Methods and Results of One Year of Balloon Flights with Biological Specimens

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IN RECENT years Dr. Herman J. Schaefer[3] has shown that heavy primary cosmic ray particles can be expected to produce ionization tracks as long as several millimeters in living tissue. These tracks reach central ionization intensities of thousands of roentgens, and significant radial radiation to the order of cell diameters. Since no particle can be accelerated artificially to compare directly with the higher weight cosmic ray primaries, there has been considerable question concerning the exact biological effect of such particles. Recently Dr. Eugster of Switzerland has reported a track through human skin imbedded in nuclear emulsion,[2] and Dr. Yagoda has reported the passage of a heavy primary through vegetable fiber imbedded in emulsion.[4]

METHODS

The Space Biology Branch of the Aero Medical Field Laboratory first attempted to expose intact animals to primary cosmic radiation in August, 1951. These early test flights were conducted by enclosing fruit flies and hamsters in a sealed spherical aluminum gondola or capsule developed by the University of Minnesota for stratosphere physical measurements. These flights were designed for eight hours, launched from Holloman Air Force Base, New Mexico, and tracked with Air Force aircraft. By the end of 1952, five flights had been launched. One was successfully recovered after a six-hour flight. Of the remaining four flights, two never reached altitude because of balloon failure, one gondola failed to hold pressure on a 1.25 hour flight, and one was successfully tracked for twenty-eight hours at which time it was lost in a thunderstorm and never recovered.

In February, 1953, the second twenty-four-hour flight was attempted using this type of capsule. The only change made from previous flights was the addition of ten pounds of water in a rubber inner tube to provide thermal ballast to keep the contents of the gondola warm at night and cool during the day time. Figures 1 and 2 illustrate the contents of the gondola which include track plates, thermograph, barograph, a box for the hamsters, and a box for soda lime.

On this flight, the instrumentation package included an AM-1 radio beacon transmitter, twenty-six-hour timed cut-down, low altitude cut-down, and a barograph. The transmitter emitted one tone above 85,000 feet, a different tone below 85,000 feet, and a third tone after cut-down. On this and four subsequent attempts to track

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twenty-four-hour flights with similar instrumentation, great difficulty was experienced with tracking through the night because the balloon beacon radio

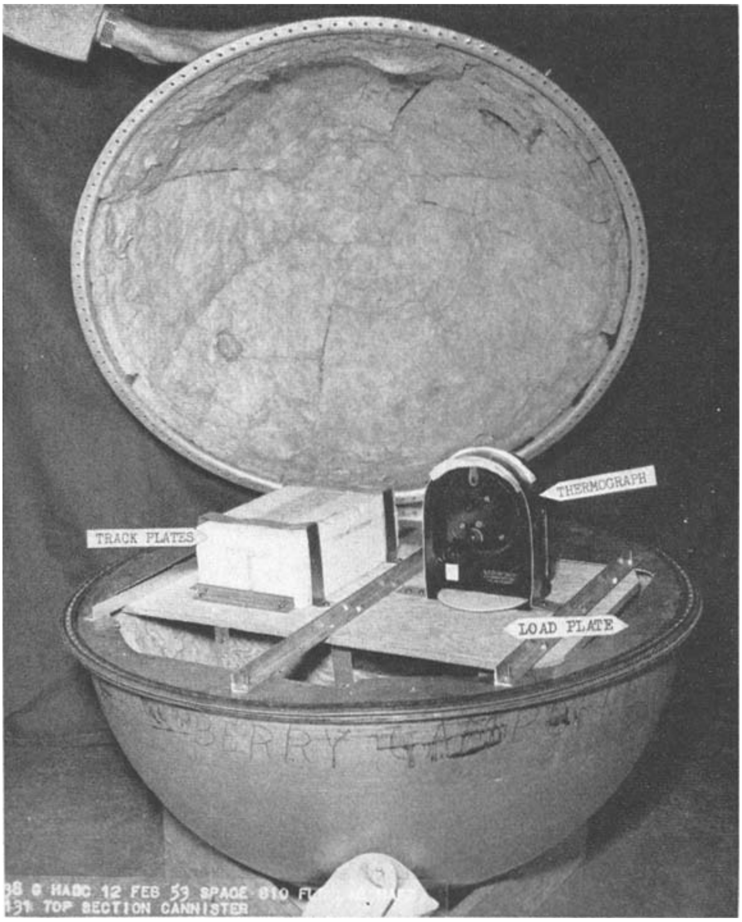

Fig. 1. Top view of load plate, February, 1953 flight.

signal was not sufficiently distinctive to permit positive identification, and because so little information concerning the altitude of the balloon was provided. Later these problems were resolved.

As shown by Dr Schaefer[8] and reconfirmed at the Space Medicine Association meeting of 1953, to obtain exposure to heavy primary thin-downs it is necessary to fly at geomagnetic latitudes above 50°. This is true because of the increased equitorial deflection effect of the earth's magnetic field on the more abundant lower energy heavy particles. These lower energy particles (approximately one billion electron volts per nucleon) are most likely to escape termination by nuclear collision or star formation. Full exposure is obtained anywhere above 58° geomagnetic latitude because of the low energy cut-off of the primary energy spectrum.[1] Based on this necessity to provide exposure north of 50° geomagnetic latitude, preferably north of 58°, two series of two flights each were launched from Great Falls AFB, Great Falls, Montana, during June and July of 1953.

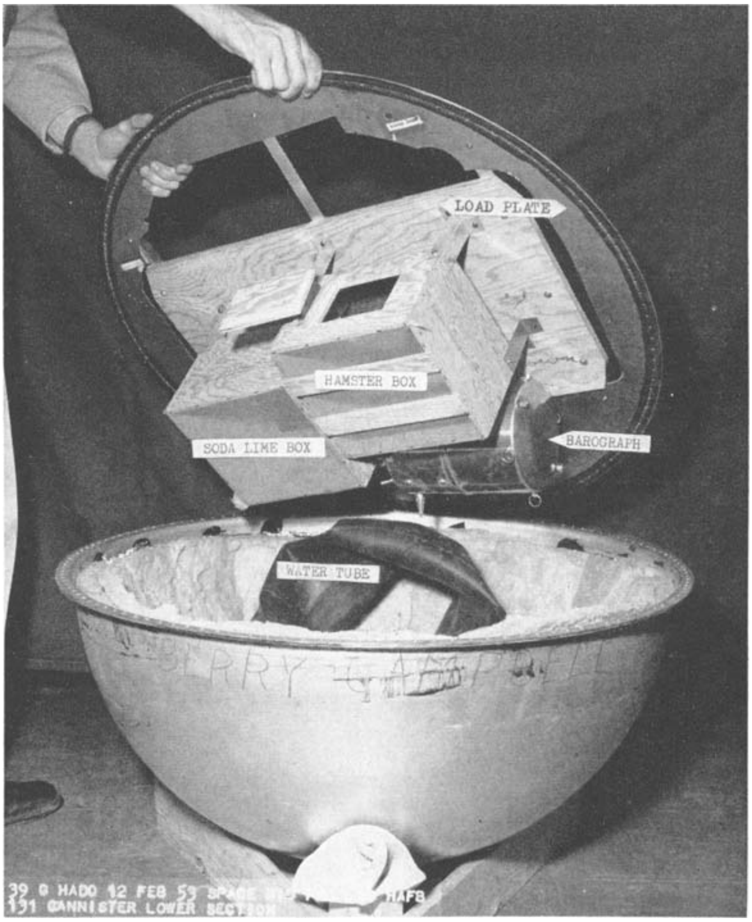

Fig. 2. Bottom view of load plate, February, 1953 flight.

Two instrumentation improvements were made on these flights. A modified radiosonde commutator bar selected one of five tones which provided altitude data of 5,000 foot resolution with numerous ambiguities. This information was alternated with an identifying code signal which permitted unequivocal identification of the transmitted signal. No attempt was made to ballast these flights, because a constant altitude was considered less desirable than the greater maximum altitude otherwise obtainable.

The first two flights were successfully tracked and recovered. The third flight was successfully tracked, but due to balloon transmitter and parachute failure at the time of cut-down. the packages were not recovered. On the fourth flight both the altitude coding device and the tracking aircraft's radio compass failed shortly after launch. While the aircraft radio compass was being repaired the balloon descended prematurely. The packages have never been recovered.

In October and November, General Mills conducted a series of flights from Pierre, South Dakota, under Air Force Contract. A CW transmitter developed by General Mills, was used which provided coded altitude data of approximately 500 foot resolution at floating altitudes. These flights also included provision for radio controlled release to effect command separation of the packages at any time during the flight. This was used to advantage on several occasions during the series. The 90,000 foot automatic ballast control operated very effectively on these flights.

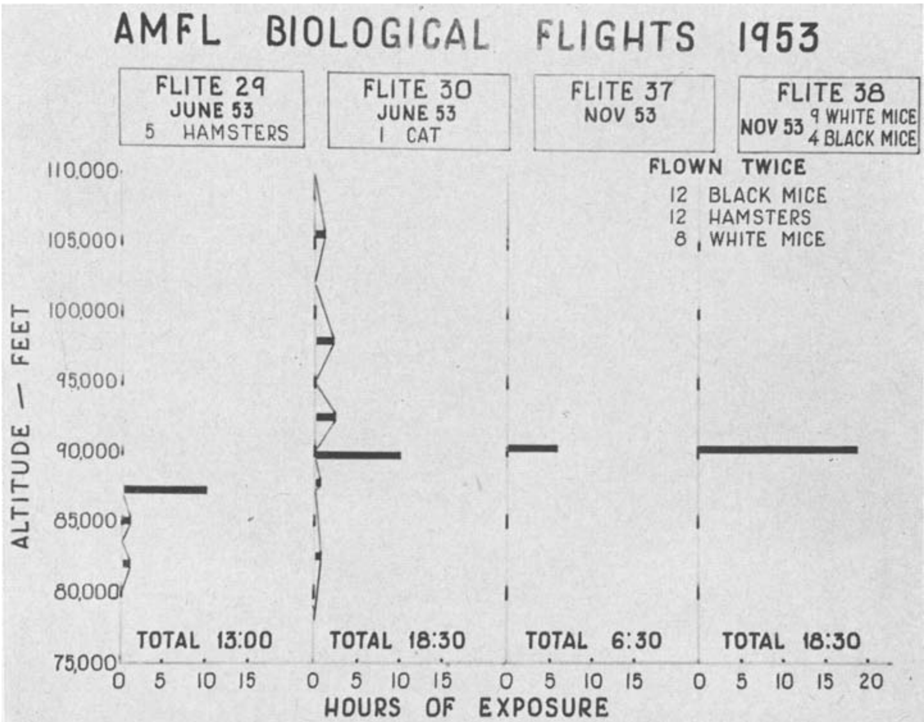

Fig. 3. Duration-altitude graph of four successful flights.

The first General Mills flight was successfully tracked for twenty-eight hours, but the value of the experiment was lost due to a combination of parachute and capsule pressurization failure. Two subsequent flights totaling twenty-five hours were successfully recovered.

The time-altitude graphs for the four northern flights successfully recovered to date are shown in Figure 3. On these flights, track plates, onions, and white mice were flown for other agencies. The black mice were evaluated by Dr. Chase of Brown University. The brains of the hamsters recovered from these flights were carefully examined for streaks of damaged or dead cells attributable to bombardment by cosmic particles. On preparations stained with Holmes silver technique and examined by Dr. Berry Campbell of the University of Minnesota, no such tracks were observed.

Since the gondolas on the earlier flights carried so few animals, rudimentary internal environment control was adequate. This was proven by the fact that the six hamsters in the capsule flown in February, 1953, were alive when the capsule was opened in Florida one week after launch.

The gondolas used on the November flights included thermostatically controlled heating and cooling devices, an ample oxygen supply, carbon dioxide removal, and water absorber sufficient to provide for the needs of the equivalent of sixty adult mice. The animal gondola, ready for flight weighed 89 ± 2 pounds on this series of flights.

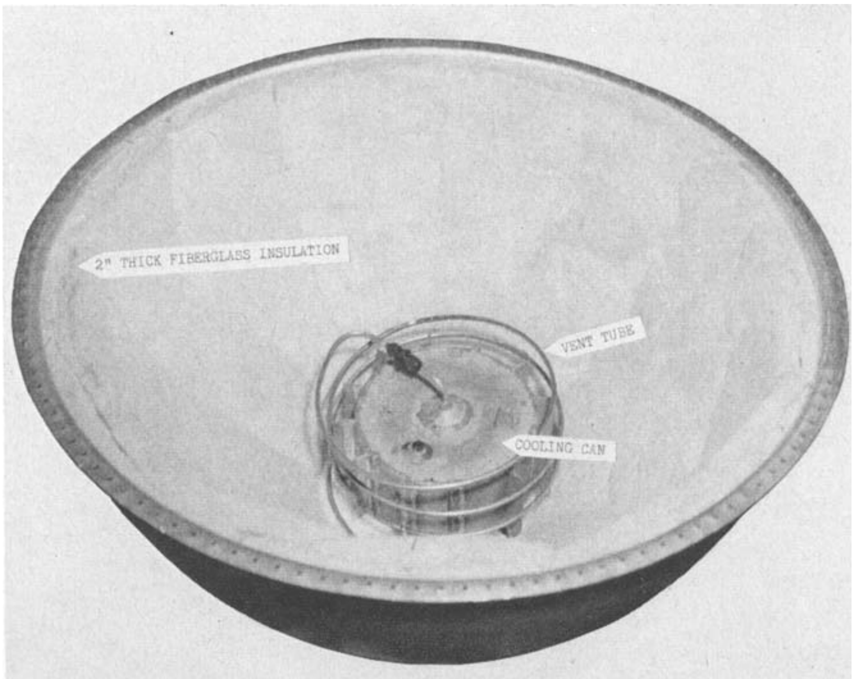

Fig. 4. Water cooler installation.

Chamber tests and calculations* of heat flow indicated that several hundred watts of heat in addition to that produced by the animals would be necessary to keep the internal capsule temperature above 65° F during the

*Mathematics performed by Dr. G. R. Rosenthal and Dr. Fritz Hoehndorf of the Technical Analysis Division, Hafia night. Likewise, tests and calculations indicated that 560 Kilo Calories must be removed during the day to keep the internal temperature from rising above 75° F.

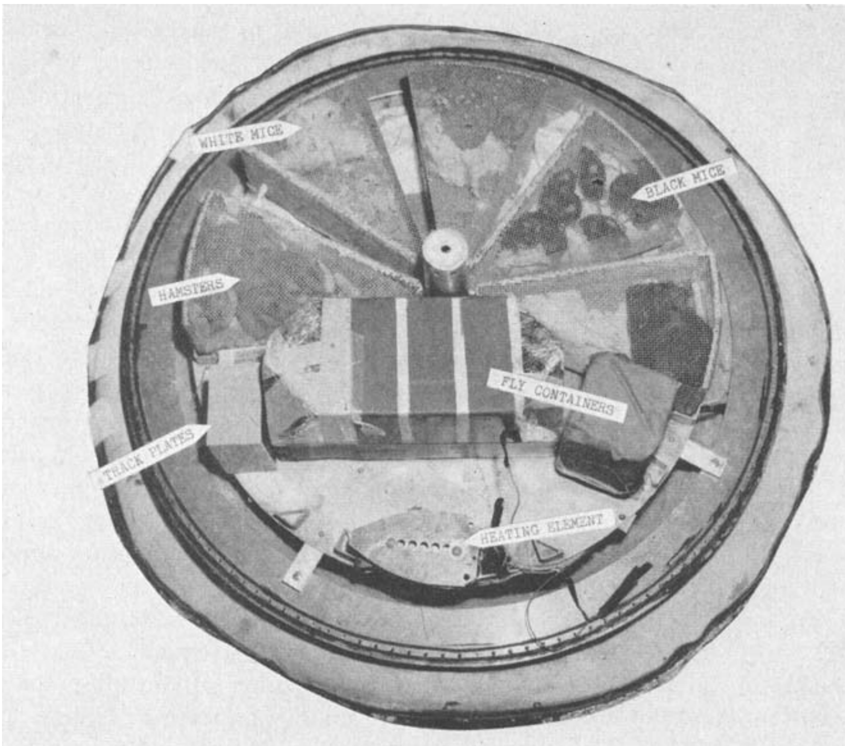

Fig. 5. Top view of load plate, November, 1953 flight.

Heat was supplied by a 5-ampere-hour 28-volt lead-acid battery weighing twenty pounds. Cooling was obtained by taking advantage of the fact that at 90,000 feet, water boils at 60° F. The temperature of a simple water can (Fig. 4) vented to the outside pressure at 90,000 feet will not go above 60° without making the water boil. Any heat absorbed that would tend to raise the temperature above this value converts some of the water to vapor, taking 587 calories per gram with it. Although only a few grams of the 640 grams of water carried on flight 38 were vaporized, the cooler was effective during the daytime since the temperature dropped whenever the thermostat reached 75° and made the fan circulate air through the cooling chamber.

Oxygen was carried in a steel cylinder at 450 psi pressure and metered into the capsule through a two-stage demand valve. Carbon dioxide was removed by three pounds of soda lime spread out on a crinolin-covered tray which formed the ceiling of the water-cooler compartment.

Figure 5 shows the load ring which is clamped between the two halves of the gondola when ready for flight. The cages contain white and black mice, and hamsters. Fruit flies were sealed in a thermos bottle encased in styrafoam to give them added protection from depressurization and loss of temperature control. Unfortunately, difficulties with their media prevented successful recovery and evaluation of genetic effects. The electric iron heating element was actuated whenever the fan blew air upward to warm the capsule. The heating and cooling functions were controlled by two thermostats through a double-pole double-throw, sealed relay.

The barothermograph indicated the time and duration of activation of either the heating or cooling functions, and recorded internal temperature and pressure. Records of flight 38 showed that throughout the flight the temperature was maintained between 65° and 75° F.

The capsule, prepared for flight, was attached to the balloon train as the polyethylene balloon was being inflated with helium. Only the top half of the capsule was covered with aluminum foil to reduce heat absorption during the day while the bottom half was left dark to facilitate absorption of earth radiation at night.

DISCUSSION

The early difficulty in tracking a balloon for thirty hours has largely been overcome by employing a coded signal which can be readily and unambiguously identified. The addition of high resolution altitude data greatly facilitates anticipation of balloon performance. The increased length of time which the chase aircraft can safely remain on the ground between airborne checks on the exact balloon position reduces the cost of the mission, and increases air crew effectiveness.

The loss of several 30-hour flights could be attributed directly to the fact that there was no way of terminating the flight before the preset clock timers functioned. The successful use of a radio controlled command separation device marks a major instrumentation advance for this type of flight.

By providing carefully controlled environmental conditions within the gondola physiological stress can be practically eliminated. This reduces the parameters which may affect the results of the experiments and permits the same specimens to be reflown on successive flights without seriously jeopardizing their chance of survival.

The biological effects observed on the black mice are being reported separately by Dr. Herman B. Chase.

Computation of the hit probability for the flight patterns of these specimens indicates that, statistically, none of the hamsters can be expected to have suffered termination of nuclei of the atomic number range 20 to 26 (Iron Group). However, many particles of the atomic number range 6 to 8 (CNO) group would have terminated in their brains. Failure to observe histologic evidence of CNO tracks suggests that such tracks may not be detectable with current techniques. However, due to the few animals examined, and the considerable difficulty in locating a few microscopic tracks in an entire brain, particularly if they are not nearly parallel to the cut sections, this finding must be considered tentative. If similar results are obtained from flights designed for exposure to the Iron group of primary particles, the negative findings with respect to the CNO group will be confirmed.

It seems clear that the most effective way to determine directly the presence of observable primary cosmic ray effects on animal tissue is to design flights to obtain numerous hits per specimen by the most damaging primary cosmic particles present in significant quantity, namely, the Iron Group. To do this requires flights of 100 to 150 hours total duration per specimen at altitudes between 100,000 and 116,000 feet. Serial flights of thirty hours duration reaching 90,000 feet have been successfully accomplished. Similar flights can be maintained near 100,000 feet by using a 116-foot balloon rather than a 90-foot diameter one.

Although technically very difficult, if the specific region of the termination of Iron particles in tissue can be determined by track plate monitoring, it will considerably improve the efficiency of these studies.

CONCLUSIONS

1. Instrumentation and balloon tracking techniques are described which permitted serial 30-hour flights designed to float at 90,000 feet.

2. Environment control techniques have been developed which permit the oxygen-consuming equivalent of sixty mice to be flown at 90,000 feet.

3. By use of the techniques described in conclusions 1 and 2, living biological specimens were exposed to primary cosmic radiation on four successfully recovered flights. These flights totaled 56½ hours exposure above 85,000 feet north of 55° geomagnetic latitude. One group of specimens was recovered from two successive flights.

4. Primary emphasis was placed on technical developments. The biological data is submitted as a sample of the type of information that may be obtained by use of these methods.

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