MCTAL FORMS
TIN
SOLID SUSPENSION
SPACE MANUFAC

EXPERIMENT DESIGN
BUBBLES
ZINC COMPS.
CARBONATE
REDUCED GRAV.
RADIATION SHIELDIN

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Design of an Experiment for the Production of a "Foamed" Tin Sample

by

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Abstract

~~The purpose of this paper is to present to fellow GAS users a portion of Purdue University's efforts.~~ One of the major experiments in our GAS container is concerned with the experimental production of a foamed metal. A foamed metal is one that contains a significant amount of gas bubbles suspended in its solid volume. Purdue's GAS team proposes to do this with the help of a solid zinc carbonate that gives off carbon dioxide at high temperatures. Because of low energy requirements, the metal used for this experiment is tin. It is hoped that the use of near zero environment will keep the suspended bubbles more uniform than in an earth based process, hence not depleting the physical strength of the materal as greatly as is observed on earth.

1. Introduction

A major problem with construction of large space structures is that large amounts of material must be brought from either the earth or the moon. This is both expensive and time consuming. One method that has been proposed to overcome this problem is to produce at the construction site a material that has small gas bubbles uniformly distributed throughout the foamed metal's volume. This process greatly increases the useful material while decreasing the expense to bring the material to space. Not only could this type of material be used for structural purposes but also for radiation shielding from the sun. The amount and type of gas would largely depend on the purpose chosen for the foam metal.

The Purdue GAS team is planning to produce a sample of a foamed metal. This will be a cylindrical piece of tin, 3 inches in height and 1 inch in diameter, having 1/2 of the volume occupied by carbon dioxide. Placing the carbon dioxide into the tin will be done by a foaming agent (a chemical that gives off a gas at high temperatures). For our purposes, a minimum energy foaming agent is desired, so zinc carbonate is chosen. At 575 kelvin, zinc carbonate decomposes to zinc oxide and carbon dioxide. Because of the small amount of foaming agent required, the impurity resulting from the zinc oxide is negligible.

This experiment is broken down into three distinct phases: (1) construction (preflight), (2) experimental (flight) and (3) testing (postflight). Each of these are discussed below.

2. Construction (preflight)

In order to obtain the desired final geometry, a cylindrical containment vessel with moveable piston heads is chosen. A movable piston is necessary to allow expansion during the foaming process when the carbon dioxide gas is given off. The temperatures required for the decomposition of zinc carbonate (the foaming agent) suggested that a ceramic container would be suitable.

Another consideration in this selection is that the vessel has to be structurally strong, have high thermal conductivity (k), low specific heat (Cp) and low density. These requirements will minimize the chances of the vessel breaking on launch due to vibrations and provide for a low weight container. The high conductivity would insure that the heat given off by the nichrome heating coil around the container would quickly be transferred to the tin sample. The low capacity would insure minimal heat retension by the container. After much consideration an alumina ceramic container is chosen with dimensions given in Fig. 1 (and the physical properties of k = 18.5 W/m K, Cp = 906, J/kg K, density = 3850 kg/cubic meter). To heat the zinc carbonate, to decomposition temperature, a nichrome wire is used. For the heat requirements, a total of 9.2 turns (.66 container height ohms/ft.) is needed, requiring one turn every 1/3 inch. To ensure that most of the heat given off is effectively used, a glass fiber blanket (k = .038 W/m K, Cp = 835 J/kg K, density = 32 kg/cubic meter) is used to insulate the nichrome wire from the environment.

To enable the now liquid tin to solidify, after the zinc carbonate has decomposed, an aluminum rod (1/8 inch diamter, density = 2700, kg/cubic meter, k = 237 W/m K, Cp-903, J/kg K) is placed so that when the two containment pistons, seen in Figure 1, are expanded fully, one is in contact with one end of the rod. The other end of this rod is connected to the passive thermal control salt that is used to control the temperature of the whole payload. By doing this, the thermally "hot" region of the experiment is connected with the thermal sink of the passive heat cells. The heat cells absorb energy if not fully charged, which will be the case by the time the experiment is in operation. This speeds up the cooling process, which prevents the sample from having nonuniform carbon dioxide bubbles that can be caused by possible orbiter maneuvers during a long solidification period.

To insure that in a weightless environment the poston heads stay in contact with the tin-zinc carbonate mixture a "pseudovacuum" is created. This is done by first heating up the required amount of tin to the liquid phase, but below the decomposition temperature of zinc carbonate (575 k), then adding the zinc carbonate as a solid. This liquid mixture is poured in to the containment vessel with one end blocked by a piston head. After allowing it to solidify, the solid cylinder of tin-zinc carbonate mixture is removed from the container and the ends of the sample are ground to remove any oxidized tin as well as modifying a flat surface for contact with the other piston head. Next, the solid tin-zinc carbonate and one piston head are held against one another while these two pieces (tin-zinc carbonate first) are pushed into the containment vessel until the uncovered end of the tin-zinc carbonate is flush with the centerline of the hole for the stopbar (see figure 1). The stopbars are used to prevent the piston heads from overextending during the foaming process. In this position the other piston can be put in place while the trapped air escapes out the stopbar hole. These three pieces are pushed down a little more and the stopbars are put in place. Because there is little space between the pistons and container wall, no air is able to separate the pistons and the tin-zinc carbonate sample, regardless of relative position of the piston tin-zinc carbonate pieces to the containment vessel. The nichrome heating wire is then wrapped around the containment vessel. The glass fiber insulation blanket is added leaving room for the exit of the aluminum heat sink rod and the nichrome heating wire leads to the power supply. The entire apparatus is now complete and ready for launch.

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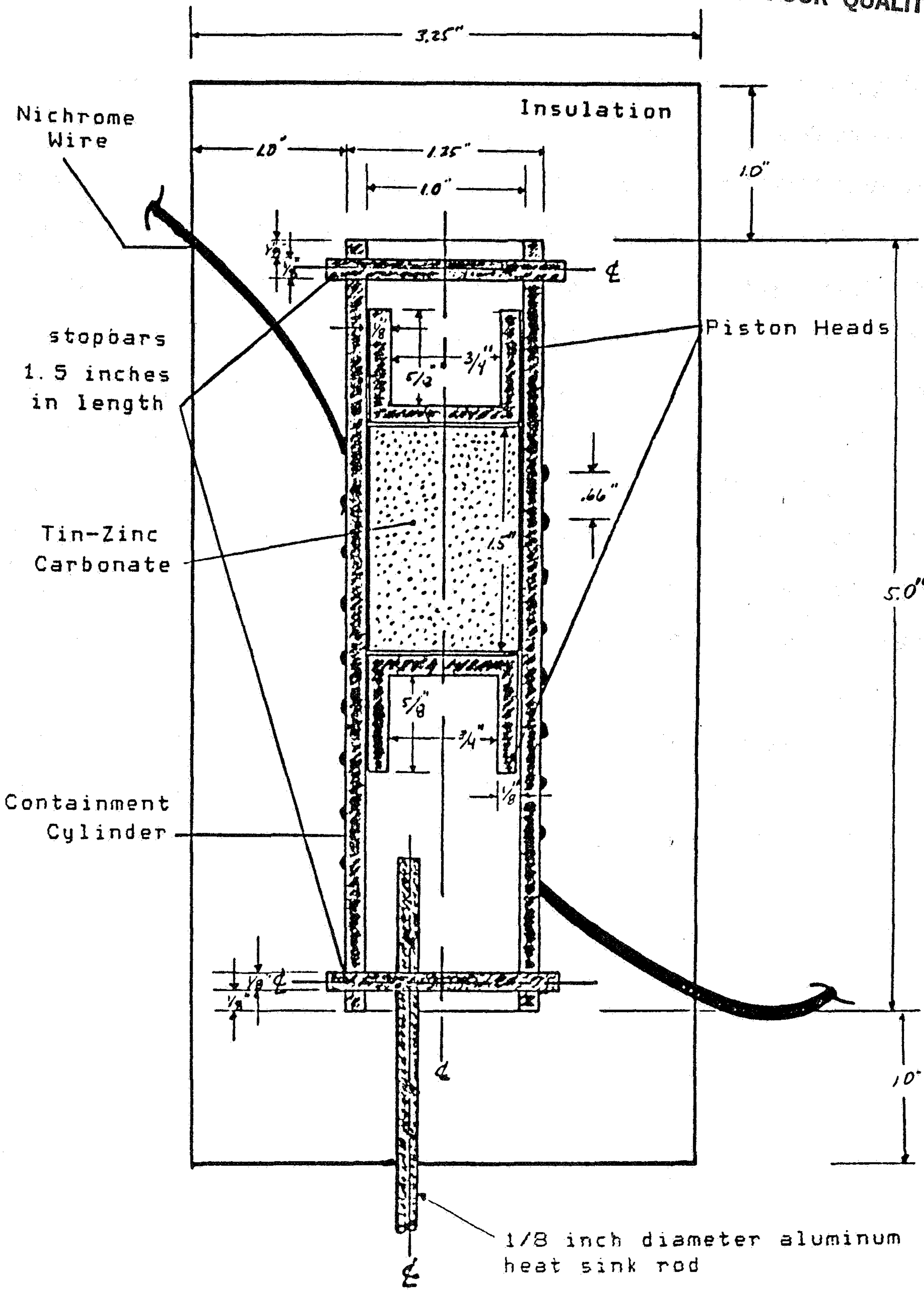

Figure 1 Cross Sectional view of Apparatus

3. Experimental (flight)

Once in orbit during a period when the Orbiter is not making any maneuvers, the nichrome heating wire is turned on by the canister's micro-controller. The micro-controller will hold the temperature of the wire at about 600 K which is approximately 25 K above the decomposition temperature of zinc carbonate. This is to be done by a direct temperature feedback system using a thermocouple placed on the outer containment vessel wall (not shown in Fig. 1). Once power is applied, there will be a short warm-up period for the container, then the tin sample goes into the liquid phase (595 K). Decomposition of zinc carbonate begins at about 575 K. During this decomposition the zinc carbonate becomes zinc oxide and carbon dioxide. Because carbon dioxide is a gas and zinc carbonate is a solid the volume increases greatly, moving the pistons away from each other until stopped by the stopbars. Using a finite difference thermal model the approximate total time required between warm-up and decomposition of zinc carbonate will be 10 seconds. Thus a timed power shut down after 15 seconds is sufficient. Because of the insulation almost all of the required 10.5 kJ of power will be dumped into the passive heat cell used by the entire canister. Using another finite difference thermal model, the estimated time required between power shut down and solidification will be less than 5.0 minutes.

4. Testing (postflight)

After the flight the foamed sample made in space will be strength tested against samples of solid tin and aginst other foamed samples made on earth. The sample foamed in space is tested against samples made on earth to determine if the carbon dioxide gas generation is more uniform in space and if so how uniformity effects the strength. Using strain gage analysis the Purdue GAS team will be able to determine the full extent of the changes in material strengths under shear, torsion, compression and tension. It is hoped that the strength to weight ratio will greatly increase in all areas.