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UNITED STATES NAVY YARD

PHILADELPHIA, PA.

[redacted]

NAVAL AIRCRAFT FACTORY

15 May 1935

SUBJECT: Acceleration Belt.

Reference: (a) Report on the Physiological Effects of Sudden Changes in the Speed and Direction of Airplane Flight.
(b) Report on possible methods of reducing the Symptoms produced by rapid change in the Speed and Direction of Airplanes.

1. References are reports of studies undertaken with the cooperation of the Department of Physiology of the Harvard School of Public Health. These studies were prompted by the increasing hazard to aviators of the high accelerations encountered in highly maneuverable airplanes. The virtual universality of symptoms on the part of aviators subjected to high accelerations made it imperative that the underlying physiological causes of these symptoms be disclosed and possible relief measures be devised.

2. The summary of findings in these two studies are quoted, in part:

"Dogs anaesthetized with Nembutal were mounted in an airplane in a position exactly similar to that occupied by the aviator and subjected to rapid horizontal turns and dives. Direct records of arterial pressure were made during these maneuvers.

"A drop in arterial pressure occurs which is directly proportional to the severity and time of application of the abnormal forces. This causes a severe cerebral anoxemia which accounts for the symptom of 'going black.'

"A belt embracing the entire abdomen and containing an inflatable bag was strapped about the dog. Inflation of this bag produced an increase in intra-abdominal pressure. This was done at different times in relation to the maneuvers.

"Raising the intra-abdominal pressure shortly before the high accelerations of the maneuvers, produced no material improvement in the physiological changes incident to these high accelerations.

SUBJECT: Acceleration Belt.

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"Raising the intra-abdominal pressure by inflation of the belt at least one-half minute before the high accelerations produced a marked improvement in the physiological changes. The improvement was a preservation of carotid cerebral circulation at a level above that resulting in severe anoxemia and consistent with freedom from subjective symptoms.

"Raising the intra-abdominal pressure by the inflation of such a belt at least one-half minute before subjection to high accelerations, should relieve an aviator of the symptoms experienced as a result of these accelerations."

3. Further studies have been carried out at the Aircraft Factory toward the development of a belt and methods of inflation adaptable to service conditions. This is to report on these studies:

4. The Belt.

The belt should be made of inelastic fabric. It should cover the entire abdomen, extend well down over the symphysis and as high over the epigastrium as can be held in position without restricting the lower ribs. It should be held in position by straps which extend around the back so that inflation of the contained bag will produce no bulging outward. The projection over the lower abdomen should be held in close apposition to the symphysis by perineal straps. Comfort and freedom of movement should be preserved as far as possible.

The inflatable bag should embrace the entire abdomen extending well into the flanks. Expansion should be uniform over the entire area. It should be sufficiently pliable so that the contained pressure will not be absorbed by the elasticity of the bag, but will be transmitted into the abdomen.

A belt has been developed which meets these requirements, (N.A.F. Drawing 66710). It is deemed practicable to make all belts in conformity with one pattern, making due allowances by adjustment features for variations in the size and shape of different individuals.

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Six ounce canvas backed by three-ply rubberized fabric has been used for the front surface of the belt. The rubberized fabric does not extend beyond the limits of the inflatable bag, but the canvas extends over the back in two aprons. One apron terminates in two herringbone tapes which are adjustable and are hooked or buckled on two fittings on the other apron.

The perineal straps of herringbone tape are sewed to the aprons of the belt and are snapped on the lower front projection of the belt.

The tube leading into the bag is secured into the front upper edge and projects at an angle towards the left. (It is assumed that in practically all planes, the valves and attachments preferably will be on the left side of the cockpit). The tube should be of sufficient rigidity so that it will not be collapsed or kinked by the clothing over it.

The bag is made of one sheet of pure Para rubber joined to the back of the belt by means of two strips in a bellows-like manner so that inflation of the bag will result in uniform separation of the two layers over its entire extent. This prevents excessive bulging in the center and very little at the edges.

The Source of Air Pressure

5. Requirements.

The bag, inflated, is of approximately two quarts capacity. This varies in different individuals, is dependent upon the closeness of fit, and changes during the period of use. As fluids are forced out of the abdominal cavity, and as the contained viscera conform to the increased pressure, the intra-abdominal volume changes and the volume of the bag must change accordingly to maintain constant pressure. The volume can be considered as being constantly variable from an original volume of about two quarts.

The pressure of the supply must remain constant at about one and one-half pounds. During accelerations, the pressure in the belt rises as a result of hydrostatic changes in the abdomen and this increase should be preserved. This is effected by interposing a check valve between the belt and the supply. As the volume and pressure in the belt change as a result of physiological changes and those resulting from change in atmospheric pressure, the supply must be capable of briskly supplying any deficiencies.

SUBJECT: Acceleration Belt.

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The original volume at the desired pressure should be attained in from 15 to 20 seconds.

To summarize: The source of air should be capable of delivering two quarts of air against a a one and one-half pound head in from 15 to 20 seconds, and then maintain that pressure.

6. Possible Methods.

For practical purposes there are three methods adaptable to airplane use:

(1) Flask with reducing valve.

(2) Engine driven pump.

(3) Electric driven pump.

Other proposed methods include:

(4) Constant volume reservoir with a tripping device to apply pressure and force air into the belt. This procedure is entirely impractical in view of the changes in atmospheric pressure.

(5) The slip stream. Static pressure of the slip stream is virtually nil.

(6) Air driven pump would be too parasitic.

(1) The flask method. The advantages of a flask system are that it introduces no additional load on the motor or battery - it would be self contained and might be constructed sufficiently small to be worn by the pilot. Its disadvantages are size and weight, and the problem of service. To be sufficiently capacious and be reasonable in size and weight, it would require frequent and regular charging to several hundred pounds pressure. This would require the additional services of personnel and the installation of elaborate air compressors at points (such as hangars) where it would find no other use. Without a gauge on each unit and perfect valves, the possibilities of failure when most needed, are many. It is believed

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the disadvantages far outweigh the advantages and this method is impractical for service use.

The use of constant volume and pressure flasks such as are used in life preservers, boats, etc., are not practicable unless combined with control valves. With constantly varying volumes in the belt, such cartridges would deliver varying pressures. The volume at desired pressure delivered at high altitudes would be inadequate at lower altitudes.

A sylphon operated reduction valve was designed and constructed, (N.A.F. Drawing 56389) for use on a flask. Because the desired pressure was not exactly known, an adjusting feature was incorporated in this valve which interfered with its proper performance. It was found to be impractical. Reduction valves are available which would meet the requirements, but the additional weight makes this method further prohibitive.

(2) Engine driven pump. Objections to this method arise from the additional load on the motor, additional weight, inaccessibility, constant operation while motor is running and variation in capacity with variations in engine speed. The advantages lie in constant availability and hence dependability and ease of maintenance.

Several tests have been made of different types of pump geared directly to the motor. A point of attachment is found on all motors used in planes in which high accelerations develop in the form either of an extra tachometer drive shaft or synchronizer gear.

An F-4 fuel pump was fitted with an oiling device and adapted to the tachometer drive of a motor on the test stand. Supplying only one belt, at idling speeds (600-700 r.p.m.), the pressure failed to rise above 35 mm. Hg., or about 0.7 lbs. At 1600 and 1700 r.p.m. with relief valve closed off, the pressure rose to 50 mm. (1 lb.), but only after a lapse of 25 seconds. With the relief valve set for 50 mm. at 1600 r.p.m. the pressure did not rise above 45 mm. during 50 seconds.

It is possible that a rotary pump designed to pump air instead of fluid could be found which would serve the purpose and still be reasonable as regards size and weight. Certainly one could be designed.

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A Pesco vacuum pump was tested, using the discharge. It was reported that the resistance did not materially interfere with the normal performance of the pump. At practically all speeds, with the relief valve set at 1 lb., this pump filled one belt in 7-8 seconds and two belts in 15-17 seconds.

Such performance is highly satisfactory. An added advantage is apparent in that if and when this or a similar vacuum pump is accepted for service use, the source of air pressure for the belt will require no additional installation except the tubing and the use of the pump to operate air driven instruments will not be impaired thereby.

(3) Electric driven pump. The disadvantages of an electric driven pump are the additional drain on generator, and/or battery, and the weight of installation. The advantages are that it would be switch controlled and would operate only when needed. Two types have been tested: (a) an impulse pump, and (b) a motor driven rotary compressor.

(a) A unit of two Auto pulse Electric Fuel Pumps was tested with both 6 and 12 volts. Designed to pump gasoline, these units were not capable of delivering sufficient air against the desired pressure. The diaphragms and valves were not suited to pumping air. It is believed that an impulse pump can be designed with diaphragms and valves suited to pumping air which would serve the purpose. The design and testing would consume several months and the weight and complexity of the finished pump make such a project unwarranted, especially in view of the fact that there is available on the market, a combination

(b) motor driven rotary compressor which has been found very satisfactory. This combination consists of or is similar to a Bodine Electric Company Catalog #16112, type V-10, 1/100 H.P., 12 volt D.C. series wound 2400 r.p.m. clock rotation motor, and a Vernon Rotary Compressor No. 1. Driven directly by a flexible coupling, this pump has been found capable of meeting the requirements. The assembly without explosion proofing, housing and mounting weights 4.37 lbs.

7. <u>Connections</u>.

Metal tubing is used between the source of pressure and the control assembly, (N.A.F. Drawing 46641-1).

A relief valve set at one and one-half lbs. is incorporated in this line at a convenient position.

The control assembly consists of a unit including a ball check valve, a hand valve and a quick release fitting. The ball check valve serves to maintain any increase in pressure resulting from hydrostatic or physiological forces operating during the high acceleration. The hand valve is for directing the air from source to belt, or from belt to outside. The quick release fitting is designed to make connection between the pilot and the plane negligible in case of forced parachute jump. Flexible rubber tubing is used in the belt connections.

8. Method of Use.

The belt should be used in all maneuvers in which high positive accelerations may be anticipated.

The belt should be snugly adjusted over the abdomen, under the trousers. It should be adjusted so as not to interfere with necessary movements, but close enough to reduce the volume at pressure to a minimum.

The belt should be inflated at least one and one-half minutes before the anticipated acceleration. On the preliminary physiological studies it was found that the efficacy of the belt lay less in its acting as a dam to prevent centrifugal concentration of blood in the abdominal veins than in its serving to cause a redistribution of blood from the abdominal pool into the general systemic veins. The more profound drop in cerebral pressure resulted from drainage of blood below the heart level, reducing heart output because of reduced supply. By diverting some of the excess from the abdominal pool into the large veins above the level of the heart, the supply, and therefore the volume and pressure of output are preserved. To effect this redistribution requires time because of the anatomic considerations involved. The diversion can only be effected by forcing the blood through either or both of two capillary beds. From this experimental knowledge it is assumed that an interval of one and one-half minutes may be considered as a minimum. The belt may be deflated at any time after the completion of the maneuver.

To illustrate in detail: In dive bombing the belt may be inflated at any time, but at least one and one-half minutes before diving, and, if the interval between dives is of several minutes duration, it may be deflated between dives. If the interval is short it should be kept inflated during the practice. Because of this necessary delay the operation of inflation should in no way interfere with arming of bombs, adjustment of controls, sighting, etc. In combat maneuvers the belt should be inflated at least one and one-half minutes before the beginning of the combat and kept inflated during the entire combat. In high speed runs over short courses the belt should be kept inflated all the time. Where pylons are sufficiently far apart to make transit of each leg of several minutes duration, it may be deflated over straight courses, but should have been inflated at least one and one-half minutes before rounding each pylon.

The only known restriction to be observed is the use of the belt by pilots suffering from high blood pressure persistently above 135 mm. Hg. if the individual be less than 25 years of age, or above 145 mm. Hg. if he be older than 25.

9. <u>Summary</u>.

The findings of the physiological studies were positive and conclusive.

On the basis of these findings but in the absence of practical laboratory methods of confirming them in man, certain conclusions about the physiological causes and corrective methods applied to man are justified.

Extreme symptoms of high accelerations are well recognized and encountered with increasing frequency. They are generally described in terms of decreased vision, e.g. "going black," "twilight," etc. Such conscious subjective symptoms are poignant and tangible. Of lesser severity and below the threshold of conscious awareness there are other symptomatic manifestations of high accelerations. In this category fall such symptoms as slight reduction in attention, motor coordination, judgment, abstract reasoning, etc. These are symptoms which naturally result from the cerebral anoxemia produced by the high accelerations. They can be of as much significance as the more tangible ones.

SUBJECT: Acceleration Belt.

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Increasing the intra-abdominal pressure by the application of external pressure causes an alteration in the distribution of blood pressure and volume which makes it possible for the normal circulatory system to preserve cerebral circulation at a level above that causing anoxic symptoms.

Inflating a belt over the abdomen to one and one-half pounds pressure at least one and one-half minutes before subjection to high accelerations, prevents or ameliorates the symptoms of high acceleration.

It is appreciated that this project has not been exhausted in detail. Extensive testing by a number of pilots will undoubtedly disclose facts on which to base changes in the configuration of the belt, amount of pressure, methods of operation, etc. Further engineering study may disclose more satisfactory methods of installation, source of pressure, etc. The adaptation of the belt as a possible replacement for life preservers, etc., are offered as possible extensions of the problem. The above is offered as a means of reducing the symptoms of high accelerations.

/s/ J. R. Poppen