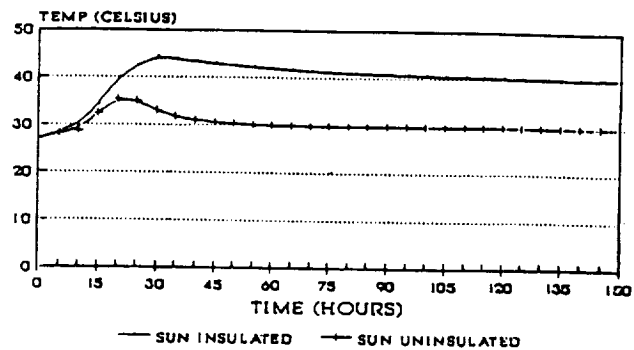

Fig. 8. Thermal Equation and ASDEQ Block Diagram

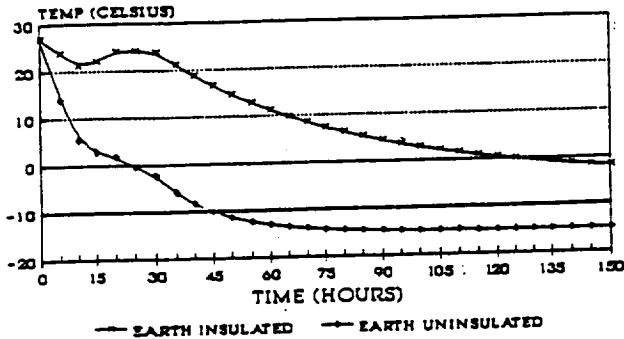Fig. 9. Thermal Response for Sun Viewing
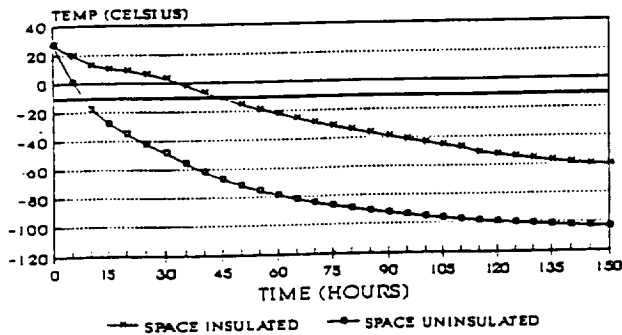
Fig. 10. Thermal Response for Earth Viewing

Fig. 11. Thermal Response for Space Viewing

and pressure transducer, as well as material that will be ignited. A custom designed control card, and a Tattletale computer will be used for the control of the experiment as well as data storage. The two major thermal design concerns for this experiment are the presence of four 250-W lamps and the ignition of the combustible material in each of the canisters. Both the lamps and the heat released from the ignited material will cause local hot spots. Analysis of these areas will provide information on the thermal environment of the experiment and its interaction with the other experiments in GASCAN II.

The combination of the lamps and the ignited material will generate heat within each container that could be radiated throughout the compartments the containers are placed in. The electronics for this experiment, primarily the computer components, were determined to generate a minimum amount of heat, which for this analysis is negligible.

The Microgravity Ignition Experiment involves the heating and combustion of a cellulose material inside an aluminum container. The lamp in each of the four canisters will be on for a maximum of 30 sec. It must be determined if for this period of time the temperature rise of the outside of the aluminum chamber will be a safety concern.

The analysis of each individual canister will determine the amount of heat the immediate outside environment must reject from the radiating body (the combustion chamber) assuming

all of the heat generated (from the 250-W lamp and combustion of material) will be radiated through the chamber. Since there is no convection, and conduction is considered to be minimal, this will represent a worst case scenario. The worst case assumptions used are (1) steady state conditions; (2) convection and conduction is minimal; and (3) all of the produced heat is immediately transferred to the environment by means of the aluminum chamber. The heat generated, Q, for 30 seconds inside the chamber is: $Q_{total}=10285$ J which results in a temperature rise of the chamber of 16°R.

Experimental results for combustion chamber. Once the approximate temperature rise for the outside of the combustion canister was established, and the components to the microgravity ignition experiment were machined and assembled, a test was performed to determine if the temperature rise calculations were accurate. The experiment was conducted with a thermocouple attached to the outside of the combustion chamber to determine the actual temperature rise due to the heat created by the 250-W lamp for a period of 30 sec.

The results of the experiment yielded only a 4° temperature rise outside of the chamber at the end of the allotted time period. This would support the assumption that there is a minimal temperature rise outside of the combustion chambers. The difference between the analysis and the actual temperature rise is likely because the actual heat release from the paper was very low. Also, the paper mount is an additional mass inside of the combustion chamber and is not considered in the analysis.

Heat Transfer Analysis: Rotational Fluid Flow Experiment

The rotational fluid experiment is the third experiment in the GASCAN II cylinder. The experiment will be isolated from the rest of the GASCAN, in that all of its equipment will be located within the rotating structure. The power supply and interface connections will be the only connections outside the rotational area.

The experiment has possible thermal problems that need to be addressed. The first problem concerns the isolation of the experiment from the rest of the GASCAN. Unlike the other experiments, this experiment is designed so that its interaction with the rest of the canister is minimal. This configuration was chosen to allow smoother rotation of the platform, with less chance of interference from the other experiments. Although this is the desired design, it may create a critical thermal problem. Energy may need to be channelled to or from the experiment to prevent overheating or freezing.

When discussing the channelling of energy, one must realize that in microgravity there is very little natural convection. The amount of free convection is directly related to the gravitational force present. Therefore, in space the amount of free convection will be very close to zero. This prediction is valid for the GASCAN only when the rotational flow experiment is not in operation. During its operation, the initial speed of the platform will create an outer acceleration of approximately 2 g. This will directly affect the convective coefficients and the rate of convection. By doubling the gravitational force, the

Grashof number, Nusselt and Rayleigh numbers will be increased. This increase will raise the rate of free convection at the initial rotation speed in the experiment.

The second potential problem area is the pump and motor-drive systems. With properly instrumented Earth-based testing, the pump system is not expected to be a problem. However, the temperature within the flow experiment compartment must not exceed the acceptable operating temperature spectrum of the pump, which is 210°F.

The motor-drive system is not anticipated to be a problem over the operating time of the experiment. Initially the motor will be brought up to full power. As the experiment continues, the motor speed will be decreased, thereby decreasing heat generation.

Other areas of interest are the bearings in the rotational hub, the camera system, and the viscosity of the fluid. The latter is not anticipated as a problem by the rotational flow MQP team. The viscosity of the fluid remains fairly constant over a wide range of temperatures. The bearings on the other hand may present a problem. If they experience a high degree of friction while in microgravity, heat will result. This heat would then be conducted outward increasing the platform temperature.

Finally the camera system presents a potential problem. The problem does not lie in heat generation, but rather energy absorption. The critical area is the film. Most films can operate in a temperature spectrum of -10 to 40°C. If the rotational compartment will not be in that temperature range, either an improved thermal design or alternate photography methods may be necessary.

Computer Thermal Analysis

Ultimately, the thermal design of the GASCAN will require a complete thermal analysis, which will show if any of the experiments inside the canister will fail due to temperature extremes.

In order to calculate temperature distribution versus time, a simulation program is needed that keeps track of time varying situations such as ambient conditions and power dissipation.

The program SSPTA (Simplified Space Payload Analyzer), which was provided to previous groups, not only solves transient problems but also provides view factors. Given the material properties, geometry, power dissipation and orbital orientation, SSPTA will allow calculation of temperatures and view factors for each thermal node at specified time intervals. SSPTA can take up to 999 surfaces and 600 thermal nodes.

It is our recommendation that follow-on design teams proceed with the full thermal analysis using SSPTA or similar analysis programs. Particular attention should be paid to those potential thermal problems identified by this design team.