nourished by fluid, which dialyses through from the opposite side of the membrane.

In our first experiments we used cellophane tubes (available as sausage skins), as shown in Fig. 1.

For the production of thick, slimy cultures on the inner side of the cellophane tube (Fig. 1a), the tube (1) is pulled over the ends of two glass tubes (2) of the same diameter and fastened to them at each end by collodion. Through the tube is passed a very slow current of air under a slight pressure, sufficient to keep the tube rigid. Through the narrow space between the cellophane tube and an outer, enveloping glass tube (3) is circulated a slow stream of the nutrient solution. All the tubes are fitted tightly in rubber stoppers (4) as shown. The culture is now growing on the inner surface of the cellophane tube, nourished through the cellophane but not contaminating the broth. As soon as the growth becomes luxurious, the culture drips down along the tube and is collected in a container (5).

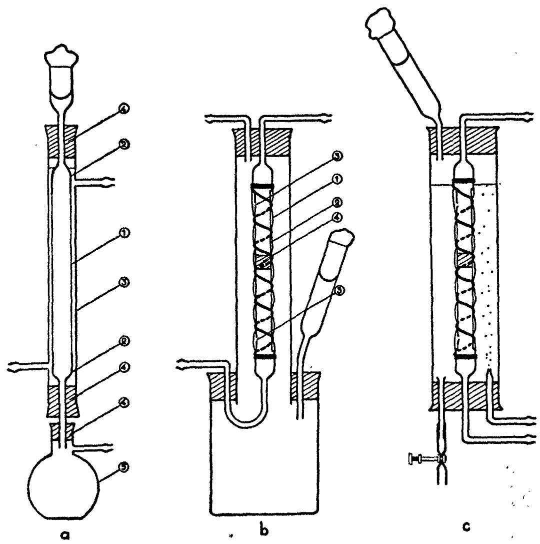

FIG. 1. The three main arrangements for experiments with cellophane tubes.

With the apparatus shown in Fig. 1b the same end is attained in a slightly altered manner. Here the culture grows upon the outer surface of the cellophane tube (1), while the nutrient broth circulates between the cellophane and a narrower glass tube (2) inserted in the cellophane tube. To prevent the cellophane from sticking to the surface of the inner glass tube, a string is wound spirally around the cellophane tube. The current is thus forced to circulate spirally around the inner tube. The nutrient solution is fed and drained off through the inner tube, which has two small openings (3) near the top and the bottom but is closed by a rubber stopper (4) between these openings.

In the third type of apparatus, shown in Fig. 1c, the culture grows not upon a cellophane surface in an air-filled space but in a nutrient broth with aeration only by a stream of filtered air, this gives a fluid, but finally very thick, culture.

This method of cultivation is of use when large amounts of bacteria (free from substrate protein) are required (e.g. rhizobia for the inoculation of leguminous plants). It has the added advantage that the culture can be grown without interruption and, if the nutrient broth is renewed from time to time, for an unlimited period. Furthermore, this principle may also prove to be of use for the study of bacterial products, which can thus be obtained free from substrate protein in the dialysate.

Our first experiments proved that the method was sufficiently productive. The apparatus shown in Fig. 1 (a or b) gave within 10 days, at 29° C., 15 grams of a rather stiff, slimy culture of *Rhizobium* of a quality similar to that derived from agar-plate culture, the total surface of the cellophane tube being 100 cm.², while the surface of agar plates for production of the same amount in similar circumstances would be nearly 150 cm.².

We do not know whether others have used cellophane in culturing bacteria or studying their metabolism; recently we have found a short communication (*1*) on the interaction of different bacteria suspended in nutrient solutions and separated from each other by collodion membranes.

The above-described method, of course, does not require that cellophane membranes be used solely. Other types of membranes may be even more suitable for some purposes.

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Laboratory Test of Aviator's Ejection Seat

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Emergency escape from high-speed aircraft is dangerous and sometimes impossible. It is not only difficult for the pilot to leave the cockpit against the force of the wind stream, but he may fail to clear plane structures as he is swept backwards along the axis of flight. In spins he may be unable to move, and at low altitudes there is often insufficient time to abandon the plane in an emergency. The most serious hazard is collision with the tail surfaces after leaving the cockpit.

Development of an ejection seat which instantaneously catapults the pilot from the plane was started in Germany during the last war (*2*) and has been continued and improved by the British (*1*). The U. S. Army and Navy are adapting and developing such devices for service aircraft from which escape is at present dangerous. Each of these groups of workers has successfully ejected aviators from planes in flight under experimental conditions.

Catapulting the seat from the plane provides an escape possibility limited by the dimensions and motion of the plane at the time of ejection and by the tolerance of the aviator to ejection. The primary restriction is the vertical distance in the cockpit available for imparting velocity and direction to the catapulted seat and pilot.

[1] The opinions expressed in this article are those of the authors and are not to be considered as reflecting those of the Navy Department. Appreciation is expressed to A. T. Kornfield and D. Weiss for the design of the velocity meter and pressure pickup and the operation of the instrumentation for these experiments.

The maximum speed of any particular plane at which the aviator may be safely ejected is determined by human tolerance to rapid acceleration. The physiology of this phenomenon is not well understood. Compression fractures of vertebrae or extrusion of intervertebral disc are believed likely to occur at accelerations, applied from seat to head, of approximately 23–25 times the acceleration due to gravity ("G"). The relations between exposure time and the critical level of acceleration which is likely to cause vertebral damage are not known. A subcritical level of acceleration applied to the seat in an elastic system may result in accelerations above the critical level in integral parts of the system. If this should occur in the spine over significant intervals of time, injury may result.

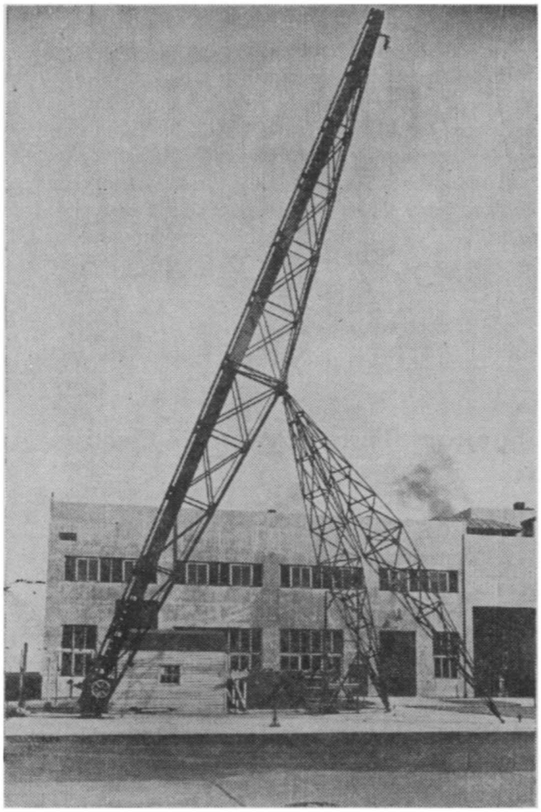

FIG. 1. Side view of 105-foot ejection seat test tower.

Previous investigations, limited by the lack of satisfactory instrumentation and test facilities, have failed to follow events in human subjects exposed to accelerations by high-performance ejection devices. The present study has helped to establish safe methods for the ejection of personnel from high-speed aircraft with a propelling device of limited stroke.

Method. A 105-foot ejection seat test tower and experimental catapult were procured from Martin-Baker Aircraft, Ltd. (Fig. 1). The catapults are cartridge-exploded piston and cylinder tubes 40, 52, and 60 inches long. A subject or dummy, strapped in a conventional aircraft seat with a standard retention harness (Fig. 2), is ejected up guide rails 70° from the horizontal by means of the powder-operated catapult. The charge is fired when the subject pulls a canvas curtain from above the head down in front of the face to the level of the chest. During the following acceleration this curtain partially supports the weight of the arms and shoulders and prevents extreme forward flexion of the cervical vertebrae. The seat is held at the top of the ascent by ratchets and is subsequently lowered by a cable operated from the ground.

Acceleration is measured on the seat and on the subject's hip, shoulder, and head by Statham (Model R-40-450) accelerometers mounted at these points (Fig. 2). Catapult pressure is recorded with a strain-gauge pressure pickup. Seat velocity is obtained by means of a coil attached to the seat and passing over magnets spaced at 2-inch intervals parallel to the motion of the seat. Maximum velocity can also be obtained by calculation from the ejection height. All data signals are simultaneously recorded with a Consolidated oscillograph (Model 5-101A).

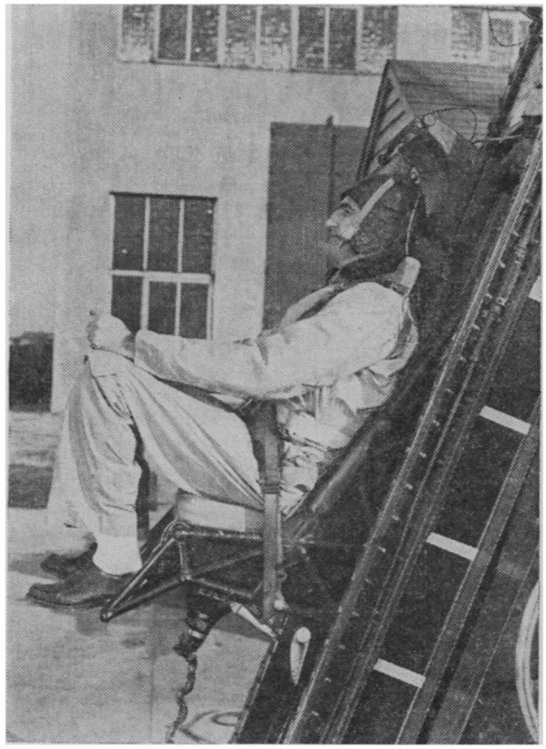

FIG. 2. Subject on test seat with accelerometers secured to hip, shoulder, and head. Handles of firing curtain can be seen above the head.

Since it was expected that vertebral injury could occur with little or no warning, subjects were progressively exposed to increasing accelerations. Three dummy ejections were made for each experimental arrangement. If maximum acceleration did not exceed 21–22 "G", volunteer subjects were then used under the same conditions. The subjects had average physiques and could be considered as a cross section of workers at a research station. Their ages ranged from 19 to 53 years, and weights from 130 to 195 pounds. In addition to preliminary experiments, 48 ejections have been made with 21 subjects, using a standardized charge designed to produce a maximum acceleration of 18–20 "G".

Results. An oscillograph record of an experiment on the test tower is shown in Fig. 3. Average data from representative ejections with each type of catapult are given in Table 1. If any subjective reaction resulted from these high accelerations, it was usually a mild pain in the lumbar, thoracic, or cervical regions followed by a generalized soreness. No injuries have occurred, and individuals could probably tolerate slightly higher accelerations, but 20–22 "G" is believed to represent the practical upper limits for seat ejection experiments. Satisfactory escape devices can probably be developed without exceeding these limits.

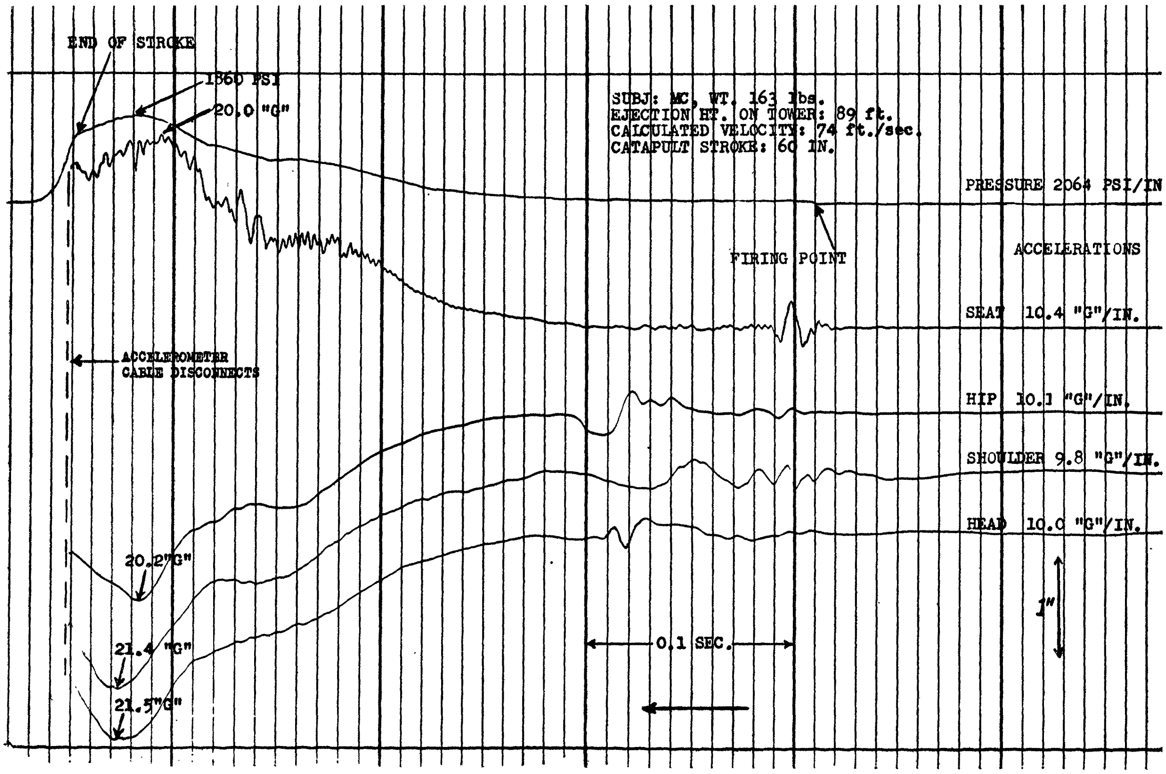

FIG. 3. Oscillograph record showing accelerations recorded on a subject during ejection on test tower.

TABLE 1

No. subjects	Avg. wt. (lbs.)	Catapult stroke (in.)	Avg. seat "G"	Avg. hip "G"	Avg. shoulder "G"	Avg. head "G"	Avg. maximum velocity (ft./sec.)
5	172	40	17.2	17.6	18.4	17.8	55.8
5	164	52	17.8	19.3	17.4	16.6	63.9
4	165	60	19.9	20.5	21.3	19.8	71.2

Additional research is necessary to determine the optimal system for ejection from aircraft. In some of our experiments with catapults producing a range of rates of accelerations, the "overshooting" of "G" recorded on the subject, compared to that recorded on the seat, became progressively greater as the rate of onset of acceleration increased. This excessive acceleration, technically the dynamic factor, is to be expected in a springmass system such as the seat-cushion-man. Compromises may have to be effected between rate of acceleration, maximum level and duration of acceleration, and cushioning devices for seat ejection at the highest velocities which can be safely tolerated in any particular airplane.

It is also believed that myotatic reflexes are important in protecting individuals exposed to high acceleration. Adequate time should be allowed for reflex muscular contraction before reaching a critical level of acceleration. Details of experiments to determine factors affecting man's tolerance to impact-like accelerations will be given in a later publication.

These experiments have shown that under controlled laboratory conditions personnel can be safely exposed to high, impact-like accelerations with a minimum of discomfort. Data obtained can be used for the design and predicted performance of ejection seats for use in aircraft. Using a catapult similar to those tested in the laboratory, an aviator was successfully ejected from a plane at an airspeed of 250 m.p.h. On the basis of laboratory data it is expected that ejections can be made at much higher speeds.

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