HUMAN TOLERANCE OF CRASH DECELERATION

Preliminary information on the results of tests using the rocket propelled acceleration-deceleration research facility at Edwards Air Force Base, Muroc, California, has been released by the United States Air Force.

Human volunteers have been subjected to decelerations of 35g - without injury. Jolt loads of 57g have been recorded on safety belts and shoulder harness during 35g decelerations. Results of this research indicate that the strength of aircraft structures and installations, rather than the strength of the human body, is the limiting factor in pilot protection.

Fig. 1. Car used for testing human reactions to crash decelerations.

The following quotations are from an article by Marvin Miles which appeared in the Los Angeles Times on January 8, 1950:

"A rocket sled, designed to duplicate air crashes, has subjected Air Force volunteers to sudden-stop pressures of four tons - without injury - and proved the amazing elasticity of the human body, it was disclosed yesterday. Developed by Northrop Aircraft, the strange device has made 47 runs at Edwards Air Base, Muroc Dry Lake, to provide flight surgeons with a dynamic stress analysis of the human body and a basis for designing pilot
and passenger safety harnesses.

"For the first time the 'air crew decelerator' has given aeromedical science heretofore unobtainable data on how much terrific deceleration a man can stand in a crash. It has proved—for what use the air transport industry may care to make of it—that a person riding backward can stand (with only a seat belt) pressures that would be fatal to a man facing forward if he was not protected by a special harness. And it has shown, too, that humans can stand the forces that would be imposed by rocket acceleration on future flights into space.

The decelerator operates on a 2000-foot track and is powered by four 1000-pound-thrust rockets that send it whipping into a series of brakes at 150 m.p.h. The brakes slow it to 75 m.p.h. in one-fifth of a second or the equivalent of a car, traveling at 75 m.p.h., stopping in nine feet. Tests to date have sent the sled slaming into the brakes at speeds that produce a pressure of 35 'Gs' (gravity pressure, or 35 times the force of gravity) and develop as much as 57 Gs for a split second on volunteer subjects. Thus a man riding in the sled would, for perhaps 1000th of a second, experience a pressure 57 times his own weight.

Northrop designed and built the decelerator under direction of the Air Materiel Command's Aero Medical Laboratory at Wright-Patterson Air Force Base and first tests, of course, were run with sand bags and dummies. 'Hot Rod' as the sled has been nicknamed, once carried 'Oscar,' a dummy figure, on a test run up to 50 Gs. An early harness was used to determine what would happen. The doctors and the engineers found out.

When the sled whizzed into the brakes, Oscar broke his moorings, tore away the harness, tore out the sled door and shot down the track for 789 feet, bouncing every now and then in clouds of dust. Subsequently the sled was altered, the housing removed and the subject now rides with only a windshield before him. But he has much more protection than Oscar had. The harness that holds him in the special seat is of double nylon web built strong enough to hold 80 men aloft—and there are six belts so devised to distribute pressures evenly.

Maj. John Stapp, Medical Corps, who explained the decelerator at Northrop Aircraft yesterday, has made 19 runs himself in the 'Hot Rod,' is convinced that man can stand more pressures than heretofore believed. There is no great physical reaction, he said. No impairment of vision or hearing or consciousness and no more aftermath than a person would feel if he had indulged in brief violent exercise. Nor is there any reaction on internal organs.

The deceleration is so fast, he explained, that the pressures haven't enough time to overcome the inertia of bodily fluids.....

Northrop's problems in designing the decelerator were myriad, especially the braking system, which comprises 45 sets of clasp-type brakes installed in the road bed 1250 feet from the starting end of the track. The brakes can be controlled individually to provide any desired variation in the braking force. Normally they slow the sled up suddenly to give the re-
quired deceleration, then permit it to roll on down the track, where it is stopped by cable action similar to the arresting gear on a carrier deck. Northrop also devised a 'shockproof' telemetering system to transmit information from the carriage to a central control laboratory. Strain gauges are employed on various portions of the subject, on the harness, etc., to determine actual pressures developed on each run, and automatic cameras watch the volunteer rider from one end of the track to the other, including a close-up camera that rides on the sled.


"Maj. Stapp declared that riding backward in the sled gives an effect 'much the same as being punched in the back of the head with a boxing glove' when the Hot Rod speeds into the brakes. Riding forward, with the special harness, gives only the feeling of the straps cutting into the body as the subject is thrown forward.

"'Our tests are continuing,' he said laconically. 'We hope to determine just how much deceleration the human body can stand up to 'useful' consciousness, or in other words, to the point where a man can still function well enough to climb out of a crashed plane before it burns... And the end isn't in sight yet.'"

The deceleration tests demonstrate dramatically that people can tolerate crash decelerations of 35g; this, so far as is known today, is more than conventional aircraft structures can withstand without destruction of the cockpit or cabin. It follows, therefore, that people can, and should, survive aircraft accidents in which cabin structure remains substantially intact. Apparently, in such cases, the difference between walking away from— or getting killed in—a crash deceleration depends on proper support of the body under crash loads.

At present, lap type safety belts are the conventional and sole installation to hold pilots and passengers in civilian aircraft. By comparison with military-type safety belts and shoulder harness (9000 pounds), safety belts in civilian aircraft are relatively weak (1000 or 2000 pounds). As presently designed and installed, 2000-pound belts do not have sufficient margins of safety to prevent failures of webbings, attachments, or anchorages in survivable accidents. When pilots and passengers "break their moorings" their chances of survival apparently are slim; they are thrown at or through aircraft structure in much the same way reported when the Muroc dummy broke the safety belt and shoulder harness.

At best, a lap type safety belt alone holds only the lower portion of the body, leaving vital parts— the head and chest— exposed to extreme damage by impact against forward structures.

The difference in safety for pilots with and without shoulder harness is repeatedly demonstrated in reports of accidents received by the Crash Injury Research project. For example:
Fig. 2. Pilot flying cross-country got lost and ran into icing conditions with low ceilings; plane came down out of overcast (which was just over the trees) and struck the ground at a 15° angle at 80 mph.

The cabin of the ship remained substantially intact. The pilot's safety belt held but the upper part of his body and his head were thrown against the control wheel and instrument panel causing FATAL CHEST AND HEAD INJURIES.

By contrast:

Fig. 3. Pilot on cross-country made precautionary landing. Taking off again into a 25 mph wind, he turned to avoid trees, then turned again downwind; aircraft stalled and dived to the ground, striking on the nose and left wing at a 50° angle at about 75 mph.

The pilot was wearing shoulder harness and suffered only BRUISES AND FACIAL LACERATIONS from flying debris.
The campaign for shoulder harness to increase the safety of pilots actually began in the Air Force in 1936. At that time Lt. Col. Malcolm C. Grow* was Chief Flight Surgeon of the U. S. Army Air Forces. One day, while he was waiting to take off from Bolling Field, the crash siren blew and Col. Grow immediately went to the scene of the accident. The two occupants of the plane had been removed, but examination of the wreckage showed that the structures of both front and rear cockpits were substantially intact. The seat in the rear cockpit had pulled free and there were areas of damage in the center of each instrument panel with a small amount of blood beneath each panel. The crash, estimated from the point of view of aircraft damage, was not severe. When Col. Grow inquired about the pilots he was informed that both were dead. At the morgue it was found that each pilot had a basal fracture of the skull, and, except for a cut on the leg of one pilot, there was no other external evidence of injury.

As a result of this crash, and many others he had observed, Col. Grow decided that better protection could be provided for pilots, and sketched up a type of shoulder harness specifically designed to prevent fatal head injuries in accidents of this kind. His concepts included (1) attachment of shoulder straps to the tongue of the safety belt buckle in order to provide a quick release of both belt and harness in emergencies, (2) a spring tensioned locking mechanism so that the pilot could lean forward, but also could lock the harness in a rearward position, and (3) attachment of the shoulder harness to basic aircraft structure so that it would carry heavy loads.

There were two important questions which had to be solved before such an innovation could be put into use. First, would the snubbing of the shoulders cause the head to snap forward with resultant injuries of the neck? Secondly, how strong should the shoulder harness be?

Col. Grow outlined his ideas to Capt. Harry G. Armstrong**, then Director of the Aeromedical Research Laboratory at Wright Field who referred to his study of these problems in his book "Principles and Practice of Aviation Medicine" (1939) as follows:

"As a result of having investigated several accidents in which personnel were uninjured except for skull fracture, Lt. Col. M. C. Grow of the United States Army Medical Department two years ago initiated a movement to have a shoulder type of safety belt designed and adopted. The present author has recently completed a comparative study of the protection afforded by the conventional lap type belt in a crash and the shoulder type suggested by Col. Grow with some interesting results.

"With the lap type belt it was found that a sudden deceleration of 8 G's or more caused the body to jack-knife forward with such force that if the head had struck any solid object, such as it undoubtedly would have in the conventional airplane, the skull would probably have been fractured. With the shoulder type safety belt under similar circumstances it was found that decelerations up to 15 G's were readily toler-

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ated without any displacement of the body and without any significant
discomfort. In these tests it was originally feared that, since the
shoulders were held back in the seat and the head unsupported, there
might be danger of the neck being snapped and possibly broken. The
tests showed, however, that there was no tendency for the head to jack-
knife forward on the body even at 15 G's and the only reason for termi-
nating the tests at that point was because that happened to be the limit
of the recording instruments available. It is estimated that one could
live through a deceleration of somewhere between 30 and 50 G's with the
shoulder type safety belt providing the belt and seat did not give way.
There can be no question that the use of the shoulder type safety belt
would save most of the 42 per cent of those in aircraft accidents who
are at present killed or injured from trauma to the head and face only
and perhaps many others."

Capt. Armstrong's estimate that "one could live through a deceleration
of somewhere between 30 and 50 G's with the shoulder type safety belt" was
not widely accepted in 1939 and the idea persisted that use of harness would
result in broken necks.

The Muroc tests now have demonstrated dramatically that human structure
not only can "live through" but can tolerate 35g decelerations with only
moderate discomfort. Not only do they show that the body can be protected,
but they also demonstrate two ways in which protection can be provided, —
by use of shoulder harness and by reversed seats.

One result of the Air Force high-g research program is the probability
that rearward facing seats will be developed for use in military air trans-
ports and will provide information for evaluating reverse seating for future
airline use.

Evidence of the protection provided by shoulder harness — in the Muroc
deceleration research as well as in actual crashes of fighter aircraft —
indicates that an amazing increase of safety will be achieved when such in-
stallations are made available in personal aircraft and come into broader
use by amateur pilots.

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The Muroc experiments represent an exceptionally daring and valuable
research achievement. The Crash Injury Research project takes this occasion
to compliment the Air Force for initiating these tests and for the care,
patience, and courage shown by personnel in the safe accomplishment of numer-
ous high-g deceleration test runs.