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THE BEGINNINGS OF AEROMEDICAL ACCELERATION RESEARCH

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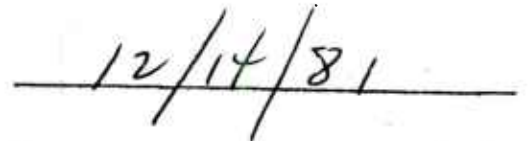
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (UNCLA) In the early twenties, when structural strength, maneuverability and power of aircraft had increased sufficiently, grey-out and black-out made their first undesirable appearance during flight. Temporary loss of vision was first observed in test flights conducted by the National Advisory Committee for Aeronautics (NACA) with the "novel" aircraft Fokker PW-7 and also in air races during and/or after the pilots rounded the pylons. At first only a small sector of the aeromedical community was attracted to do research into		

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20. Abstract (Continued)
this new field. The early contributions of Garsaux (1919), Doolittle (1924), Bauer (1926), Dobrotvorskii (1930), Flamme (1931), and von Diringshofen (1932) are reviewed and discussed. Several misquotations, partly caused by faulty translations, are clarified. It becomes apparent that the exchange of information between the aeromedical investigators, as well as between the engineering and aeromedical community, was far from satisfactory. This may be the reason that more than one decade passed before the mechanism of visual impairment was understood and the hemostatical theory by von Diringshofen was established, experimentally proven and generally accepted.

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Foreword

This Report is an enlarged and actualized version of a paper of same title presented at the Session Acceleration I of the 49th Annual Scientific Meeting of the Aerospace Medical Association in New Orleans, Louisiana, May 8, 1978.

The Beginnings of Aeromedical Acceleration Research

by

Harald J. von Beckh, M.D.

The Forerunners: R. Cruchet and R. Moulinier

René Cruchet was associate Professor of Internal Medicine at the University of Bordeaux and René Moulinier was Professor at the School of Naval Medicine, also in Bordeaux.

At the Aviation Festival in Bordeaux, 11 - 18 September 1910 they began their studies on the participating pilots.

One must consider that this festival took place less than four years after the flight of Santos-Dumont with the Bagatelle, and less than seven years after the flight of the Wright brothers at Kitty Hawk.

At the festival, Cruchet and Moulinier befriended the participating pilots, among whom were such well known aviators as Morane, Bregi and Chavez. Cruchet and Moulinier took measures of blood pressure and heart rate before take-off and immediately after landing, and questioned the pilots about their symptoms during the flight. The pilots showed a hypertension and an accelerated pulse rate after landing as compared with before take-off.

At this time "High Altitude Flights" reached an altitude of only 3000 m (10,000 feet) which was attained by an ascending flight of circa 45 minutes. The descent was of only 5 - 7 minutes duration which corresponds to a continuous diving flight at a rate of 8 - 10 m/sec. The total duration of the flight was roughly 50 minutes. It is no wonder that the pilots complained about headache and earache, especially during the descent (Dysbarism).

They also complained of the cold and the effects of windblast and showed such symptoms as cyanosis of the extremities, hyperaemie of the conjunctivas and subjective cold feelings.

The authors combined all these symptoms in the somewhat ill-defined "Aviators Sickness" ("Mal des Aviateur"), which also included the beginning Hipoxia symptoms such as sleepiness, exhilaration, etc., and published their findings in 1911 (8).

It is interesting to note, that the pilot Morane described at altitude an "Anxiety and a great loneliness which one feels" (L'angoisse et la grande solitude que l'on ressent). This is a precursor of the recent description of the "Break-off Phenomenon" noted by B. Clark and A. Graybiel (7) in pilots at high altitude and is also characterized by "remoteless, loneliness and anxiety of the pilot".

The authors do not mention the effects of acceleration at all; they were certainly very small during most of the flights, but certainly reached noticeable values in the pull-outs after diving flights.

All in all, Cruchet and Moulinier deserve to be considered as the first Flight Surgeons. They were certainly the first physicians who occupied themselves with the problems of aviators in vehicles that were heavier than air.

The Pioneer: Paul Garsaux

At the end of WWI the G tolerance of aircraft was sufficiently increased to make problems for the pilot. P. Garsaux was the first scientist who studied these accelerations (5, 13).

Garsaux used an improvised centrifuge with a diameter of only 0.6 meter. Dogs of 10 to 13 kg served as his subjects. The dogs faced tangentially, so they were exposed to mainly transverse acceleration. Garsaux exposed these dogs to unrealistically high G loads: namely 20, 40, 60 and 98 G, for a duration of five minutes. No wonder that Garsaux detected in the surviving animals severe neurological sequelae such as Saint Vitus dance movements, extension contractures of the paws, epileptic seizures and others (Fig 1).

Garsaux was neurologically oriented, and believed that the major damage of the acceleration was caused by the displacement and compression of nervous centers, especially those of the cerebellar peduncle.

Some years later, when grey-out and black-out made their undesirable appearance, he again tried to explain the visual impairment by the compression of the optic chiasma through the increased weight of the frontal lobes, and so became the originator of the Compression theory of black-out.

In 1926, Garsaux wanted to compliment his results by experiments with man in the manege de Saint-Cyr. This improvised centrifuge had a diameter of 54 feet and was driven by an 80 HP motor. The maximum G obtainable were only 2.5 G. This was of course not enough to produce grey-out and black-out in man. Thus, the lack of suitable equipment kept French investigators out of the mainstream of acceleration research until the end of WWII.

BULLETIN 1919.
DE
L'ACADÉMIE DE MÉDECINE

1. Note préliminaire sur l'étude des effets de la force centrifuge sur l'organisme,

par MM. les D^rs ANDRÉ BROCA et GARS AUX.

Cette question a été mise à l'ordre du jour par l'accident de Gilbert. On a évalué que la force centrifuge avait atteint 5,5 fois la pesanteur, alors que le calcul de la résistance avait été fait pour 7 fois. Le coefficient de sécurité était donc trop faible.

Avec les derniers appareils donnant 320 kilomètres, la force exercée en bas d'un cherrage ordinaire peut atteindre 9 fois la pesanteur, et on a admis, pour la sécurité, la résistance à 20 fois la pesanteur. Mais, vu l'audace des pilotes, on a craint de les voir se servir de toute la puissance possible de leur avion, et aller au-devant d'accidents physiologiques; c'est pour cela qu'on nous a chargés d'étudier la question.

L'expérience nous a prouvé tout de suite qu'on n'a pas à craindre d'arrachements d'organes, mais qu'il faut prendre en considération

PARIS

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Figure 1: The paper of A. Broca and P. Garsaux, 1919 (5). They exposed dogs to unrealistically high G loads until 98 G. They believed that the major damage of accelerations is caused by the compression of nervous centers.

General Doolittle - An Early Pioneer In Aeromedical Acceleration Research

In March 1924 Lt General James H. Doolittle, then a Lieutenant assigned to M.I.T. to write his master thesis used the then Norton/Emerson accelerometer to measure the accelerations generated by pull-outs and aerobatic maneuvers.

Flying the Fokker PW-7 pursuit airplane over Mc Cook Field (now: Wright-Patterson AFB) he executed high speed pull-outs, single and multiple barrel rolls, power spirals of short radius, and spins (Fig 2).

He published his findings as NACA Report No. 203 with the title "Accelerations in Flight"; these findings also served as Thesis for his Master's Degree from M.I.T.

".... THE MAXIMAL ACCELERATION WHICH A PILOT CAN WITHSTAND DEPENDS ON THE LENGTH OF TIME THE ACCELERATION IS CONTINUED. IT IS SHOWN THAT THE PILOT EXPERIENCES NO DIFFICULTY UNDER THE INSTANTANEOUS ACCELERATIONS AS HIGH AS 7.8 G, BUT THAT UNDER ACCELERATIONS OF 4.5 G, CONTINUED FOR SEVERAL SECONDS, THE PILOT QUICKLY LOOSES HIS FACULTIES....

THIS LOSS OF FACULTIES IS DUE TO THE FACT THAT THE BLOOD IS DRIVEN FROM THE HEAD, THUS DEPRIVING THE BRAIN TISSUES OF THE NECESSARY OXYGEN. TO THE PILOT IT SEEMED THAT SIGHT WAS THE ONLY FACULTY THAT WAS LOST " (10).

It is hard to understand why this report did not find its way into the aeromedical literature. Other NACA reports, like report 386 by C. H. Dearborn and H. W. Kirschbaum (1931), have been quoted frequently by aeromedical investigators, although they were published much later and are much less informative with respect to Aviation Medicine.

This was certainly not General Doolittle's fault, because he shared and discussed his findings with the Flight Surgeons at Mc Cook Field. I quote from his report: "The Flight Surgeons at Mc Cook Field are of the opinion that sight is the last faculty to be lost". (Needless to say that they were wrong; General Doolittle's statement was correct).

But, why these Flight Surgeons did not forward Doolittle's findings to the late Dr. Louis H. Bauer, the most prominent Aviation Medicine expert of this epoqe, is difficult to understand.

It appears that the communication between the aeromedical and the engineering community was not better then it is now. This becomes obvious when we read on page 121 of Dr. Bauer's book "Aviation Medicine" which appeared two years later, in 1926, the following statement:

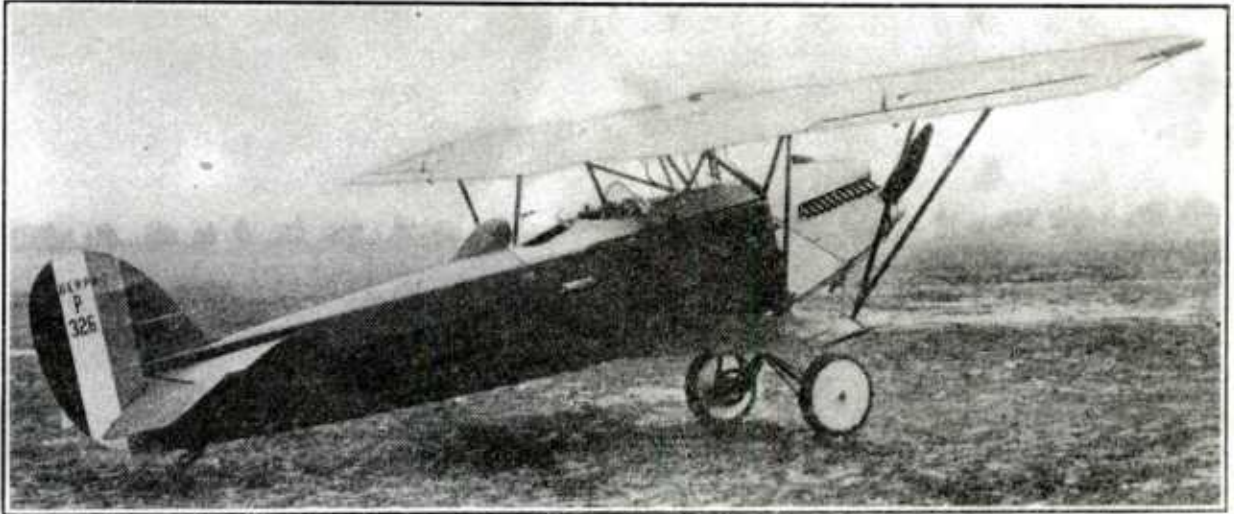


FIG. B.—Fokker PW-7 pursuit airplane

Figure 2: The Fokker PW-7 pursuit aircraft, which was used by General Doolittle in his pioneering acceleration experiments in the year 1924 (10).

".... THE WINNER OF THE PULITZER TROPHY IN 1922 IS SAID TO HAVE STATED THAT HE BECAME UNCONSCIOUS WHEN MAKING TURNS. THE WINNER IN 1923 IS SAID TO HAVE BEEN IN MORE OR LESS OF A DAZE. THAT HE MUST HAVE BEEN IS EVIDENCED BY THE FACT THAT HE WENT AROUND THE COURSE AN ADDITIONAL TIME, NOT BEING SURE HOW MANY LAPS HE HAD COMPLETED. WHAT IS THE EXPLANATION OF THIS? IT IS BELIEVED THE ANSWER IS CENTRIFUGAL FORCE...." (3).

Thus, although General Doolittle was not trained in Aviation Medicine, and although his findings went unheeded by the aeromedical community for many years, he certainly deserves the credit for having been the first man to understand the biomedical effects of sustained accelerations.

The Soviet Investigator N. M. Dobrotvorskii

Dobrotvorskii was an Associate Professor on the Psychiatric Clinic of the University of Moscow and was the most renowned author of the "Central Psychophysiological Laboratory for the studies of the Military Air Service" to which he belonged since its foundation in 1924.

In 1930, he published the first Soviet textbook on Aviation Medicine (9) entitled, "Letnii Trud" - ("The Task of Flying"), based on lectures which Dobrotvorskii delivered at the Zhukovskii Military Air Academy. His work is seldom if ever quoted in the Western Literature. Dobrotovorskii came one step closer to the hemostatic theory in the chapter "The Influence of Inertial Forces"(pp 37-43) (Fig 3).

He theorized that the left ventricle under normal conditions ejects 70 g of blood, which corresponds to a workload of 0.1407 kgm (kilogrammeter). The right ventricle makes a workload of 0.0567 kgm, and the workload of both ventricles combined is 0.1974 kgm. In the case that the pilot makes a turn of 5.75 G for 20 seconds, the required workload will be $0.1974 \times 5.75 \times 24$ (heartbeats during 20 seconds) = 27.2412 kgm. Dobrotvorskii doubts whether the human heart can perform such an increased workload, and he deduces correctly that below the heart we encounter an excessive filling with blood, and above the heart, we find at first a slight anemia, but later an acute anemia, fainting and death. It is no doubt that N. M. Dobrotvorskii, based on theoretical considerations, came very close to von Diringshofens Hemostatical Theory.

Большое влияние должны иметь силы, возникающие при перегрузках на сердечно-сосудистую систему. Кровь, как известно из физиологии, выбрасывается с известной силой из желудочков сердца вверх, левым желудочком в аорту, правым в легочные артерии. При каждом сокращении левый желудочек выполняет работу в 0,1407 кг/м выбрасывая с каждым сокращением 70 гр крови. Работа правого желудочка выражается за одно сокращение 0,0567 кг/м.

Работа обоих желудочков при одном сокращении выразится в 0,1974 кг/м.

При наличии перегрузки выбрасываемое желудочками количество крови под влиянием перегрузки представит желудочкам сопротивление соответственное величине перегрузки и потребует от них соответственного усиления работы. Так, при выраже в 80° (перегрузка 5,75) при каждом сокращении желудочкам при условии подачи в артерин того же количества крови необходимо усилить свою работу в 5,75 раз на все время продолжительности выража (15—20 сек).

В таком случае работа, которую придется сделать желудочкам, будет равняться:

$$0,1974 \times 5,75 \times 24 \text{ удара (за 20 сек)} = 27,2412 \text{ кг.м.}$$

Figure 3: Excerpt of page 40 of the Soviet Textbook "Letnii Trud" (The task of Flying) of N. M. Dobrotvorskii (1930). He calculates that the heart of a pilot who makes a turn with 5.75 G of 20 seconds duration needs a workload of 27 kgm to irrigate the brain arteries sufficiently (9).

Andre' Louis Flamme

The French Military Physician A. L. Flamme was an experienced pilot and collaborator of Broca and Garseaux. He partly maintained their Compression Theory, but he came in many ways near the hemostatic theory.

In an article published in 1931 (12) Flamme quoted the acceleration experiences of many pilots like the physician and pilot Georges Ferry (11), the English pilots Waghorn and Orlebar, who participated in the Air Race of the Schneider Cup in 1929 and 1931, and Hans Ritter of the Junkers Aircraft Factory in Malmoe (Sweden).

He came to the conclusion that the circulation in the internal Carotid Artery under the action of Head-to-Foot acceleration would be slower, arrested, and even reversed ("circulation contrarié").

Prof. Dr. Heinz von Diringshofen (1900-1967)

Heinz von Diringshofen deserves credit for three important achievements:

(1) He created the Medical experimental flight, transforming his aircraft into a flying laboratory that included medical monitoring devices and an X-ray machine (Fig 6, 7, 8, 9, 10, 11, 12, 13, 14, 15).

(2) He established and proved experimentally the Hemostatic Theory of Black-out (Fig 8, 9, 10).

(3) He built with his brother Bernd, a mechanical engineer, the first human centrifuge for aeromedical research in Berlin (1934) (Fig 16,17).

Heinz was born in Magdeburg (Germany) in 1900, the son of Lieutenant General Max von Diringshofen. After completion of his Medical Studies at the University Berlin in 1927, he entered the German Forces, and in 1929 was transferred to the Luftwaffe where he earned his military Pilot License. In 1930 he was detached to the University of Wuerzburg where he began his studies on human tolerance to acceleration in aircraft, and thus became the initiator of the medical experimental flight.

For his early experiments (1931 - 1933), he used an obsolete reconnaissance aircraft, the Albatros L78 (Fig 5), which he transformed into a Flying Laboratory. The instrumentation included an accelerograph, an electrocardiograph and a pneumotachograph. For registering Blood Pressure, he used an Autotonograph described by Lange (16), and modified by von Diringshofen, to make a continuous graph of the blood pressure. His first studies on the effects of acceleration were published in 1932 (21) under the title "The importance of pressure differences for the human circulation by the action of high accelerations". He correctly found that the tolerance of the upright seated pilot is between 4.5 and 5.5 G. He also described an increased pulse rate, extra systoles during the acceleration, and a reflexive increase of blood pressure at the level of the heart. In addition, he stated that, in a prone or supine position, the hydrostatic level differences are much smaller, and therefore the tolerance to acceleration is much greater. He proved this by some flights with the subject in a supine position. Accelerations of 5 G were tolerated without symptoms. Much later, in 1937 Buehrle (6) verified this increased tolerance by his experiments on the Human centrifuge in Berlin.



Figure 4: Portrait of Prof. Dr. Heinz von Diringshofen (1900 - 1967).



Figure 5: The aircraft Albatros L 78 used by von Diringshofen for his early acceleration experiments. During diving spirals he exposed his upright seated subjects to G loads up to 6.5 G, producing grey-out, black-out and sometimes loss of consciousness. (The pilot avoided those symptoms by leaning forward (Crouch position)).

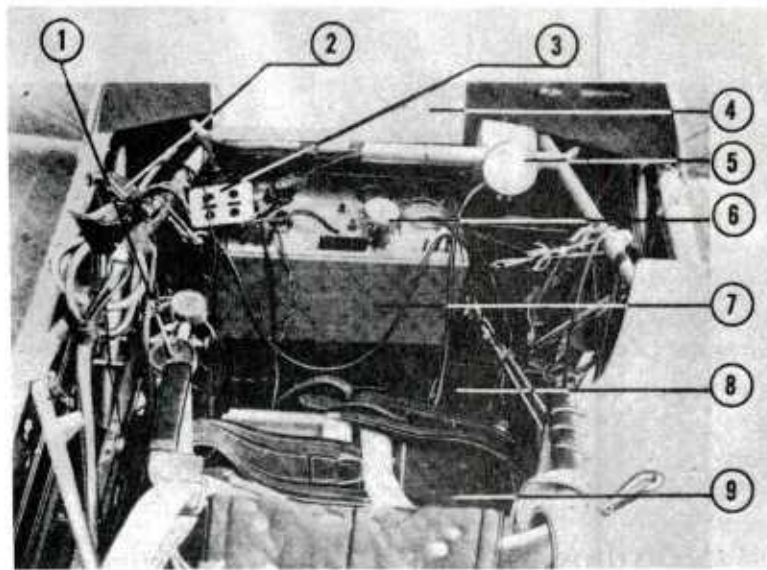


Figure 6: Subject's seat in the aircraft Albatros L78. 1 = Oxygen bottle; 2 = Mouthpiece for oxygen; 3 = Signal lamps for communication between Subject and Pilot; 4 = Instruction for Subject; 5 = Manometer for Blood Pressure; 6 = Electric Watch; 7 = Apparatus for blood pressure registration; 8 = Electrocardiograph; 9 = Seat of subject with parachute. (From von Diringshofen (23), 1933).

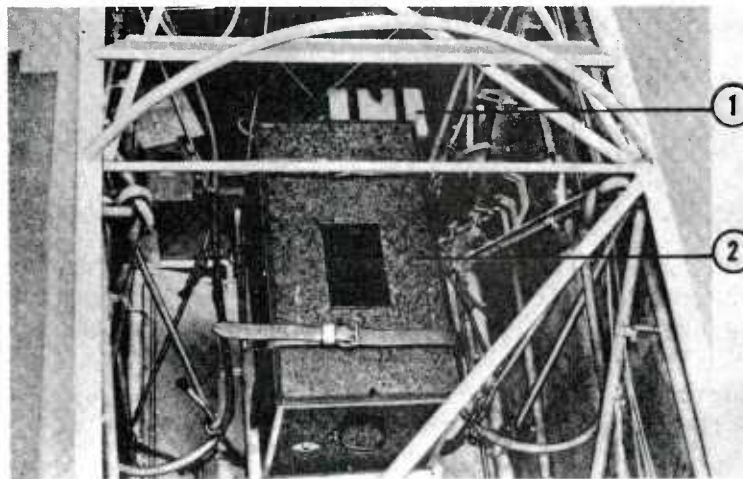


Figure 7: Additional instrumentation located in the rear part of the fuselage 1 = Accelerograph; 2 = Pneumotachograph. (From von Diringshofen (23), 1933).

Sonderabdruck
aus der „Zeitschrift für Flugtechnik und Motorluftschiffahrt“
1932, Heft 6
Verlag von R. Oldenbourg, München und Berlin

**Die Bedeutung von
hydrostatischen Druckunterschieden
für den Blutkreislauf des Menschen
bei Einwirkung hoher Beschleunigungen.**

Von H. v. Diringshofen.

Aus dem physiologischen Institut der Universität Würzburg.

Die außergewöhnliche Steigerung der Geschwindigkeit
und Wendigkeit moderner Flugzeuge macht es jetzt notwendig,
die physiologische Auswirkung der Kräfte zu stu-

Figure 8: This early paper of von Diringshofen appeared in the "Journal for Aviation Technology and Motoraviation" in 1932. Its title is: "The importance of hydrostatic pressure differences for the human circulation at the action of high accelerations". He established and proved the hemostatic theory of black-out by numerous flights with pilot subjects. In addition he stated that in prone or supine position the hemostatic level differences are much smaller, and therefore the acceleration tolerance much greater (21).

Zeitschrift für Biologie, Bd. 93.
J. F. Lehmanns Verlag, München 1932.

**Experimentelle Untersuchungen über den Einfluß hoher
Beschleunigungen auf den Blutdruck des Menschen.**

Von **H. v. Diringshofen** und **B. Belonoschkin.**

(Aus dem Physiologischen Institut der Universität Würzburg.
Vorstand: Geh. Rat M. v. Frey †.)

(Mit 6 Textabbildungen.)

(Der Schriftleitung zugegangen am 12. März 1932.

Die Entwicklung der modernen Verkehrstechnik hat dazu geführt, daß
der menschliche Organismus heute Lebensbedingungen ausgesetzt ist,
die weit vom bisher als normal Angesehenen abweichen.

Figure 9: This paper appeared in the "Journal for Biology" in 1932. It's translated title is: "Experiments about the effect of high accelerations on the human blood pressure." H. von Diringshofen reports ten experimental flights which were made between the 24 August 1931 and 1 September 1931. Each flight had three High G episodes until 4.8 G. He observed that the maximal blood pressure (at the level of the heart) was increased for 70 mm Hg.

Zeitschrift für Biologie, Bd. 95.

J. F. Lehmanns Verlag, München 1934.

**Die Wirkung von gradlinigen Beschleunigungen und von
Zentrifugalkräften auf den Menschen.**

Allgemeine Einleitung und physikalische Einführung.

(1. Mitteilung.)

Die Hämostatik bei Beschleunigungseinwirkung.

Von **Heinz von Diringshofen.**

(Aus der Direktorialabteilung, Med. Univ.-Klinik, des Eppendorfer Krankenhauses
[Direktor: Prof. Dr. Brauer] und dem Institut für Luftfahrtmedizin und Klimaforschung,
Hamburg-Eppendorf. [Direktor: Prof. Dr. Brauer].)

(Mit 16 Textabbildungen.)

(Der Schriftleitung zugegangen am 3. Juni 1933.)

Figure 10: This paper appeared in the "Journal of Biology" in 1933. Its translated title is: "The effect of linear and Centrifugal Forces on man." In this paper von Diringshofen summarizes the results of his acceleration test flights.

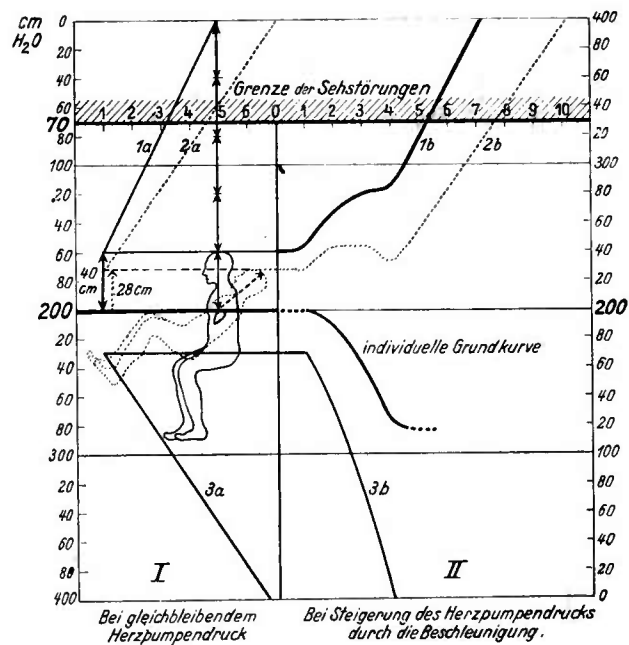


Figure 11: This diagram is contained in von Diringshofens paper "About the effect of accelerations in Flight on Man", "Journal of Flight Technology and Motor Aviation", 1933, 21:1-3 (24). On the abscissa are the G loads and on the ordinates, the pressure levels in cm Water. The horizontal shaded area at the level of 70 cm Water is marked "Grenze der Sehstörungen" i.e. "Boundary of visual impairment". The figure also shows that a reclining subject (here indicated by the dotted lines) has a higher G tolerance.

In his early papers (24), von Diringshofen also published a diagram which shows the Hemostatic theory for an upright seated and a semisupine subject (Fig 11). On the abscissa are the G loads, and on the ordinates, the pressure levels in cm Water. The horizontal shaded area at the level of 70 cm Water (equivalent to 50mm Mercury) is marked "Grenze der Sehs-toerungen" i.e., "Boundary of visual impairment", which represents the pressure at the level of the eyes necessary to assure an adequate blood flow to the retina. The figure also shows that a reclining subject (here indicated by the dotted lines) has an increased G tolerance.

Later, von Diringshofen became Director of the Air Force Medical Corps Research Unit in Jueterbog (Germany), and had various airplanes available for his research. With the reconnaissance aircraft Heinkel He 70 he made the first airborne X-rays by installing behind the seat a Siemens-Mueller X-ray tube "Centralix" (Fig 14). The X-ray also depicted an accelerometer reading which indicated the G load at the time the picture was taken (Fig 15).

In 1934 the first Human Centrifuge for aeromedical research was built at the Aeromedical Research Institute in Berlin according to plans provided by Heinz von Diringshofen and his brother Bernd. Even by todays standards the centrifuge was a highly sophisticated research tool (Fig 16, 17). It had a diameter of 5.40 meters, and an optical periscope within the hollow shaft of the centrifuge enabled the experimenter to view the subject from the control room located above the center of the arm. Numerous lines for electrical power, control, and measurement of data were connected via sliprings. Maximum performance was 20 G, with a maximum rate of onset of 1.5 G/sec. (This centrifuge was used amply by German Investigators until the end of WWII, when it was dismantled and was transported to Russia by Soviet Commandos).

At the beginning of 1939 von Diringshofen authored a Manual for Flying Personnel of the Luftwaffe entitled "Medizinischer Leitfaden fuer Fliegende Besatzungen", a book of 204 pages, which covered hypoxia, accelerations, and sensory functioning. After the beginning of WWII, this Manual was translated in Canada (needless to say without authorization) under the title "Medical Guide for Flying Personnel" by V. E. Henderson, a professor at the University of Toronto, and was distributed to the Flying crews of the Royal Canadian Air Force and also to the English Royal Air Force (27, 28). It was first printed in June 1940 and was reprinted in October 1940 and November 1940. In addition, it was translated in French by the de Gaulle Forces and in Roumania by the Roumanian Air Force. Thus, the Flying Personnel of five or more nations learned about the medical aspects of flight from the book by von Diringshofen (Fig 18).

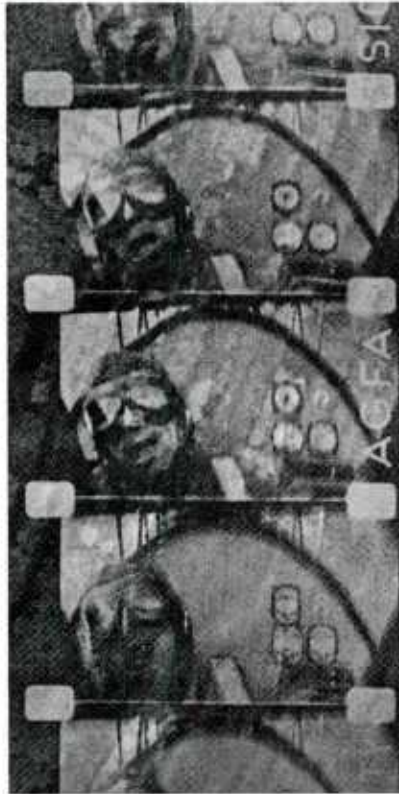


Figure 12: Subject seating erect, suffers at 5.5 - 6 G black-out and loss of consciousness. At right from the subject appears an accelerometer, variometer and altitude meter.

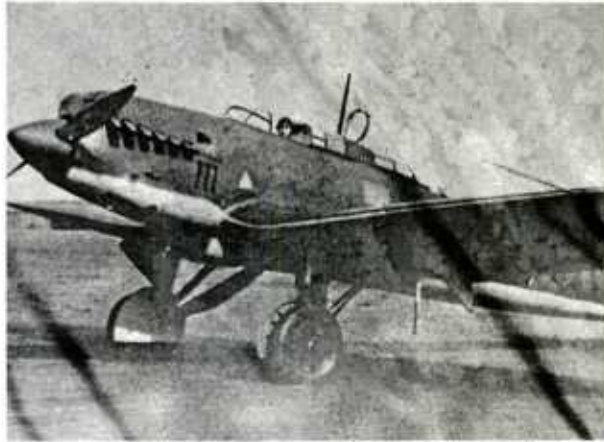


Figure 13: The Reconnaissance aircraft Heinkel He 70. With this aircraft von Diringshofen made the first airborne Thorax X-ray (26).

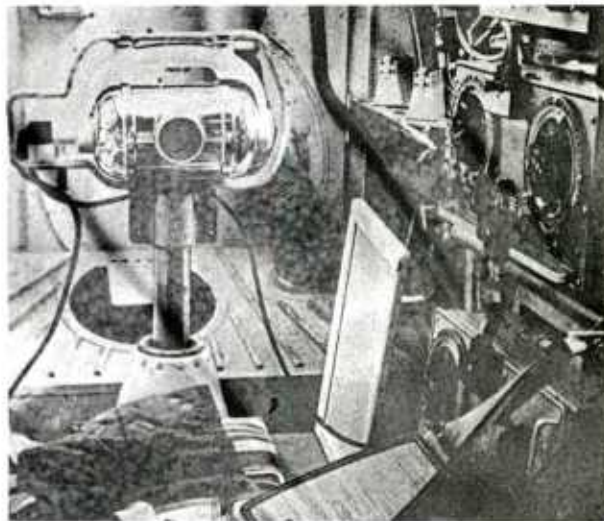


Figure 14: An X-ray tube ("Centralix") is installed behind the subject's seat in the Heinkel He 70 (26).

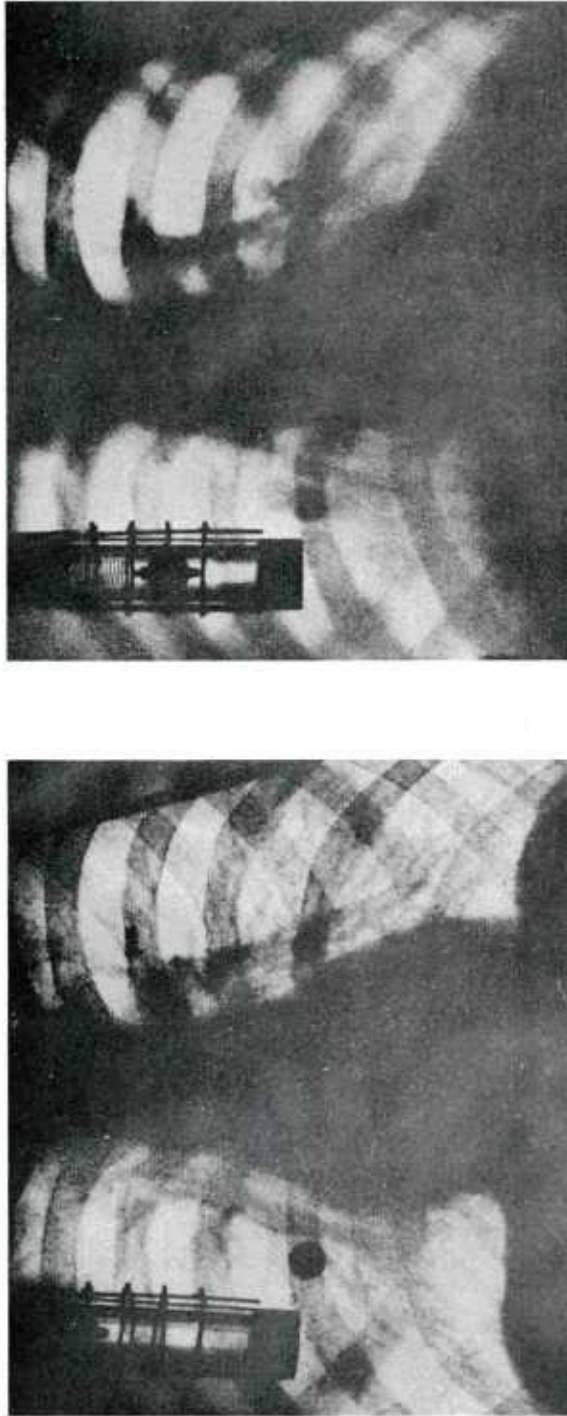


Figure 15: Two airborne Thorax X-rays taken in the Heinkel He 70. At left in straight level flight; at right at 6.5 G, showing the reduced volume of the heart of a semi-conscious subject (26). The X-ray also depicts an accelerometer reading which indicates the G load at the time the picture is taken.

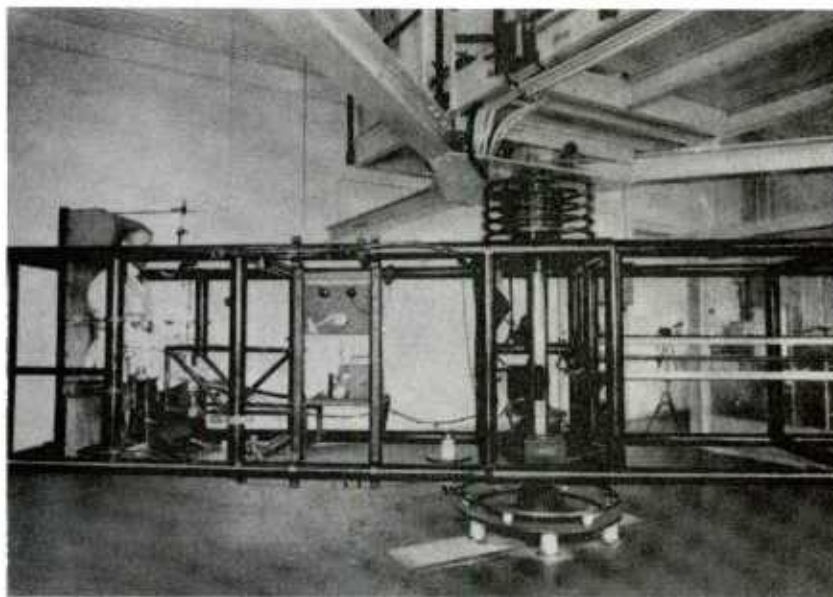


Figure 16: The first Human Centrifuge for aeromedical research. Built in 1934 according to plans provided by Heinz von Diringshofen and his brother Bernd von Diringshofen.

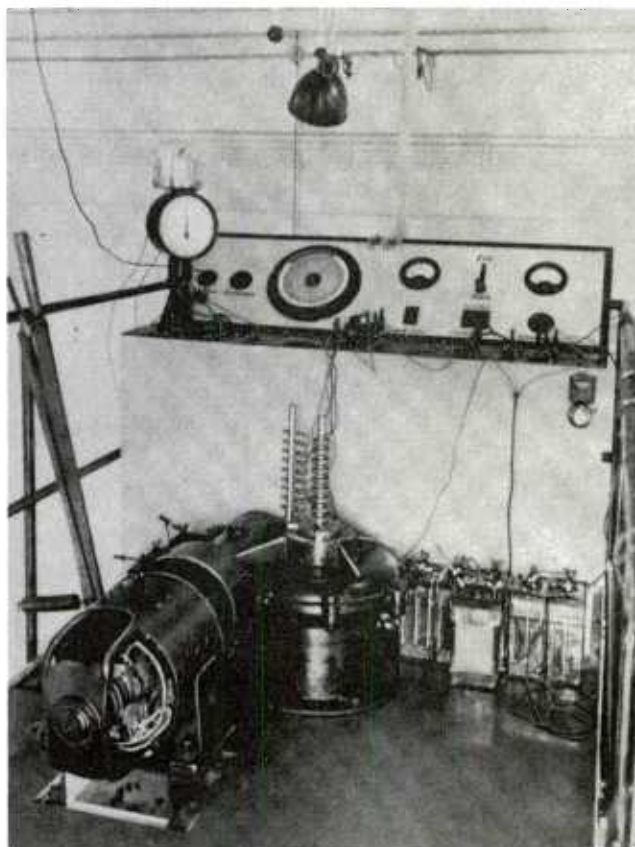


Figure 17: Control room located on the top of the centrifuge, showing the motor, instrumentation, and sliprings.

MEDICAL GUIDE FOR FLYING PERSONNEL

By
HEINZ VON DIRINGSHOFEN
Oberstabsarzt der Luftwaffe
1939

Translated by
MAJOR VELYIEN E. HENDERSON
M.A., M.B., C.A.M.C.; Retired
Professor of Pharmacology, University of Toronto



TECHNICAL REFERENCE BOOK

THE UNIVERSITY OF TORONTO PRESS
1940

Figure 18: Front page of the "Medical Guide for Flying Personnel" by Heinz von Diringshofen. During WW II in 1940 in Canada, this manual was translated in the English language (needless to say without authorization of the author) and was distributed to the Flying crews of the Royal Canadian Air Force, and later the American Air Force. In addition it was translated into French for the deGaulle Forces and in Roumania for the Roumanian Air Force.

Misquotations

Having summarized the work of von Diringshofen, I will show now how incomplete or faulty translations can easily lead to misquotations: P. Andina was the Senior Resident of the Surgical University Clinic in Basel, Switzerland.

He was personally well acquainted with von Diringshofen, and published in the Swiss Medical Weekly (Schweizerische Medizinische Wochenschrift No. 33) of August 14, 1937 in the German language the article (Fig 19) "Ueber Schwarzsehen als Ausdruck von Blutdruckschwankungen bei Sturzfluegen" ("About the Black-out as a result of blood pressure changes in diving flights"). In this paper, Andina claims by no means to be the originator of the Hemostatic Theory. On the Contrary, he quotes von Diringshofen in the text, twice giving him credit for his airborne experiments and for the hemostatic Theory, and also cites four of his papers in the bibliography. Andina's contribution was to relate the phenomenon of Black-out in Flight with the visual impairment that is on the ground produced when pressure is applied to the eyeballs by a dynamometer. An opthalmologist observed the fundus while pressure was applied. Andina calculated that visual impairment begins when a pressure of 50 mm Mercury is applied at the level of the eyes. The same value was reported by von Diringshofen five years earlier. This was the only paper in the area of accelerations that Andina published. He spent most of his professional career as Surgeon in the Regional Hospital in Lugano (Switzerland) until his death.

In the otherwise very complete Textbook of Aviation Physiology edited by J. A. Gillies (14) we find the following description of Andina's Work: Chapter 23. "The Physiology of Positive Acceleration upon Vision", by P. Howard, Subchapter "The Origin and Mechanism of Black-out", p. 552, (Fig 20) reads: "Andina (1937) was apparently the first to suggest a mechanism for black-out". That is not true: von Diringshofen in his early papers (1932-34) had the hemostatic theory established. P. Howard may have not been aware of these early papers, because in the chapter bibliography on p. 681, he quotes only three papers by von Diringshofen. All of these papers cited in Howard's chapter appeared in the Journal "Luftfahrtmedizin" ("Aviation Medicine") from the years 1938 to 1942. The Journal "Luftfahrtmedizin" began publication in June 1936, and von Diringshofen's pertinent papers were published much earlier: In 1932, 1933 and 1934 in the "Journal for Aviation Technology and Motoraviation" (21, 24) in "Acta Aerophysiological" (23) and in the Journal of Biology (22, 25). It may be that these papers were not available to P. Howard.

The second phrase to which I must take exception is underlined at the end of p. 552: "Earlier German theories of black-out which postulated deformation of the brain with compression of the optic chiasma, were thus finally displaced by a retinal theory". This statement is also incorrect, because the cerebral compression theory, as mentioned before (see chapter about P. Garsaux), was postulated by the French Investigators, A. Broca and P. Garsaux and not by German authors. On contrary, von Diringshofen Hemostatical Theory was already uniformly adopted in Germany in the early thirties.

Schweizerische Medizinische Wochenschrift Nr. 33

Aus der Chirurgischen Universitätsklinik Basel
Vorsteher Prof. C. Henschen

Über „Schwarzsehen“ als Ausdruck von Blutdruckschwankungen bei Sturzflügen

Von F. Andina, Assistent der Klinik

Die Technik des modernen Flugzeugbaues ist in eine Phase getreten, welche die Frage des „fliegenden Menschen“ neuerdings zu einem Problem macht. Als die Fliegerei noch in ihren Anfängen steckte, waren die Schwierigkeiten technischer Natur.

Diese Versuche sind meist gescheitert an den Schwierigkeiten der Methodik, da diese eine unblutige, fortlaufend-registrierende Blutdruckmeßapparatur erfordert, die zudem beschleunigungsunempfindlich sein muß. Die Ausbeute dieser Versuche ist daher höchst bescheiden ausgefallen. Erst die Apparatur von H. von Diringshofen scheint diese Postulate erfüllt und brauchbare Resultate geliefert zu haben. Sie stellt einen für diesen besonderen Zweck modifizierten Autotonographen (von Lange) dar. Auch dieser Apparat hat jedoch seine definitive Fassung noch nicht erreicht, da er noch verschiedene Mängel aufweist. Zudem teilt er mit den üblichen, einfachen Tonometern alle Nachteile der Manschettenmethode.

Der Beginn der Sehstörung (Dunkelschen) wurde meist um 4,5 g bemerkt, vorausgesetzt, daß die Fliehkraft während einer gewissen minimalen Dauer von einigen Sekunden einwirkte. Vollständiges Schwarzsehen ist einige Male bei 5 g aufgetreten, jedoch durchaus nicht immer (Abhängigkeit von der Dauer der Beschleunigungseinwirkung) und nur bei rückwärtsgeneigtem Kopf mit gestrecktem Hals und Blick gegen die am oberen Tragdeck angebrachte Sehtafel. Dabei soll durch Verlängerung der Blutsäule Herz-Kopf der hydrostatische Druckabfall in ihr größer werden (*v. Diringshofen*) und die Gehirngefäße somit beschleunigungs-empfindlicher. Bemerkenswert ist noch, daß nach vorausgegangenen Rückenflug (Kopf nach unten) das Auge empfindlicher zu sein scheint. Beim halben Looping nach unten aus der Rückenlage waren die Sehstörungen zwischen 4 und 5 g durchwegs leichter zu erzeugen. Erfreulicherweise stimmten die Eindrücke des Piloten fast immer mit denjenigen des Schreibenden überein.

Zusammenfassung

Es wird im Flugzeuge bei gemessener Beschleunigungseinwirkung das Schwarzsehen beobachtet, das nachher im Testversuch durch Druck auf den Bulbus reproduziert wird. Mittelst der dabei gemachten Beobachtungen am Augenhintergrunde und der dynamometrischen Messungen (Blutdruck von *Bailliant*) können die Druckverhältnisse bei Fliehkrafteinwirkung in den Regionen der basalen Gehirngefäße approximativ ermittelt werden.

Acher, K.: Klin. Mbl. Augenheilk. 88. — *Bailliant, P.*: La circulation rétinienne. Doct. Paris 1923. — *v. Diringshofen, H.*: Luftfahrtmedizin 1936, 1, Luftfahrtmed. Abh. 1936/1937, 1; Z. Biol. 1934, 55; Kongressber. inn. Med. 1935, 47. — *Hess, W. R.*: Handb. d. norm. u. path. Physiologie, Die Regulierung des Blutkreislaufes, Leipzig 1930, G. Thieme. — *Jongbloed, J.* und *Noyons, A. K.*: Arch. f. Physiol. 1934, 233. — *Lange, Dtsch. med. Wochr.* 1932. — *Schubert, G.*: Physiologie des Menschen im Flugzeug, Springer 1935. — *Stachelin, R.* und *Müller, A.*: Z. exper. Med. 1924, 30/40; 1925, 46. — *Wegner, W.*: Arch. Augenheilk. 1928, 98.

Figure 19: Article of F. Andina, 14 August 1937 (1).

CHAPTER 23

The Physiology of Positive Acceleration

P. HOWARD

THE EFFECTS OF POSITIVE ACCELERATION UPON VISION

The Origin and Mechanism of Black-Out

Andina (1937) was apparently the first to suggest a mechanism for black-out. He compared the effects of acceleration on vision (as studied in an aircraft pulling-out from a dive) with the impairment produced by applying pressure to the eyeballs with a tonometer. The course of pressure blindness was found to be very similar to that of black-out, progressive impairment taking place as the external pressure was increased. Andina found that complete loss of vision was produced when the effective blood pressure in the central retinal artery was reduced to 21 mm Hg. The normal intra-ocular tension being also about 21 mm Hg, it was accordingly suggested that no blood could flow through the eye unless the pressure in the retinal artery exceeded this value. It was already known that one effect of centrifugal forces was to reduce the blood pressure at head level, and it seemed probable that black-out, like pressure blindness, arose from a failure of blood supply to the retina. Lambert and Wood (1946b), using a human centrifuge, showed that blood flow through the eye was indeed the determining factor in black-out and, by measuring pressures in the radial artery supported at eye level, found that vision was affected when the systolic blood pressure fell below 50 mm Hg. Andina had noted symptoms when the calculated retinal systolic pressure was 54 mm Hg. Complete loss of vision occurred with a systolic pressure of about 20 mm Hg, compared with Andina's figure of 21 mm Hg. Lambert (1945) had already shown the importance of the intra-ocular pressure by demonstrating that an external pressure of 20-30 mm Hg lowered by 1 g the acceleration at which black-out was produced, and that the application of suction to the eyeballs prevented black-out, or at least delayed its onset. Earlier German theories of black-out, which postulated deformation of the brain with compression of the optic chiasma, were thus finally displaced by a retinal theory, but in 1953 a Russian worker, Komandantov, claimed that haemodynamic factors played but a small part in the physiology of black-out. He considered that information travelling

Centrifuge Experiments after the von Diringshofen Era

In 1934 Jongbloed and Noyons (15) published the results of their experiments with a small animal centrifuge on which they exposed rabbits to high G loads and obtained noticeable results. They continuously measured blood pressure, blood flow, electrocardiogram, and even took X-ray pictures under G. They observed, like von Diringshofen, that the importance of the carotid sinus reflex for the maintenance of arterial blood pressure under G loads became obvious.

In 1937 Armstrong and Heim (2) reported on their experiments conducted with a rather primitive centrifuge at Wright-Patterson A.F.B., Dayton, Ohio. Despite their primitive centrifuge, they obtained valuable results with humans and goats (Fig 21). They called their centrifuge "Accelerotor". It was driven by a 25HP motor and could accelerate to 20 G.

The first modern centrifuge on the American Continent was built by the Royal Canadian Air Force in Toronto in 1941 (Fig 22); it was used extensively during WWII. W. R. Franks conducted his interesting experiments with hydraulic and pneumatic Anti-G suits on this centrifuge. The number of modern centrifuges suddenly exploded. In 1942 the Mayo Clinic Centrifuge was completed; in 1943 the old centrifuge of Armstrong and Heim was replaced by a new one; in 1944 the University of Southern California Centrifuge was built; in 1945 the centrifuge at Pensacola was completed, and in 1951 the US Naval Air Development Center at Johnsville, Pennsylvania dedicated its new centrifuge. The NAVAIRDEVCEEN Centrifuge is still in use, however because of the rezoning of the Post Office, the address of the Naval Air Development Center is now Warminster, Pennsylvania. This centrifuge is the only one of the original group that is still in full use (Fig 23).

After the centrifuge in Warminster, the explosion of centrifuges continued: they were built in Farnborough (England), Soesterberg (Netherlands), Tokyo (Japan), Moscow (USSR), Star City (USSR), Rome (Italy), Houston (USA), Mountain View (USA), San Antonio (USA), Bretigny (France) Bonn (West Germany), Fuerstenfeldbruck (West Germany), and Stockholm (Sweden).

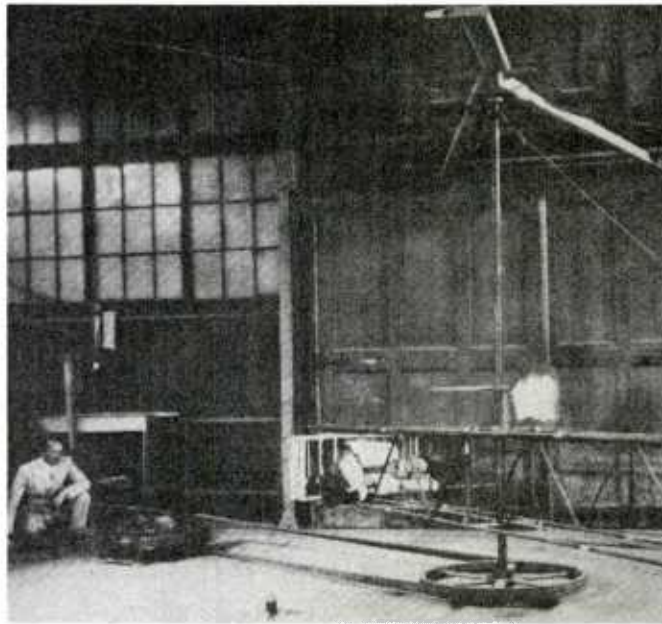


Figure 21: The Centrifuge of Armstrong and Heim, 1937 (2).

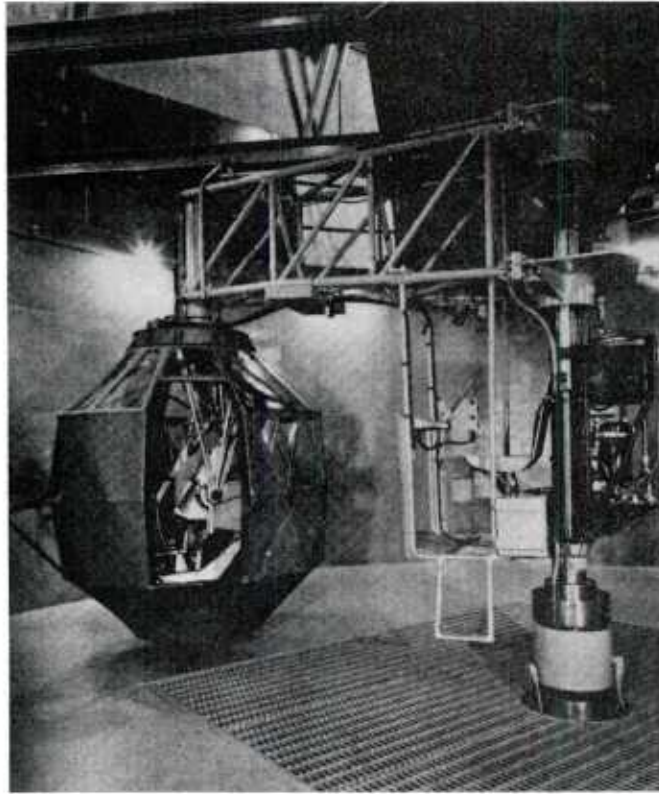


Figure 22: The first modern centrifuge of the American Continent: The centrifuge of the Royal Canadian Air Force in Toronto, Canada.

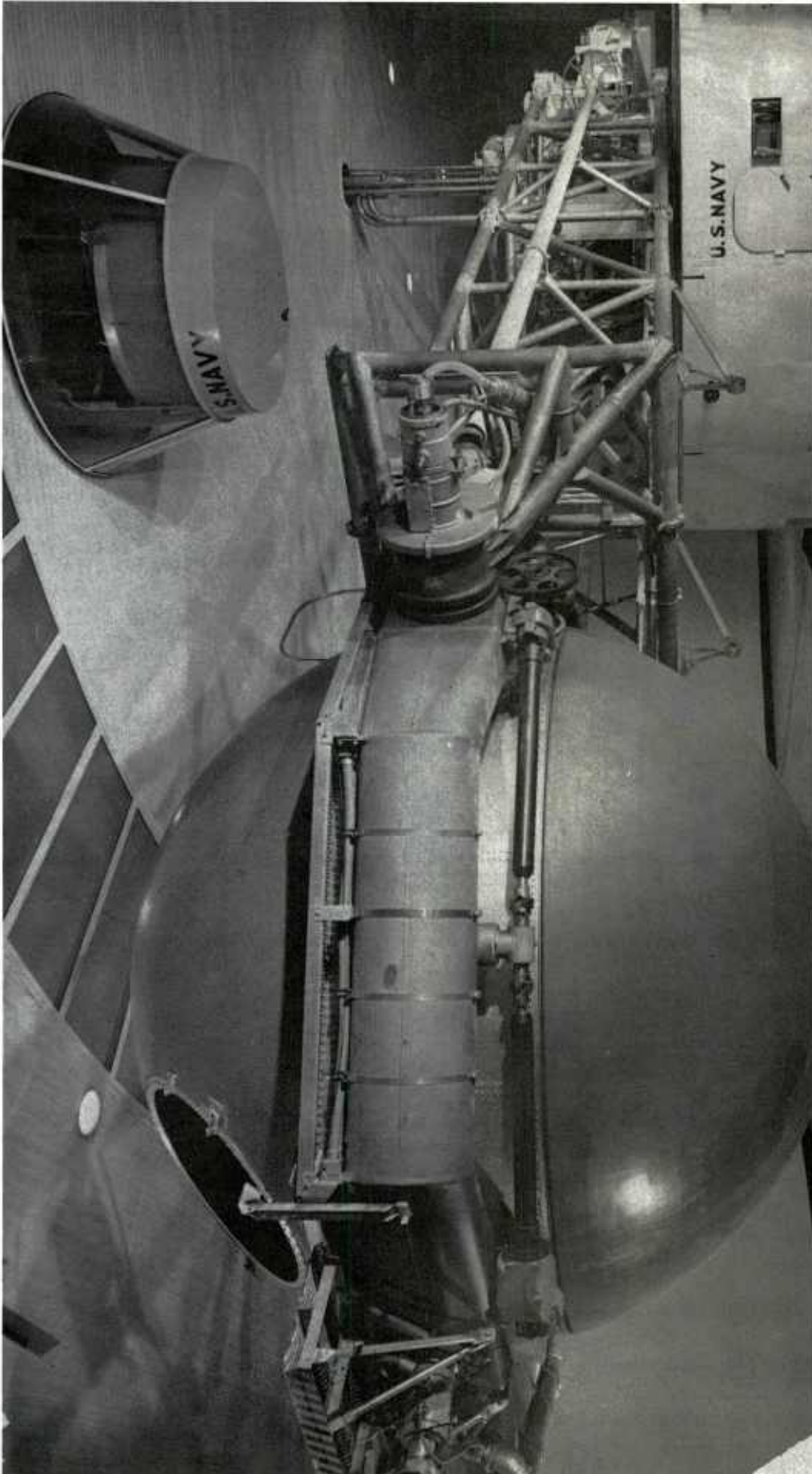


Figure 23: The centrifuge of the Naval Air Development Center in Warminster, Pennsylvania. Although built in 1950, it was modernized several times and is still in full use. Recently von Beckh (20) used the centrifuge for evaluation of a novel aircraft seat, the PALE (Pelvis and Legs Elevating) seat.

Conclusion:

The intent of this report was to describe only the beginnings of aeromedical acceleration research. Therefore it ends with the work of von Diringshofen. For later and contemporary research, the reader is referred to the pertinent literature, most of which appears in the Journal "Aviation Space and Environmental Medicine", (before 1975 "Aerospace Medicine", and before 1959 "Journal of Aviation Medicine").

Let me conclude this report with the same prophetic words of Louis Bleriot (4), that I used in 1955 to complete my text book "Physiology of Flight" (19); these words have become even more true than when they were first written in 1922:

"C'est ne pas la résistance de la matière qui sera la limite des performance acrobatique de l'oiseau artificiel, mais bien la résistance physiologique de l'homme qui en est le cerveau".*

* "It is not the resistance of material which limits the aerobatic performance of the artificial bird, but the physiologic resistance of man, who is the brain of the artificial bird".

REFERENCES

1. Andina, F. 1937. Ueber Schwarzsehen als Ausdruck von Blutdruckschwankungen bei Sturzfliegen. Schweizerische Med. Wochenschrift 67:33:753-756.
2. Armstrong, H. G., and J. W. Heim. 1937. The effects of acceleration on the living organism. Air Corps Technical Report No. 4362, Material, Division, Dayton, Ohio. Dec 1, 1937. Also published: J. Av. Med. 9:199-224, 1938.
3. Bauer, L. H. 1926. Aviation Medizin. Publisher Williams and Wilkins, Baltimore.
4. Bleriot, L. 1922. L'oiseau artificiel. L'Aerophile 19:20, 15 Oct 1922.
5. Broca, A., and P. Garsaux. 1919. Note preliminaire sur l'étude des effets de la force centrifuge sur l'organisme. Bulletin de l'Academie de Medecine, Paris, 82:75-77.
6. Buehrlen, L. 1937. Versuche ueber die Bedeutung der Richtung beim Einwirken von Fliehkraeften auf den menschlichen Koerper. Luftfahrtmedizin 1:307-325.
7. Clark, B., and A. Graybiel. 1957. The break-off phenomenon. J. Av. Med. 28:2:121-126.
8. Cruchet, R., and R. Moulinier. 1911. Le mal des aviateurs. La Presse Medical, Paris, 19:50:589-592.
9. Dobrotvorskii, N. M. 1930. The Task of Flying (Letnii Trud). USSR Academy of Sciences Publishing House, Moscow.
10. Doolittle, J. H. 1924. Accelerations in Flight. Report No. 203:373-388 in "Tenth Annual Report of N.A.C.A." Government Printing Office, Washington, DC.
11. Ferry, G. 1927. A propos d'une cause d'accident au cours du vol en avion: moyen de l'eviter. 4th International Congress of Aerial Navigation, Rome, Italy. 1927. Quoted by A. L. Flamme, Arch. Med. Militaire 96:266, 1931.
12. Flamme, A. L. 1931. Influence et limite physiologique de la vitesse et de ses derives. (Accelerations, choque, trepidations). Arch. Med. Milit. 96:263, Paris, France.
13. Garsaux, P. 1918. Experiments de l'action de la force centrifuge sur l'apparat circulatoire des chiens. Exper. Service Techn.. Sect. Milit. Aeronautique, Ministere de Defense National. Paris, France.

14. Gillies, J. A. 1965. A Textbook of Aviation Physiology. Chapter 23. The Physiology of positive acceleration upon vision, by P. Howard. Page 552. Pergamon Press, London.
15. Jongbloed, J., and A. K. Noyons. 1934. Der Einfluss von Beschleunigungen auf den Kreislaufapparat. Pflueger's Archiv der gesamten Physiologie 233:67-97.
16. Lange, N. 1932. Autotonographie. Deutsche Medizinische Wochenschrift II:121.
17. Ruff, S. 1937. Ueber das Verhalten von Blutdruck und Pulsfrequenz unter dem Einfluss von Fliehkraefte und ueber Versuche zur Steigerung der Beschleunigungsertraeglichkeit. Luftfahrtmedizin 2:259-280.
18. Schubert, G. 1935. Physiologie des Menschen im Flugzeug. Publisher J. Springer, Berlin.
19. Von Beckh, H. J. 1955. Fisiologia del Vuelo (Physiology of Flight). 147 pp. Publisher Editorial Alfa, Buenos Aires.
20. Von Beckh, H. J. 1981. The development and airborne testing of the PALE seat. Report No. NADC-81200-60, Naval Air Development Center, 20 June 1981.
21. Von Diringshofen, H. 1932. Die Bedeutung von hydrostatischen Druckunterschieden fuer den Blutkreislauf des Menschen bei Einwirkung hoher Beschleunigungen. Zeitschrift fuer Flugtechnik und Motorluftschiffahrt, 6:1-6.
22. Von Diringshofen, H., and B. Belonoschkin. 1932. Experimentelle Untersuchungen ueber den Einfluss hoher Beschleunigungen auf den Blutdruck des Menschen. Zeitschrift fuer Biologie 93:79-92.
23. Von Diringshofen, H., and B. von Diringshofen. 1933. Elektrokardiographie, Blutdruckschreibung und Pneumotachographie im Motorfluge. Acta Aerophysiologica I:1:48-60.
24. Von Diringshofen, H. 1933. Ueber die Wirkung von Beschleunigungen im Fluge auf den Menschen. Zeitschrift fuer Flugtechnik und Motorluftschiffahrt 21:1-3.
25. Von Diringshofen, H. 1934. Die Wirkung von Gradlinigen Beschleunigungen und von Zentrifugalkraefte auf den Menschen. Die Haemostatik bei Beschleunigungseinwirkung. Zeitschrift fuer Biologie 95:1-26.

26. Von Diringshofen, H. 1938. Vorlaeufige Mitteilung ueber Roentgenaufnahmen und Durchleuchtungen des Herzens bei Fliehkrafteinwirkungen im Flugzeug. Luftfahrtmedizin 2:281-286.
27. Von Diringshofen, H. 1939. Medizinischer Leitfaden fuer fliegende Besatzungen. 204 pp. Publisher Theodor Steinkopf, Dresden.
28. Von Diringshofen, H. 1940. Medical guide for flying personnel. Translated by V. E. Henderson. Publisher University of Toronto Press, Canada.
29. Von Diringshofen, H., and H. J. von Beckh. 1952. Aspectos medicos de la astronautica. Revista Nacional de Aeronautica 12:128:17-26, Buenos Aires, Argentina.

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