Soviet High Altitude Pressure Suit Development, 1934-1955

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As part of a continuing study in international high altitude physiological research, protective equipment development, operational support, and aerospace life-support subsystem planning, an open-source review was made of Soviet high-altitude pressure suit development, testing, and use. Beginning with a crude prototype suit in 1934, the Soviet pressure suit program quickly expanded into an exceptionally well organized, staffed, and funded effort. Their accomplishments included a thorough review of world literature on high altitude physiology, aircrew requirements for stratospheric flying, and foreign technological developments; design of many suits; combined low-temperature, low-pressure, and flight tests; electrically heated face plates and clothing; reliable closed circuit aircraft and escape environmental control systems.

Soviet aviation medicine specialists enjoyed long, continuous assignment to research problems with the notable exception of the years 1943-1946. Translated open-source literature is abundant; several superb reports are doctoral theses. All evidence suggests that Soviet life scientists have been earnest and sincere in striving to provide adequate personal equipment for their aircrews.

INTRODUCTION

A MAJOR GOAL OF USAF aerospace medicine is to assist in providing our aerospace crewmen with the most desirable personnel subsystems. The over-all success in design of such subsystems depends upon effective application of knowledge and experience gained from many professional disciplines. Selection of the most appropriate personnel pressurization, a part of the subsystem in aerospace craft, is a complex matter. Routine and emergency crew pressurization can be accomplished by use of many techniques. Since each technique has advantages and drawbacks, the most suitable one should be selected for the particular aerospace system under design.

This study is directed toward assisting in the design of superior personnel subsystems. The results of a review of domestic and foreign aerospace medical research, development, and operational testing of personnel subsystems contributes toward achieving improved systems. Such a review can also be an excellent indicator of a country's growth, maturity, philosophy, and management of human and other resources in aerospace medicine. Analysis of the aerospace craft crew pressurization systems which a nation develops reveals much concerning crew compartment design, the propulsion vehicle, and the state-of-the-art of life sciences in that country.

This paper presents an evaluation of the high-altitude pressure suit program in the USSR from its inception in 1934 through 1955. From April 1943, when the Institute of Aviation Medicine was closed, until the end of World War II, very little pressure suit or any other aviation medical research was conducted in the USSR.[7]

BACKGROUND

One might have expected early low pressure physiologists such as Boyle, Bert, or Hoppe-Seyler to suggest the use of a pressure suit or capsule for protection of humans at low ambient pressures. It appears that they

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did not. It seems appropriate to give credit to Jules Verne for first clearly describing in 1872 a closed-circuit extravehicular pressure suit operation during a flight around the moon.[11] D. I. Mendeleyev suggested before 1875 the use of a gas tight gondola for personnel protection in stratospheric balloon flights. Haldane in 1922 first clearly stated the internal suit pressure needed to protect humans from hypoxemia when ambient pressure is negligible. Although a few early patents were granted on pressure suits,* the real credit for design and low pressure chamber test of a closed-circuit, injector circulating, CO_2 absorbing protective suit is held by Haldane and Davis.†

First prototype high-altitude pressure suits were built in various countries approximately as follows: England (October 1933), U. S. (April 1934), USSR (late 1934), France (June 1935), Germany (late 1935), Spain (1935), and Italy (1936). Since 1938, many other countries have constructed a variety of altitude suits for complete or partial body protection. They include Canada (1942), Japan (1943), Poland, China, Norway, Sweden, and Czechoslovakia.

Stimulus for the development of early pressure suits originated in general either from individual aviation and balloon contestants (Wiley Post, Mark Ridge, Lt. Col. R. Herrera) or from various national organizations responsible for achieving and maintaining air superiority.

SOVIET PROGRAM 1934-1955

NEED:

Written remarks from several Soviet aviation medical specialists indicate that the USSR was very well aware of the value of military aviation superiority in the stratosphere, and for that reason among others a national effort was undertaken to achieve that goal. Translated quotations are offered in support of this statement. ". . . the utilization of stratospheric protection suits will advance considerably the domination of the stratosphere, especially by the air forces. The protection suits permit the creation of a stratospheric air force within a very short time. It will constitute a very potent war weapon, since all present ground defenses are powerless against it."[1] "Aviation reconnaissance by an aggressor armed with the latest equipment can secretly reconnoiter the territories of a future adversary from great altitudes—even in peacetime."[8] "During this period 1935-1943 the Air Force High Command and the research men themselves were specially interested in two questions: (1) personal altitude ceilings . . . and (2) the possibility of training a flyer's resistance to altitude factors. For Sector IV* these two questions had urgent priority."[7]

*Name and organization changed in 1936 to the Pavlov Red Army Institute of Aviation Medicine, Moscow.

*See French Patent 421, 212 (1910); U. S. 1,272,537 (1918), U. K. 248,356 (1925) as early examples.

†U. K. Patent Specification 429,276 (28 Nov 1933).

RESOURCES:

The USSR expended very considerable resources in a highly successful effort to develop life support equipment to protect aircrews in the stratosphere. Balloon gondola life support research was conducted beginning in 1933 by the Aviation Medicine section of the Civil Air Institute of Scientific Research (AISR), Leningrad, the Institute of Aviation Medicine (IAM), Moscow, the Kirov Military Medical Academy, Leningrad, and the All-Union Institute of Experimental Medicine. The results of scientific experiments in the low-pressure chambers and stratosphere balloon flights were of immense value to those later undertaking pressure suit development. Altitude chambers were installed at IAM (August 1930) and the Kirov Academy (1936). The AISR suffered a staff of only one and essentially no equipment until the late 1930's. All of these facilities and others (see Approach) were directed toward achieving military aircrew protection for stratosphere flight.[7]

APPROACH TO THE PROBLEM:

It had become apparent that there would be a need and a means to fly large forces of men at ambient altitudes in excess of 15 km. Provisions for adequate crew life support equipment was identified as a major obstacle confronting military planners. In 1936 a task force of All-Union aviation medical talent was mobilized to attack and solve this problem. Vladislav Akimovich Spasskiy, a military physician assigned to the IAM, became the focal point for determination of those aviation medical criteria to be used by the design engineers when making stratosphere equipment. The prevailing opinion of Soviet aeronautical designers then was that pressurization of crews on military missions would best be achieved by a high altitude pressure suit, despite its recognized limitations. Although nearer an ideal, pressurized cabins if selected would have entailed too many disagreeable features when compared with suits. Undesirable cabin features included: special aircraft required; gas leakproof design problems, especially on armament; loss in aircraft performance in climb, altitude, range, and speed; large target in cabin volume; loss of cabin pressure would affect all crew members; poorer vision in a pressurized cabin for that era; difficulty in emergency egress by crew members; expensive, even if mass produced; required a long lead time for production on a grand scale; less likely mission completion.

With the guidance and assistance of the first director of IAM, Prof. Dr. Feodor Krotkov, a careful and rather thorough review was made of foreign pressure suit developments and high altitude physiology.[1,4,9] No mention appears to have been made of German pressure suit developments in Soviet aeromedical literature until after World War II. Dr. Spasskiy conducted a five-year study to define and test life support requirements. This work is summarized in a superb and unparalleled document as a thesis for a doctoral degree in 1940. Despite its occasional errors, it is considered an outstanding treatment of a very complex problem at a time when some great nations of the world officially rejected pressure suits as not desirable. The document became the USSR national reference, stating requirements for protection of crews in stratospheric flight. These requirements were developed by late 1936, and the Society for Aeronautics and Chemistry organized an All-Union prize-winning contest encouraging development of stratosphere suits. Participating organizations included the Central Institute for Aerodynamics and Hydrodynamics (Boiko, A. I., Dolgi, and A. I., Khromushkin); Air Force of the Red Army Workers and Peasants (E. E. Chertovskoy); USSR Army Artillery Transportation; the People's Commissariat for Heavy Machinery. Chertovskoy, of AISR, had been chief design engineer on the Leningrad stratosphere balloon project.

All of the suits designed by various organizations were tested in the laboratory and, where appropriate, in flight under the medical supervision of Spasskiy.

ACCOMPLISHMENTS:

The first Soviet prototype pressure suit was built in 1934-35 by Pereskokov and Rappaport and designed for open circuit ventilation with oxygen.[6]

The medical requirements developed by Spasskiy included: minimum suit pressure to avoid dysbarism 267-268 mm. Hg (5.2 psi); minimum inspired P_{O_2} 125 mm. Hg; maximum P_{CO_2} in inspired gas is 15 mm. Hg; temperature range for comfort + 16 to 18°C; critical upper limit of relative humidity 85 per cent, desirable range 40-60 per cent; air flow minimum 50 1/min; emergency egress descent by parachute and survival. These suits were to be worn for four to six hours by as many as four crew members while in sustained stratosphere flight. The above-stated requirements evolved from an unusually careful and thorough review of aviation and physiological literature, and conduct of laboratory experimentation where indicated.[9]

E. E. Chertovskoy received the Soviet prize for a suit of his design. In 1937 it was tested in the low temperature and low pressure chamber to 90 mm. Hg chamber pressure (15.2 km) and -50°C. It was flight tested on several occasions to a maximum altitude of 9.02 km, and the subject accrued 70 hours of suit experience in all experiments. He too published an excellent thesis on this military aeromedical problem and his experimental results.[1] Highlights of this development were: satisfactory operational suits; helmet containing electrical heating of double walled visor; a helmet gas spray tube to reduce visor fogging; study of the effects of ozone and ultraviolet light on gas-tight fabrics; closed circuit fan and later injector systems for O_2 supply and CO_2 and water vapor removal; emergency bailout closed circuit life support system with one hour capacity; satisfactory electrically heated clothing, outside suit usually.

A. I. Khrommshkin, a mechanical engineer, also contributed a very superior book on this subject as a result of more than fourteen years of research and experience in this area.[2,3] It updated the work of Spasskiy and Chertovskoy, and much discussion is devoted in it to those engineering problems associated with pressure suits. It included: an almost exact restatement of Spasskiy's list of physiological requirements; detailed discussion of the regenerative jet circulation system; chemicals for absorption of CO_2 and water vapor;* liquid and gas (not solid) O_2 sources; data on parachute jumps with suits; design of helmet and gloves for quick-don use after emergency decompressions; electrically heated fur clothing; stress analysis of fabrics for suits; analysis of thermal loads and means of achieving crew comfort; a discussion of ejection seats and emergency crew-escape modules; recognition of Western allied developments in pressure breathing, capstan, and bladder suits.

From the end of World War II through 1955, the Soviets accomplished additional advances in aviation medicine and pressure suit protection. The more important appear to be: a clearer awareness of the value of denitrogenation which Spasskiy did not recognize; wide use of the capstan and bladder suit originally designed in the U. S.; more interest in the effects on humans of rapid decompression in the stratosphere; use of the suit as an emergency pressurization system, relying on engine pressure as the primary source; extensive research in positive pressure breathing; search for materials and designs to improve the safety, comfort, mobility, visibility and operational effectiveness of Soviet aircrewmen; testing of improved systems in the low-temperature and pressure chamber.

DISCUSSION

From the available and abundant translated public domain literature, it is clear that the Soviet Union organized and executed an excellent high altitude pressure suit development program during this period. The strengths of the program included excellent talent, management, resources, and an urgent priority. All-Union experts in engineering, medicine, and physiology were directed to devote their skills to this project. While allowed to remain with their respective parent organizations, scientists were charged with supporting this project. The scientists were assigned to the project for a prolonged period, allowing for continuity in research and development. Also they were permitted to use this research on military problems as the source of candidate and doctoral thesis material. Adequate laboratory and flight test facilities were placed at their disposal. The USSR Air Force High Command endorsed and supported the effort with an urgent priority. The extent and thoroughness of the Soviet program at least equalled and probably surpassed the combined efforts of all other nations for the period 1934-1940. Soviet aviation medicine specialists have long given careful professional attention to the perfection of their aircrew personal protective equipment and aircraft subsystems. There is every indication from these documents that Soviet life-scientists have been sincere, vigorous, and generally successful in their efforts to provide adequate personal protective equipment for their aircrews. It is an unfounded myth that Soviet aircrew personnel are thought to be expendable and therefore are not provided appropriate life support gear. Their keen interest in pressure suit development, safe parachute jumping techniques, oxygen equipment, ejection seats, ear defenders,

*Water vapor was absorbed by silica gel. CO_2 was absorbed by a per cent mixture: $Ca(OH)_2$ 76; $MnSO_4$ 2.66; $Fe_2(OH)_2$ + $Al(OH)_3$ 1.20; NaOH 1.83; moisture 18.31.

cold-weather gear, and physical-fitness regimens are a few representative items which strongly support the conclusion that Soviet life-support scientists have in general been responsible professionals seriously interested in protecting their crewmembers.[5,7,8]

One has to search diligently to find significant weaknesses in their program when compared with available knowledge for that period. Perhaps the largest error was that Spasskiy did not recognize the prophylactic value of denitrogenation on oxygen for protection from dysbarisms. As late as 1948 he did not discuss its value despite the fact that as early as 1941 Soviets demonstrated to themselves most convincingly its benefits.[10] As a result Spasskiy recommended a minimum suit pressure of 268 mm. Hg (5.2 psi), thus limiting the operational capabilities of it due to the high internal pressure. Their estimation of alveolar gas composition was hampered by lack of accurate alveolar gas equations. Apparently they had not considered the advantages of positive pressure breathing until it was introduced by Gagge in 1941. Unable to conduct extensive research on any aeromedical problem during World War II, the Soviets used the US A-14 regulator and instructions. They were not then concerned with physiological effects of rapid decompression since most of their aircraft were not pressurized until after World War II. This is in contrast to great interest and research by the Western Allies and the Germans in rapid decompression effects. Later when pressurized cabins entered the inventory of research and operational Soviet aircraft, they began to design some pressure-suit helmets and gloves for quick donning after decompression.[3] This may have been an unwise choice. It required the crewmember first to diagnose the decompression event which, in fact, is often thought to be an explosion and fire due to the fog, the thud, and flying debris. Then the crewman must don and secure the helmet and gloves within a total of 6-7 seconds. Pressure suits should work automatically.

Soviet engineers neglected to conduct a thorough study of ways of applying pressure to the body. In addition to full pressure suits and pressurized cabins, they might have included bladder, rigid metal, fabric, and closed-cell sponge suits, and at least a theoretical consideration of the feasibility of artificial gravity, liquids, and a high-energy electrical field for retention of gas pressure on the body.

It is surprising that they chose a closed circuit life support system instead of the simpler, less expensive, lighter, and more reliable ventilation system, using liquid oxygen. Open circuit ventilated pressure suits are nearly the rule in world aviation today.

Soviets along with the other nations first employed high-altitude suits as the primary source of pressure, with no other backup than to increase gas flow and descend if a suit leak developed. Gradually, with aircraft engine and structural improvements, pressure cabins became feasible for stratospheric military flight. Subsequently the suits were used as a backup to the primary system. This evolution of uses appears to have been most reasonable and consistent with aviation vehicle technological developments.

SUMMARY

From 1934 to 1943 and 1946 to 1955 the USSR had an excellent high altitude pressure suit program. The effort was staffed with excellent quality technical personnel and adequate support facilities were used. From 1934 to 1940 the Soviet program at least equalled and probably exceeded in scope and excellence the combined efforts of all other nations in this technical area. Soviet aerospace life scientists in general have been serious and vigorous in their efforts to protect their aircrew members.

The weaknesses of their program for portions of that period include the following: lack of appreciation of benefits of denitrogenation; quick don of portions of the pressure suit after the rapid decompression event; early lack of appreciation of benefits of pressure breathing; lack of accurate formulae to estimate alveolar gas tensions; no original work on bladder and capstan suits; reliance on a closed circuit life support system.

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