A Gondola for Physiological Research in the Atmosphere

By William D. Murray
Project Director, Research Division, College of Engineering, New York University

FOR MANY years atmospheric research has been carried out using the balloon as a vehicle. Although animals, mainly humans, flew on the earlier flights, altitudes attained were not sufficient for a determination of any harmful physiological effects other than the classical ones due to lowered temperatures. Indeed, the only major effects noted on animals sent aloft up to the past few years, were those due to decreased temperature, pressure and oxygen content of the atmosphere.

With the advent of high altitude aircraft there has been a renewed interest in a determination of the effects of atmospheric phenomena at very great altitudes on the human physiology. A special interest in the effects of natural cosmic radiation has been generated by recent information regarding the intense energies of such radiation coupled with new knowledge of the effects of radiation on the cells of the body. Although a deduction of possible high altitude effects can be made by laboratory studies of radiation and radiation effect, a final confirmation of results obtained by such a method can only be made by exposing animals to high altitude radiation conditions and examining the effects of such exposure on blood and tissue.

In spite of high energy levels the intensity of cosmic rays is low, hence in order that valid results be obtained with these experiments it is necessary that the animals be maintained aloft for a long duration of time. For this reason the specimens must be housed in a container designed to maintain internal conditions at a level to support animal life for periods of a day or more. Containers for substaining small animal specimens at high altitudes have been used by the Aero Medical Laboratories, Wright Air Development Center, which have conducted experiments in Aerobee rockets, and the University of Minnesota in balloon experiments.

A need was foreseen for development of a container specifically designed to carry animals weighing up to twenty pounds to altitudes between 80,000 and 100,000 feet and maintain internal conditions at a level to permit flight durations of thirty-six hours. Under the sponsorship of the Air Research and Development Command, a program for such a development was carried out by the Research Division, College of Engineering, New York University, in collaboration with the Aero Medical Laboratories, Wright Air Development Center.

Presented before the 24th Annual Meeting of the Aero Medical Association, Los Angeles, California, May 11-13, 1953.

REQUIREMENTS FOR AN ANIMAL CONTAINER

In designing a container for this research, requirements for several systems of the container are imposed by the specimens, the balloon vehicle, and the atmospheric environment. All of these requirements must be satisfied, since failure of any portion of a balloon-borne system of this type is sufficient for failure of the experiment.

Considering first the structural requirements of the container system, there are several loads imposed on the system which must be designed to withstand these loads. The basic load to be considered is that of the pressure differential across the shell of the container. Since the pressure of the air in the container remains at approximately one atmosphere and the pressure outside the container is reduced to a value near zero at 100,000 feet, the pressure difference is approximately 15 psi. If the diameter of a spherical container is 28 inches, the force tending to split the shell is approximately 3700 lbs. It is this force which determines the thickness of the shell and the size of any attachments to hold portions of the shell together. Other considerations under structural requirements are the application of a suitable factor of safety to overcome effects of weight of internal equipment, acceleration during flight (both of which are small compared to pressure loading) over-pressurization of the container, and aging due to repeated use of the container. In addition, a method of preventing damage on impact after a balloon flight must be included.

Next, we must consider the thermal requirements of the system. The temperature of the air in the container is effected by heat gained from the specimens and any equipment inside the container and by heat lost to the cooling system and by conduction to the outside of the container. Loss of heat from the outside surface of the container is due to convection (dependent on diameter, pressure, and temperature difference), and radiation (dependent on surface material, area, and temperature difference). A solution of equations resulting from these relationships will result in a determination of the required heating and cooling rates to maintain temperature between allowable limits determined by the specimen.

Pressure within the container must be maintained between limits determined by functioning of the specimen. Low pressures will cause difficulty in breathing and oxygen concentration must be increased. When the pressure is reduced below approximately 5 psi (that at 30,000 ft.) respiratory difficulties will be encountered even if the air consists of pure oxygen. At higher altitudes other physiological effects will be found (ex.—vaporation of blood and other cell liquids). In addition, other problems are interposed if there is a large rate of pressure change (explosive decompression, etc.). For these reasons it is essential that the pressure in the container be maintained at some high value.

A fourth requirement of the container is maintenance of satisfactory air composition throughout the flight. Since the animal specimens constantly consume oxygen and liberate carbon dioxide and water vapor a method must be included to supply and remove these gases as needed. Although other methods have been suggested, the use of compressed or liquefied oxygen supply coupled with chemical adsorption of waste gases offers the only practical means of controlling the internal atmosphere at the present time.

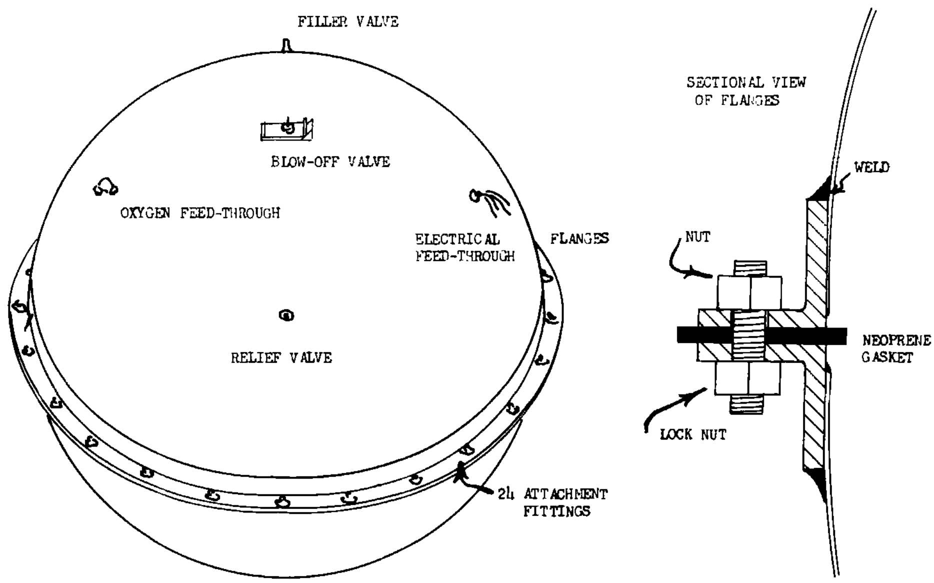

Fig. 1.

The amount of oxygen required depends on the size and metabolism of the animal used. This requirement is closely associated with the thermal requirement, since the heat output of the specimen and its oxygen consumption are mutually dependent on the metabolism. The amount of carbon dioxide required to be removed is approximately equal to the oxygen supply needed.

The need for removal of water vapor is introduced by problems of overheating of the specimens. The "effective temperature" which is a measure of effect of temperature on the animal is a function of temperature and relative humidity. This is due to the fact that, while the heat required to be released is a function of the animal metabolism, the heat lost by convection to the air (sensible heat), is dependent on the difference between the animal body temperature and the free air temperature and the air velocity. The balance of the heat required to be released must be removed by evaporation of moisture (latent heat).

Since rate of evaporation is proportional to the degree of insaturation of the air, or inversely a function of relative humidity, it is necessary that relative humidities remain at low values, especially at the higher temperatures. This is an even more important factor with small mammals than with humans, since, in addition to their poor capacity to lose sensible heat due to good insulation coating, their system for evaporation of liquid is relatively ineffective. Thus an effective system a minimum consistent with effective operation. Field operation requires that it be easily handled at launching and that it be easily, swiftly, and sure-

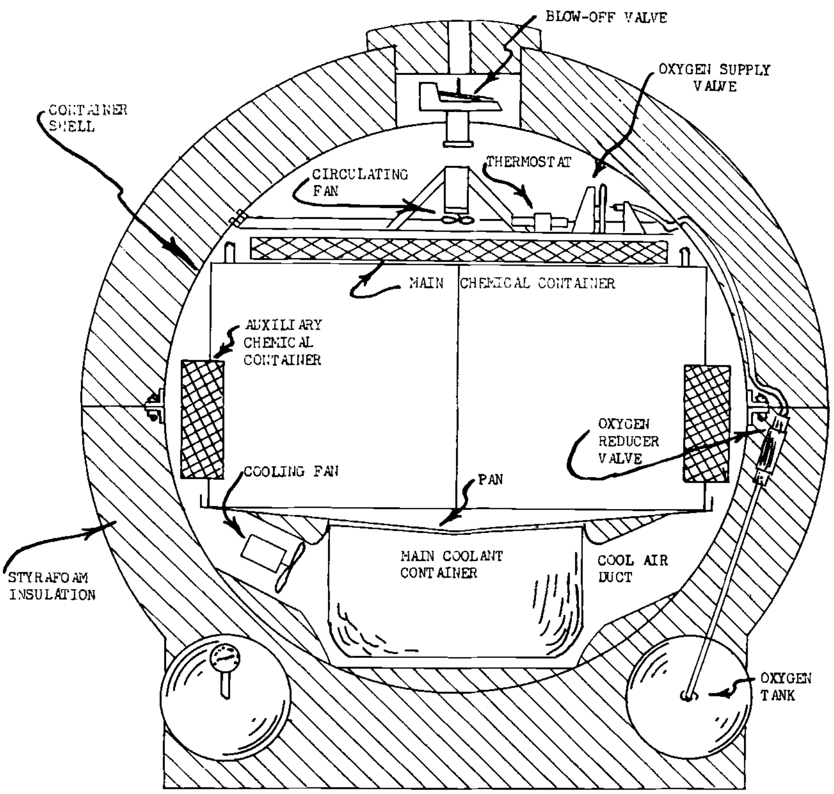

Fig. 2.

for removing water vapor from the atmosphere must be included in the animal container.

In addition to the four basic requirements of structural strength, temperature control, relatively constant pressure, and atmosphere control, there are several requirements introduced by the operational use to which the container will be placed. Since it is to be carried aloft on a balloon vehicle it is necessary that weight be kept at ly assembled and sealed before flight. Finally, it is desirable that it be readily adaptable to repair and maintenance so that it can be used repeatedly in a continuing experimental program.

THE NEW YORK UNIVERSITY CONTAINER

The animal container developed by the New York University group was designed to meet the requirements reviewed above. Although there are methods of meeting the requirements other than those used, it is felt that the system developed has made use of the most practical current techniques for satisfying these requirements.

The basic container consists of two hemispheres spun from aluminum (Fig. 1). It is 28 inches in diameter and has flanges constructed from extruded aluminum angle bent and welded into a ring. The two hemispheres are connected, using a rubber gasket for effective pressure sealing, by nuts tightened on twenty-four stainless steel studs which are imbedded in the lower flange. This sphere was designed for an internal pressure of over 50 psi and thus has a factor of safety of 3 based on a pressure differential of one atmosphere. The units, when sealed, were hydrostatically tested to 35 psi and showed no significant leakage at this pressure.

Inside of the container (Fig. 2) is a cylindrical cage, 24 inches in diameter and 12 inches high, separated into two semi-cylindrical sections. The cage is constructed of aluminum angle and expanded aluminum and has sufficient durability to withstand rough handling. Access to the cage is through two latched doors on the top.

A circulation and cooling system is included to control the temperature and to effect efficient operation of the adsorbing chemicals. The system consists of a circulating fan, a cooling fan, a thermostat and relay control, and a battery supply in addition to coolant containers. The main coolant container is located in a styrafoam section below the animal cage. The cooling fan is placed in a duct so that it forces air past the container as required. A thermostat located above the cage activates a relay whenever the temperature increases above a pre-set design value. This relay in turn causes the cooling fan to operate, circulating warm air past the cooling container and up into the cage until the temperature is decreased below the designed value. At this time the circulating fan above the cage is re-activated.

In addition to the automatic cooling system there are two auxiliary coolant containers shaped to fit around the cage. These units hold approximately eight pounds of ice and serve to remove heat during the first day of flight. After these units have been exhausted the main cooling system will take over the job of cooling the container.

Included in the system are three chemical containers. The main container, a flat disk of wire screen, is placed above the cage and is filled with approximately four pounds of soda lime and two pounds of silica gel. Circulation past these chemicals is maintained by the circulating fan. These chemicals remove carbon dioxide and water vapor as produced by the specimens. To assure that these gases will be removed when the cooling fan is operating, two additional chemical containers are placed at the entrance and exit of the cooling duct. The chemicals will adsorb one-half their weight of the gases as produced and are sufficient for over 48 hours of experiment duration. When possible, indicating varieties of the chemicals are used in order that the amount of gas produced during an experiment can be roughly determined.

Operating in conjunction with car-

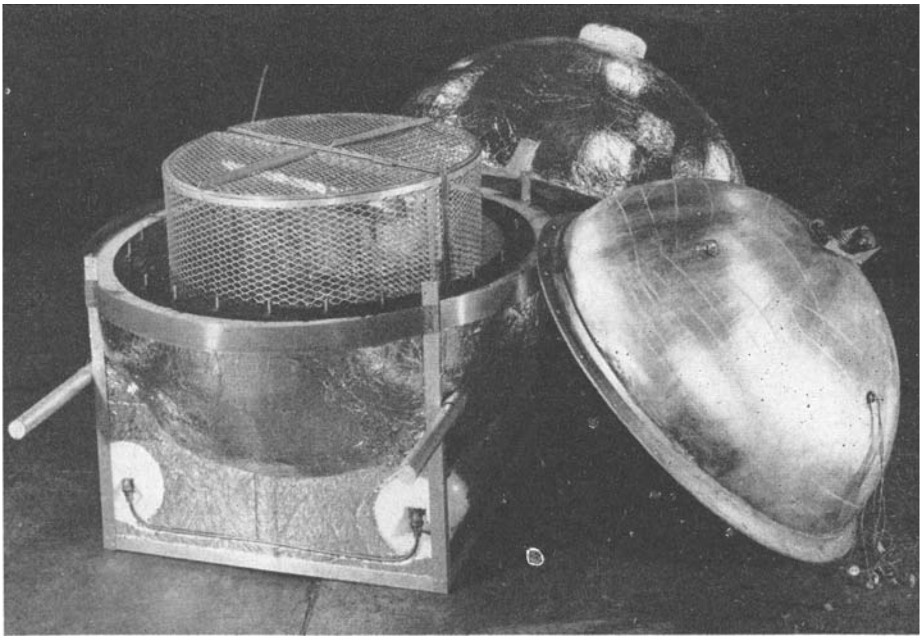

Fig. 3.

bon dioxide adsorption is the oxygen supply system. This system consists of two 500 cu. in. oxygen tanks filled initially to 450 psi, a reduction valve to drop pressure to 80 psi, a feed-through to take the supply tube through the shell wall, and an oxygen supply valve. The supply valve is aneroid activated and is controlled by the reduction in internal pressure caused by adsorption of carbon dioxide. With this system the nitrogen content of the air in the container remains constant, therefore eliminating dangers of excessive oxygen.

Other fittings in the shell are a pressure safety valve which opens when internal pressure exceeds 25 psi, an electrical feed-through for instrumentation leads, a filler valve for pressure testing on initial charging with oxygen, and a blow-off valve to open when the system returns to the ground after flight.

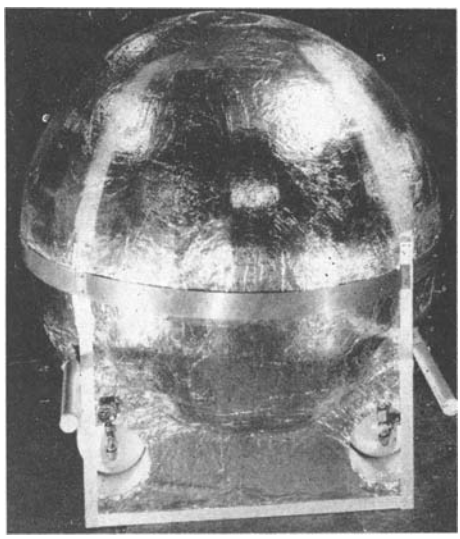

Fig. 4.

The container is surrounded by a four-inch shell of styrafoam to serve as an insulation and as a shock absorber at impact. The styrafoam is covered with aluminum foil to reduce absorption of solar energy. A frame is included around the styrafoam for attachment to the balloon load line (Figs. 3 and 4).

TESTS PERFORMED AND PLANNED

Several tests have been performed on the animal container. Two successful evaluation tests were performed in the altitude chamber at the Aero Medical Laboratories, one for twelve hours under simulated night conditions, the other for fifteen hours under daytime conditions. In these tests satisfactory performance of all components was obtained. In addition an 18-hour ground test was completed to prove operation of atmosphere control and cooling systems.

To date several flight tests have been attempted. The first was performed before need for the cooling system was ascertained and was a failure due to overheating. Other components, however, operated satisfactorily. A second flight test, after the cooling system was included, was unsuccessful due to a balloon failure during ascent. On a third experiment the equipment was lost by the tracking aircraft and results are as yet unavailable.

It is planned that a series of evaluation flights will be performed to perfect the tracking and recovery system. After this series, experiments to determine effects of cosmic radiation on animals will be carried out. It is hoped that a further report on the progress of these experiments can be made in the near future.

Refresher Course at Ohio State University

The Ohio State University College of Medicine and the Medical Division of the Civil Aeronautics Administration will jointly sponsor a graduate refresher course in aviation medicine at Columbus, Ohio, from September 13 to 18, 1954, which has been approved by the Aero Medical Association and the Airline Medical Examiners Association.

The curriculum for the course will include lectures and discussion periods on recent advances in the practice of ophthalmology, including visual stresses, eye examination of airmen, color discrimination and its measurement, and depth perception; otolaryngology; respiration and metabolism; psychiatry; endocrinology, especially diabetes; cardiology and cardiovascular diseases, including ballistocardiography and vector cardiography; aviation toxicology; medical and physiological effects of acceleration; cabin pressurization; and psychological evaluation of airmen.