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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

INTERNATIONAL AVIATION

(Selected Articles)

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AIRBORNE EQUIPMENT AND SYSTEMS

MODEL 10 SERIES AERODYNAMIC-PANEL EMERGENCY ESCAPE PARACHUTE

Wu Liyue

The eight-aerodynamic panel emergency escape parachute (series 10) developed in China has been in service for several years and has proved highly effective. Its structure and aerodynamic characteristics are described and recommendations are made for new applications.

The aerodynamic parachute is a product of China herself. After many years of efforts, it has already been developed into the model 10 series of emergency escape parachutes. It has also been equipped with the rocket shell launched emergency escape seats produced by different countries and fitted on different models of fighter aircraft. This type of emergency escape parachute fairly satisfactorily resolves the emergency escape problems of zero altitude slow speed and zero altitude high speed escape. It also has been put into actual use for the past few years and been completely successful in a number of pilot emergency escapes.

PRIMARY CHARACTERISTICS

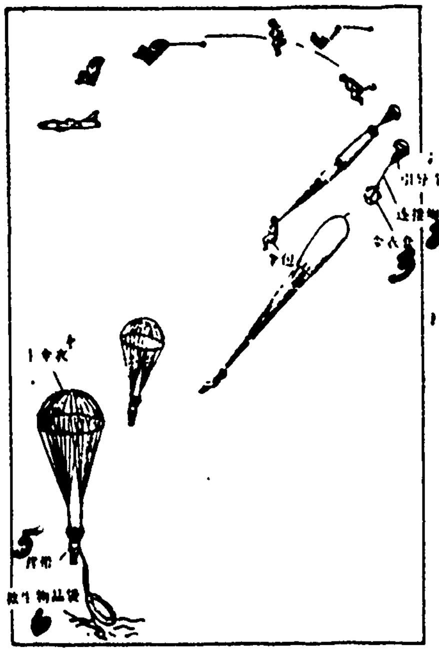

Fig. 1: The Operational Sequence and Composition of the 10 Series Parachute. 1 - lead chute; 2 - cords; 3 - chute sack; 4 - main chute; 5 - back straps; 6 - first aid materials strap.

The model 10 emergency escape parachute is a type of eight aerodynamic panel parachute. Its characteristics are excellent. This point can be seen through a comparison with the Soviet improved C-3 parachute and the U.S. C-9 parachute.

The Soviet improved C-3 parachute also the emergency escape-7A, began being used by the Chinese Air Force in the sixties. The 56 m chute is square shaped. It is made from highly permeable fabric. It is packed in a long chute pack. This chute has excellent deployment characteristics at high speeds, but its deployment altitude at low speeds is 100 meters. These poor low altitude characteristics have led to a number of accidental injuries and deaths. In addition, it also has quite a few additional shortcomings such as the back straps are not easy to adjust, the chest type latch can violently strike the chest of the pilot at the instant of chute deployment, and the relatively thick chute pack will not allow the pilot to maintain a proper sitting position, which can easily result in spinal injuries when the pilot ejects.

The U.S. C-9 standard emergency escape parachute is made from less permeable fabric. The chute is disc shaped (area is also 56 m). It uses a short chute tube pack. A large number of tests have demonstrated that the C-9 has excellent low altitude deployment capabilities. However, it has poor high speed capabilities (500 kilometers per hour). Therefore, it is also unable to satisfy use requirements.

The model 10 aerodynamic panel parachute has better capabilities than either of these emergency escape parachutes. It has a minimum safe deployment altitude of 60 meters, 40 meters below that of the Soviet escape-7 parachute and ten meters below that of the C-9 parachute. It has an area of 48 m , with only 24 parachute cords. This greatly reduces the volume and weight of the chute. The actual landing speed is 1.07 meters per second slower than that of the escape-7 parachute and 1.353 meters per second slower than the C-9 parachute. Its pack is 75 mm thinner than that of the escape-7, creating favorable conditions for ejection seat design. This type of aerodynamic panel parachute can reduce the deployment load, reduce the injuries to the pilot and accelerate deployment. Average deployment loading at low altitude (under 1000 meters) at 550 kilometers per hour is only 1687 kilograms. At speeds of 600 kilometers per hour, the deployment load is 1739.7 kilograms. At high altitude of 4000 meter and a speed of 600 kilometers per hour, the average deployment load is 2186 kilograms. Damage to the chute is also relatively rare.

STRUCTURAL CHARACTERISTICS

The model 10 eight-panel aerodynamic emergency escape parachute is composed of a lead chute, connection cords, the chute sock, the back straps, the parachute pack and the first aid materials strap (see illustration one).

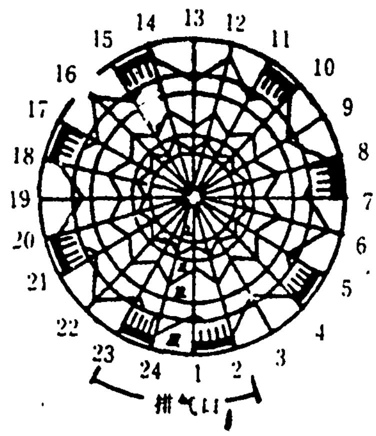

Fig. 2: Eight Panel Aerodynamic Parachute. 1 - vent.

The parachute (see figure w) is an eight panel aerodynamic configurations with 24 conical shaped panels. This is a recent new model parachute. The crown uses a highly permeable and strong 509 cotton netting. The fabric of the other portions of the parachute is a 602 cotton lattice which is somewhat less permeable and less strong. The bottom has eight vents, and each vent has an aerodynamic panel. The entire parachute is reinforced with four concentric circle reinforcement cords. When the parachute deploys at low speeds, the eight aerodynamic panels can assist in opening up the lower edges of the parachute sack, shortening deployment time. Over a stable decent, there is a partial air current overflow from the bottom of the parachute sack at the vents. This improves the parachute's external surface flow field and widens the wake area. As a result, it also increases the drag coefficient and reduces the rate of descent. When the chute is deployed at low altitudes and high speeds, because of the high permeability of the crown portion, the parachute takes on a light bulb shape which reduces the pressure differential between the inside and outside of the parachute sack and extends the time for the parachute sack to fill up. This helps reduce the deployment load. The reasonable arrangement of the eight aerodynamic panels and the lengthening of the four thin parachute cords at the rear of the parachute sack are enough to cause the parachute to generate a horizontal speed of one to two meters per second, increasing stability of descent.

The new model container type chute case (fig: 3) is the part that ensures the deployment sequence of the chute. It has two transparent bags into which the folded parachute is placed in layers. This greatly reduces the thickness of the pack. When the lead chute fully opens and pulls the chute sack, the chute will not suddenly bunch up and damage the rubber rings. Therefore, it will not cause the cords to strike against the chute fabric and lead to abnormal deployment of he chute. The sides of the transparent bag are single stitched with thread of appropriate strength to sew it to the main part of the chute sack. If the chute is pulled to hard during the pulling sequence, these threads will be palled apart, ad the chute can then smoothly be pulled according to the proper sequence, increasing he probability of chute deployment.

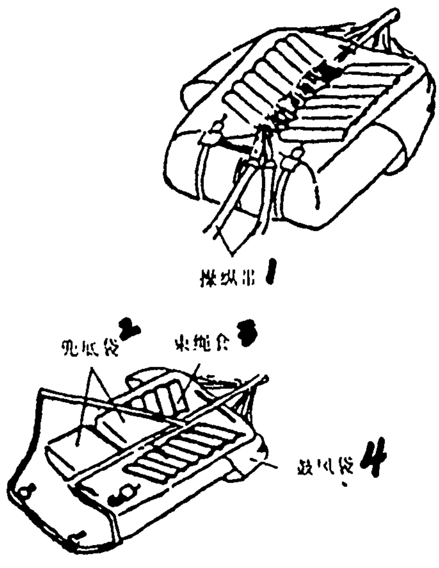

Fig. 3: COMPACT TYPE PARACHUTE PACK
1 - horizontal strap; 2 - pads; 3 - cord bundle pack; 4 - wind sack.

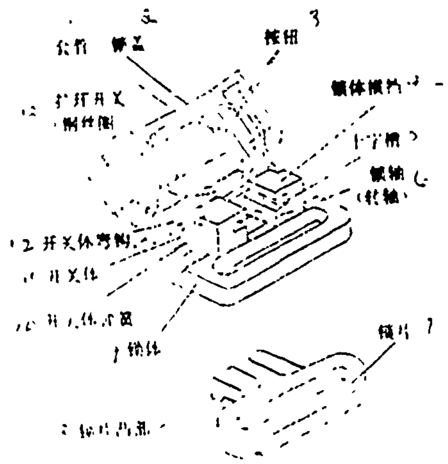

Fig. 4: HALF AXLE SHOULDER LATCH
1 - casing; 2 - latch cover; 3 - release; 4 - crosspiece; 5 - cross groove; 6 - axle shaft; 7 - handle; 8 - latch handle cam; 9 - latch body; 10 - lock spring; 11 - lock; 12 - lock coupling; 13 - ring lock (steel cable loop.

The back strap is composed of the pack straps, the shoulder straps, the chest straps and the crotch straps and the half axle shoulder latches. After the pilot has pulled the chest straps tight in the cabin, he can use both hands both hands to quickly adjust the shoulder straps and crotch straps. This type of back strap has a wide range of adjustments. It distributes stress evenly, is comfortable, and is suitable for different pilots.

The shoulder latches (fig: 4) include the latch, the latch post, the lock, the pull ring lock, and the latch cover. The latch post (axle) is half a cylinder. When the pull ring lock is unlocked, tne lock turns the axle. The half axle part then locks or unlocks the lock plate to open or close the latch. The lock has a safety spring (second level). When the latch cover is in place, a pair of couplings on the button of the latch plate match up with couplings on the lock, making up the first level safety. This latch not only is a brand new design, but it also is lighter, smaller, safer and more reliable than the U.S. shoulder latch.

IMPROVEMENTS AND DEVELOPMENTS

The model 10 aerodynamic panel emergency escape parachute high sped deployment maximum load clearly increases at higher altitudes. Tests were conducted at an altitude of 4000 meters with a total weight of 100 kilograms and at a sped of 600 kilometers per hour, and the results of the tests are shown in figure 5. The curve shows how filled the chute was at times of chute peak deployment force. We can see from this illustration that the maximum shock in high altitude deployment of the parachute occurs after the chute has been fully deployed. The reason for this is that because the atmosphere is thin at high altitudes, the loading energy expended by the parachute system in the process of opening - chute system pulled straight - filling with air to the light bulb shape. Therefore, the loading energy is still fairly great after the chute is completely filled with air, and the shock force generated is the greatest.

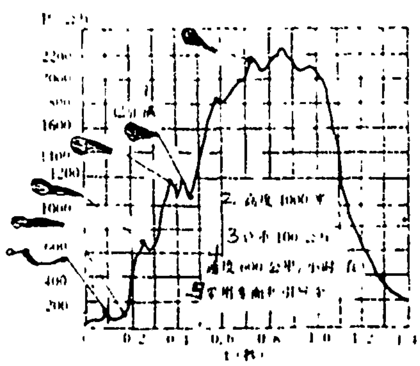

Fig. 5: Curve of change in chute shock force. 1 - Fully filled; 2 - altitude 4000 meters; 3 - total weight 10C meters; 4 - speed 600 kilometers per hour; 5 - using a variable area lead chute.

The chute deployment overloading limit allowed in China for the human body to withstand has been temporarily set at 20 G (the international standard is 25 G). Therefore, at an immediate chute deployment speed of 550 kilometers per hour, the model 10 emergency escape parachute may not be deployed at more than 2000 meters. At altitudes of more than 2000 meters, delayed deployment must be used.

In order to improve the high altitude high speed deployment capabilities of the model 10 parachute, a variable area lead chute has been developed.

The model 10 parachute uses a flat octagonal lead chute. It is made of 411 plain weave silk. It has an area of 0.78 square meters, which is 0.3 square meters larger than the lead chute of the Soviet escape-7 parachute (0.48 square meters). The reason it uses a lead chute with a relatively large area i to have the main chute be pulled and to fill with air more quickly to reduce the altitude loss during deployment as much as possible. However, multiple high speed tests have demonstrated that pulling out the main chute to quickly at high speeds can increase the loading of deployment and can also increase the damage rate of the chute.

As everyone knows, low altitudes and high speeds require a lead chute with a larger area, higher resistance and greater tension. However, for high altitudes and high speeds, the opposite is true. The variable area lead chute was developed to meet these conflicting requirements.

The variable lead chute (figure 6) is composed of the parachute, parachute cords, central cord, positioning cords, a tension setting cord and a metal ring. The parachute cords are connected to the metal ring and the central cord passes through this ring. One end of the positioning cord, which has a strength of 185 kilograms, is connected to the metal ring. The other end is attached to the central cord so the central cord is kept slack. When the lead parachute operates at low speeds, the positioning cord is not broken and the lead chute operates with a large area, generating a great deal of resistance to accelerate the pulling out and pulling straight sequence of the main chute. When deploying the chute at high speeds (greater than 400 kilometer per hour), the positioning cord is pulled apart, and area of the lead chute is reduced and the resistance characteristics are reduced from those of a area of 0.536 square meters to those of an area of 0.3 square meters, thus slowing down the pulling out-pulling straight process and lowering the loading of deployment.

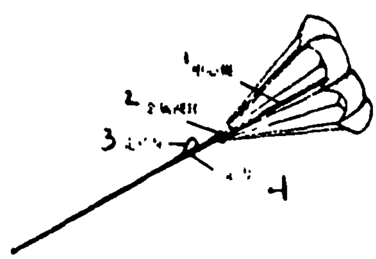

Fig. 5: Variable Area Lead Chute. 1 - central cord; 2 - metal ring; 3 - positioning cord; 4 - tensioner cord.

The model 10 B aerodynamic panel emergency escape parachute with a variable area lead chute has been tested four times using a dummy to eject at an altitude of 4000 meters and speeds of 600 kilometers per hour. The average parachute loading was measured at 2186 kilograms. The maximum parachute loading was 2386 kilograms. The parachute deployed well and there was no obvious damage to the chute.

According to data from simulated human model and in air ejection of dummy testing in wind tunnels, it is possible to believe that a person falling through the atmosphere has wind resistance characteristics of 0.4 square meter while the wind resistance characteristics of the iron torso dummy was only that of 0.138 square meters. Therefore, the data from the dummy in air ejection tests are on the safe side. It is possible to believe that within certain speed ranges we may use the maximum deployment loading measured at 600 kilometers per our to calculate maximum deployment loading for 550 kilometers per hour to obtain reliable results. The maximum deployment loading at 600 kilometers per hour was 2386 kilograms. According to this study, the model 10 B aerodynamic emergency escape parachute with a variable lead chute can be deployed immediately at an altitude of 4000 meters and a speed of 550 kilometers per hour.

If the physiological tolerance limits of the human body were relaxed to 25 G, then the model 10 B emergency escape parachute with a variable area lead chute could be deployed immediately at 600 kilometers per hour.

The emergency escape parachute requires continuous advancement and development. The results of the study with variable area lead chutes can be further extended, and consideration can be given to enlarging the resistance of the relative movement systems between the man and the chute and the connection parts. For example, adding small resistance chutes to the parachute cords connected t the control cords and having one or a group of chutes opening at the instant the parachute system is pulled out. This would reduce the relative speeds of the human body and the main chute during the pulling straight process when deploying the parachute at high speeds, reducing the maximum deployment loading. In this manner, the high altitude high speed deployment capabilities of the model 10 emergency escape parachute could be even further improved.

AIRBORNE EQUIPMENT AND SYSTEMS
CHINA-MADE LIQUID COOLING VEST FOR PILOTS

Ouyang Hua

Construction of China-made liquid cooling vest for pilots is described. Test performed in the field demonstrate that the vest is effective. It may be used by helicopter and fighter pilots.

In hot regions, pilots on the ground and flying at low altitudes are exposed to a great deal of heat and reliance on aircraft circulation systems is limited by many factor, and at times the circulation system is not able to completely resolve this problem. The use of liquid cooling vests and liquid cooling clothing is an effective means of solving this problem. When fighter aircraft are flown for a short time, the pilot does not need to wear full body liquid cooling clothing, but only needs to cool the major parts of his body in order to reduce the amount of heat load. Following the liquid cooling helmet, China has also developed a pilot liquid cooling vest.

This type of liquid cooling vest can cool the torso and the hips, which constitutes about 40 percent of the total body area. Researchers have simulated cockpit tropical heat conditions in High temperature laboratories to obtain large amounts of data with great practical value. Helicopter and fighter aircraft test flights have found that the water cooling vest meets use requirements for watertightness, compatibility with other clothing and equipment and for putting on and taking off. When the cockpit ambient temperature is between 40 ad 45 degrees Celsius, it provides excellent cooling results. The officers and men of flight units are all very much satisfied with the form and the cooling capabilities of the vest.

The pilot liquid cooling vest which China has developed is tubular. It uses cold water circulation to lower temperatures. The water tubes are made from soft transparent polyvinyl chloride tubing. There is one main water intake pipe and one main water return pipe, both of which are eight millimeters in diameter. The walls are 1.5 mm thick and 350 mm long. There are 30 branch tubes which are 2.4 mm in diameter, have walls 0.4 m thick and have a total length of 54 meters. This vest uses a soft twill for a framework, and the branch tubes are secured within the framework cloth, with a layer of nylon on either side (see figure 1).

Fig. 1: Pilot Liquid Cooling Vest

The water in the tubular vest moves in only one direction. The water enters between the lower back and the buttocks and flows upward toward the back. It then circles around the shoulders ad flows down past the chest and abdomen to the top of the legs. It finally returns to between the lower and back and buttocks where it enters the main return tube. EAch liquid cooling vest weights about 1180 grams (including the sealing couplings in both directions ad 250 grams of water).

The liquid cooling vest cooling tank uses evaporation circulation cooling equipment (developed by the Beijing Aeronautics and Space College) (see Fig. 2). It is connected to the aircraft 24 volt DC electrical supply and has maximum cooling power of 200 watts. A microfan turbine pump circulates the water at an adjustable rate between 0.7 to 1.3 liters per minute. The temperature of the water entering the vest can be regulated as required.

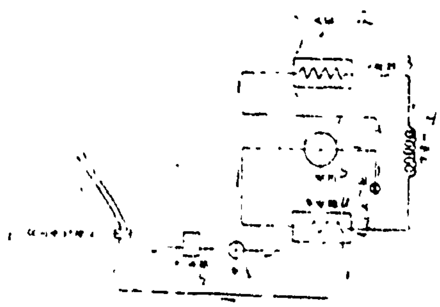

Fig. 2: Evaporation Circulation Cooling Tank Principles. 1 - bidirectional connection; 2 - fan; 3 - cooler;4 - capillary tubes; 5 - compressor; 6 - evaporator; 7 - temperature control; 8 - pump; 9 - circulation tank.

In 1986 and 1987, the flow resistance and heat resistance of the liquid cooling vests were measured in the high temperature laboratory of the Air Force Aviation Medical Research Institute where physiological testing and research was also completed. The ambient temperatures for these tests were 35, 40 and 45 degrees Celsius. The temperatures of the water entering the vest were 12, 16, 20 and 26 degrees celsius. The circulation rate was one liter per minute. During the tests, physiological standards such as the pulse rate, skin temperature at 13 points, ear canal temperature, amount of perspiration, and evaporation rate were measured. Finally, the temperature lowering results were evaluated as composite heat reflex index.

The results of the tests show that in a hot environment of between 35 and 45 degrees Celsius, wearing the liquid cooling vest had an obvious decrease in the composite heat reflex index when compared to not wearing the vest. A decrease of over 40 percent met the physiological requirements. We can see from the results of the test that the composite heat reflex index was greater than 70 percent, which means that under optimum cooling conditions, the liquid cooling vest can reduce the temperature load of the entire body of the pilot by about 70 percent. The average skin temperature of the entire body and the skin temperature of the trunk and upper legs can all be maintained at a comfortable physiological level.

The heat transfer of the liquid cooling vest is between 174 and 203 watts, comparable to 75 to 95 percent of the total human body heat load at rest in an environment of 35 to 45 degrees Celsius. When the water is appropriately cooled, the body perspiration rate is 77 to 100 percent. We can see from this that the tube type liquid cooling vest does not affect the perspiration evaporation and moisture dispersion from the surface of the skin on the trunk and the upper legs and does not clearly add to the heat load.

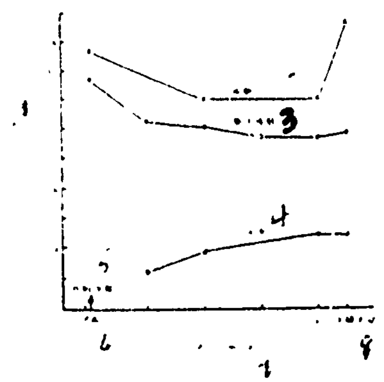

Fig. 3: Temperature Reductions in
in MI-8 Helicopter Flight Tests
1 - temperature C ; 2 - cabin air:
3 - skin of trunk; 4 - intake water;
5 - begin cooling; 6 - before the test;
7 - Length of test flight (min.); 8 - descent and landing.

In 1987 the liquid cooling vest was tested in helicopters. During the time the tests were conducted, the outside temperature was 35 degrees. When the helicopter was at a height of 600 meters, the cabin temperature was higher than the outside temperature. The co-pilot wore a liquid cooling vest and a summer flight suit. Each time the flight would last for 40 minutes. The skin temperature of the chest, stomach, back and waist were taken as well as the temperature of the intake. The results of the flight test show (as seen in figure 3) that when the water temperature at the intake was between 22.5 and 25 degrees, the average trunk skin temperature was 31 degrees. When the intake temperature was between six and 32.2 degrees centigrade, the copilots felt comfortable and were not obviously perspiring.

In August of 1988 in the southern tip of China, we selected a jet trainer aircraft for flight testing of the liquid cooing vest on pilots. The flight testing was done at an altitude of 100 to 200 meters. Each test flight was 40 minutes long. The results of the testing show (as in figure 4) that average skin temperature of the trunk and upper legs were within the range of physiological comfort. The test flight pilots were very satisfied with the cooling effects of the liquid cooling vest.

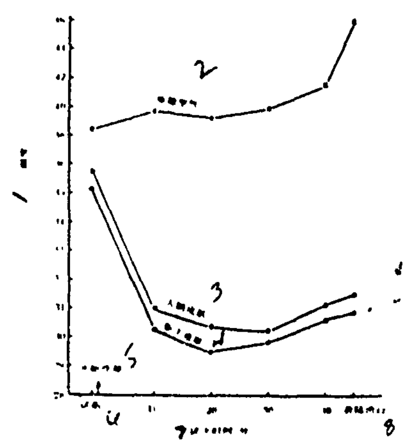

Fig. 4. JIAN JIAN 6 flight test cooling
1 - Temperature C; 2 - cabin air; 3 - skin of upper legs; 4 - skin of trunk; 5 - begin testing; 6 - before testing; 7 - flight test time; 8 landing and taxi

The fighter aircraft pilots had to wear different types of protective clothing depending on the flight zone or the flight lessons. Anti loading clothing and compensation clothing are two types of protective clothing which are related to the liquid cooling vest. The results of the test show that the use of the liquid cooling vest together with the anti loading clothing not only did not affect any capabilities, but clearly increased the cooling results. When the liquid cooling vest was used together with the compensation clothing, the water circulation was not affected by changes in pressure during the climbing or descending processes at low cabin temperatures. During pressurized breathing, the body charts did not reveal any clear signs of constriction or adverse reaction. We can see that the liquid cooling vest has excellent capabilities to complement other equipment.

The liquid cooling vest can be used over a wide range of situations. It not only can be provided to unit pilots, but can also be provided to drivers of tanks, armored vehicles and large transport vehicles and workers and personnel in high temperature environments such as those in smelteries and foundries. In operations and workshops where there is a relatively large number of persons, it is not necessary that each person have his own cooling tank, but multiple person cooling equipment can be designed and used jointly. Cool tap water can be appropriately processed and used in the cooling vests to greatly reduce the expenses.

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