German Acceleration Research from the Very Beginning

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German airmen were experiencing G-induced physiological effects as early as WWI, although no research on acceleration physiology was conducted at that time in Germany. This changed in 1931 with the studies of Heinz von Diringshofen, who gained experience with prolonged acceleration in flight. The first German centrifuge was constructed by the von Diringshofen brothers and was in operation at the Air Ministry's Aeromedical Research Institute in Berlin from 1935-1945. After WWII, Otto Gauer and Heinz Haber authored the paper "Man under Gravity-Free Conditions," paving the way to manned space exploration and demonstrating the change of research interest from the effects of multiple G forces to those of zero G.

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GERMAN AIRMEN experienced G-induced physiological effects — such as black out and spatial disorientation — as early as in WWI (6). Initially, German aviation medicine researchers did not study acceleration physiology. Aeromedical activities were suspended by the Treaty of Versailles, which prohibited military and civilian flying. In 1927, with the establishment of the first German Aeromedical Institute at Hamburg University, Ludolph Brauer restarted civilian academic aeromedical research, focusing mainly on altitude physiology. Technological developments in the 1930's, such as new propulsion systems (rocket and jet engines), catalyzed the work at German aviation medical centers, such as the Air Ministry's Aeromedical Research Institute and the Aeromedical Institute of the German Aviation Test Center (DVL), both of which were located in Berlin (11).

With the introduction of high performance aircraft, like the Junkers JU-87 dive bomber, radial acceleration in the head-to-foot direction ($+G_z$) of the seated pilot, such as occurs in turns or when pulling out of a dive, became a concern. Airmen knew about G-induced physiological effects and countermeasures, such as crouching forward during pullouts and increasing the intrathoracic pressure by grunting an e-sound (M-1 maneuver). These were learned both from practical experience and from such books as "Medical Guide for Flying Personnel," written by Heinz von Diringshofen and published by the German Air Force in 1939. This explains in part why German flight surgeons rarely had to deal with acceleration problems from excessive G-forces. Only one aircraft loss due to G-LOC was reported in 1941: a German fighter school cadet was involved in a collision during combat maneuvers and blamed sudden incapacitation as a cause for the accident (1,3,23).

The effects of prolonged in-flight acceleration were first studied in the early 1930's by the flight surgeon, Heinz von Diringshofen. While in command of the Physiological Institute at Wuerzburg University, where the physiologist Hubertus Strughold had held the world's first aeromedical lecture and performed inflight aeromedical testings in 1928 (11,23), von Diringshofen pioneered investigations into acceleration protection. He conducted numerous studies with volunteers in flight and suggested that small, but strong candidates with high G-tolerance due to a resistant circulatory system be selected as pilots. It was realized that non-athletic individuals had a greater tolerance to positive acceleration. Body positioning as a means of improving tolerance to G-stress was recognized, and the supine position at a 45° angle was suggested (1,4).

To obtain more standardized conditions than were possible in flight, examinations were supplemented by centrifuge experience. Heinz von Diringshofen and his brother, Bernd, commissioned the construction of the first German 5.40-m centifuge (16.4 ft, maximum of 47 G, first 4 G in 40 s), which was operated at the Air Ministry's Aeromedical Research Institute in Berlin from 1935 to 1945 (**Fig. 1**). Scientists such as O. F. Ranke, O. Gauer, S. Ruff, L. Buehrlen, U. Fischer, and H. Pfeiffer performed many experimental studies on animals and human volunteers. These were to determine the cause of G-LOC and, later, to develop methods for the protection of aircrew. Ranke and Gauer in cooperation with Losenhaus Corporation designed and built an even larger 20-m centrifuge (66 ft), which could not be installed at the Tempelhof Airfield as planned, because of heavy air raids in 1943 (2,4–6,8,15,16). In centrifuge experiments on animals, X-rays (roentgencinematographic recordings) showed that there was

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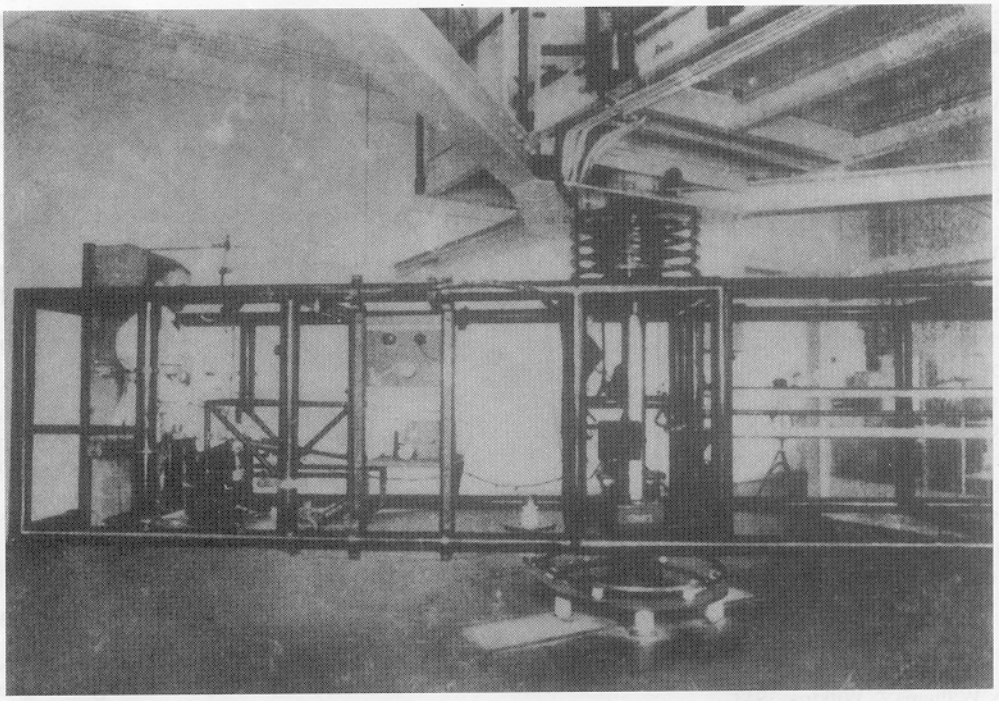

Fig. 1. Centrifuge at the Aeromedical Research Institute of the Air Ministry (1935-1945).

decreased filling of the heart in monkeys and cats exposed to high G_z-forces. The results were cross-checked on humans in experimental aircraft. For example, in 1938 von Diringshofen conducted tests to record G-effects on the heart in a Heinkel HE-70 reconnaisance aircraft equipped with an X-ray machine in the passenger-seat.

Buehrlen, a medical officer cadet, exposed himself to up to 17 G_x over 2 min on the centrifuge and found the supine and prone positions adequate to tolerate high-G forces. The studies were repeated in-flight; e.g., supine positioning was flight-tested with the Horten HO-II as early as 1935. H. Wiesenhoefer of the German Aviation Test Center developed a "flap-back seat," which automatically flapped back as the G-load increased above +3 G_z. It was tested in-flight aboard the Heinkel HE-50 dive bomber in 1938 (5,7,13,16,24).

Beginning in 1938, in-flight tests were also conducted using the FS-17, a high-G research glider. During these flights, G-loads reached a peak of more than +10 G_x for the prone-postioned test pilot. In 1939, with the start of WWII, Gauer and Ruff determined that the prone position was optimum for enhanced G-tolerance. After the war Strughold, the leading German aerophysiologist, stated, "The problem of positioning the pilot in the high-speed aircraft of the future might find its solution in the prone position (partly for aerodynamic reasons to be considered in the design of the fuselage)" (23,24). In 1944 and 1945 Gauer studied the effects of medications such as caffeine, atropine and the amphetamine, pervitin, on G-tolerance. Results of this work demonstrated the ineffectiveness of these drugs in enhancing G-tolerance.

Previously, Ruff (1938) and Matthes (1940) of the Aeromedical Institute of the German Aviation Test Center (DVL) had shown that adding 7% carbon dioxide to the breathing air improved G-tolerance by up to 1.5 G_z. It was also discovered that airmen could tolerate higher centrifugal forces during digestion. On the other hand altitude sickness has been shown to lessen the acceleration tolerance in direct proportion to the degree of hypoxia. Another result was that repeated exposures to centrifugal forces did not significantly increase G-tolerance, as it was observed in altitude (hypoxia) adaptation training (9,14,16,23).

Bandaging the extremities or compressing the legs and abdomen by the use of inflatable bladders to enhance G-tolerance was also suggested by Gauer. The use of an anti-G-suit in combination with the forward crouch position was expected to enhance the G_z tolerance to an even greater degree. It is likely that no attempts were made to develop and introduce anti-G-suits in Germany because they seemed to cause more trouble than they were worth. Anti-G-suits of American Mustang pilots, tested in flight and in the centrifuge in Germany in 1945, showed no improvement in G-tolerance over crouching. Additional tests were performed on the effects of foot-to-head acceleration, which occurred in manned missiles, when leveling off from a steep climb to a horizontal flight or to a descent (-2 G_z). Gauer and Henschke conducted centrifuge tests, while flight tests were performed by Freitag, Wiesenhoefer, and Ruff. They assumed that an airman protected by an appropriate anti-G-suit could tolerate even higher G-forces for a short time. This research was also of interest for catapult take-off, crash landing, parachute opening, and ejection from aircraft (18,22,23). At the Aeromedical Institute of the German Aviation Test Center, investigators using impact pendulum and a horizontal catapult sled found that the maximum acceleration of an ejection seat would be approximately +20 G_z within 0.1 s. In 1940, the Heinkel Corporation designed an ejection-seat that was operationally used in high-performance aircraft (19–21).

This scientific work came to an end with the capitulation of the German Armed Forces in 1945. Thereafter, many German scientists were invited to work at the USAAF Aero Medical Center (AMC) in Heidelberg, which existed from 1945-1947. They were to gather the results of German aeromedical research performed before and during the war. As a result, a 2-volume handbook, "German Aviation Medicine World War II", was published by the Department of the U.S. Air Force in the United States in 1950 and reprinted in the 1970's. Furthermore, "Space Physiology" had been introduced as a new subject by the German scientists, Otto Gauer and Heinz Haber, in Heidelberg in 1946, with their paper "Man under Gravity-Free Conditions." This paper demonstrated the broadening of research interest from the effects of multiple G forces to those of zero G, and showed the way to manned space exploration. Both of these men were among those German aerospace-medicine-specialists, invited by General Harry G. Armstrong to work in the United States (10,12).

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