Recent developments in Indian aircrew clothing

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Personnel flying military aircraft are exposed to a hostile environment which in case of emergencies can lead to disaster. Aircrew are provided with specialized equipment and clothing to protect them from these adverse effects with a view to improve operational efficiency. Defence Bioengineering and Electromedical Laboratory (DEBEL) is actively engaged in the design and development of aircrew clothing and protective equipment. A number of items developed by this laboratory are already in service use. The laboratory is currently developing light-weight integrated helmets, pressure breathing oxygen masks, flame-retardant overalls, anti-G suit, boots and automatic inflatable life jackets. The experience in the development of these items and their role in providing and improving operational efficiency is discussed.

Keywords: Flying clothing; Indigenous development

Military flying imposes considerable physiological demands on the aircrew. Any successful mission depends on the efficiency of the aircrew, hence the need to protect the crew against operational and environmental hazards such as sustained accelerations, vibration, impacts, crashes, changes in temperature and atmospheric pressure and during ejection.

DEBEL is the only laboratory in the country engaged in the design and development of flying clothing and personnel protective equipment for the aircrew to meet our tropical environment. Many of these items are currently in service use and continuous efforts are on to develop advanced versions to meet the demanding operational needs of the present and future scenario.

This paper describes briefly the various types of protective equipment currently in service use, recent developments and future plans.

Pressure breathing oxygen masks

This laboratory has built up expertise over the years in the design and development of pressure breathing oxygen masks for aircrew. Pressure breathing oxygen masks Mk I and II are developed in two sizes to meet the requirements of Indian aircrew anthropometric data, and to suit tropical environment. These masks are, at present, used in Kiran aircraft of the Indian Air Force.

Oxygen masks Mk I and II. The Mk I/Mk II oxygen masks consist of a face piece; inspiratory and expiratory valves, a microphone, a corrugated rubber hose and an exo-skeleton with a chain toggle harness. The inspiratory valve is provided with ice guard and the expiratory valve is of compensated type. The ceiling limit of this mask is 17,000 m. These masks were subjected to full functional evaluation, environmental tests, user trials and type approval tests, before introducing them into service.

Oxygen mask Mk III. Recently, the development of pressure breathing oxygen mask Mk III has been completed. This mask developed in three sizes fits wide varieties of facial contours of Indian aircrew population. These masks are undergoing user evaluation. The unique features of Mk III mask are:

(a) Compensation is provided by a separate tube running parallel to the main oxygen hose and originating from the oxygen regulator.

(b) Effective face-to-mask seal is provided by an inflator-aided harness system.

(c) Speech transmission through noise cancellation microphone.

(d) Holds positive pressure up to 60 mmHg.

The mask, being a critical life-saving equipment, is evaluated using a specially developed test rig.

Currently, a prototype mask for use in the light combat aircraft (LCA), which is under development in the country, has been developed. The mask is similar to Mk I and Mk II but the face-to-mask seal is achieved by a harness system with bayonet attachments riveted on to the exo-skeleton. This is comfortable and does not cause undue pressure on the face unlike the toggle harness system. Suitable microphone and R/T cord connector have been developed. Also, work relating to the development of silicone face piece and oxygen mask for use with pressure breathing for *g* is being carried out.

Anti-G suit (AGS)

Modern high-performance aircrafts are highly manœuverable and capable of flying at high speeds. The crew of these aircrafts are frequently exposed to high sustained positive accelerations during combat manœuvres. The effects of these positive accelerations, leading to unconsiousness, are well-known. DEBEL has designed and developed different versions of the anti-G suit. These anti-G suits provide increased tolerance, by 1.5–2 G.

AGS Mk I. Mk I suit is a polyester/cotton overall with a detachable bladder of neoprene-coated nylon fabric. The bladders inflate to give protection against positive G forces. The suit has been designed in 12 sizes and introduced in service.

AGS Mk II. Currently, the crew of IAF are using AGS Mk II. The Mk II suit shown in Figure 2 is a cutaway type, which offers greater mobility and lower heat loads. It is a trouser-like garment with cutaway portions at the seat, crotch and knees. The outer material is heavy-duty nylon fabric having higher strength and low extensibility. The bladder is made of natural rubber. The cummer-bund and leg portions are split by heavy-duty, open-end metallic slide fasteners having self-locking facility. Adjustment laces are provided at the cummer-bund, thighs and calves for providing proper fit to the crew. It has been developed in five sizes to meet the requirements of the Indian aircrew population.

AGS Mk III. Mk III has been developed specifically to meet the requirements of crew operating in hot and humid environment. The outer material is of nylon/cotton fabric specifically developed for this requirement. The nylon takes care of the strength and the cotton caters to the sweat absorption requirement. The other salient features are: (a) use of polyester slide fasteners, (b) provision of comfort zippers at the waist and thigh, (c) provision of 4 pockets, viz. 2 on the thighs and 2 on the calves to store operational and related systems, (d) provision of a concealed adjustment lacing to avoid the lacings getting accidentally caught with the cockpit equipment, and (e) provision of spring-reinforced rubber hose which can take a variety of end connectors to fit various aircraft personal equipment connectors.

AGS Mk IV. Mk IV has been developed specifically for use in high-performance aircrafts like Mirage MiG 29 and LCA series of aircrafts. The features of AGS Mk IV are similar to that of Mk II, except for: (a) larger bladder, (b) bladder to withstand high pressures, (c) provision of detachable thigh pockets, (d) facility for routing of leg garters, and (e) polyester zip and comfort zippers. The anti-G suits developed are tested for pressure holding, leak test and endurance.

Currently, the outer cover is made out of either nylon or nylon/cotton fabrics, which are flammable. Experiments are in progress to produce a core-spun yarn using either kevlar or nylon at the core and fire-retardant (FR) viscose at the sheath. The currently used bladders are made out of neoprene-coated nylon fabric which weigh around 360 g/m^2. Results on FR-sealable, light-weight polyurethane-coated fabric have indicated the suitability of the material for

Table 1. Details of the various helmets developed

	Mk I	Mk II	Integrated helmet	Light-weight integrated helmet
Outer shell	Fibreglass resinate	Fibreglass resinate	Fibreglass resinate	Kevlar fibreglass resinate
Energy-absorbing medium	Harness system	Harness system	Harness system and polystyrene padding	Polystyrene padding
Visor	Single tinted neutral grey acrylic visor	Single tinted neutral grey acrylic visor	Tinted and clean polycarbonate visor system	Tinted and clean polycarbonate visor system
Chinstrap	Chinstrap with snap on fastener	Chinstrap fixed on both sides with nut and bolt	Two-piece chinstrap with Q.R. buckle	Two-piece chinstrap with Q.R. buckle
Sizing	5 sizes, 3 fittings	5 sizes, 3 fittings	3 sizes	3 sizes
General	Used with cloth helmet which has earcapsules, earphones R/T	Used with cloth helmet which has earcapsules, earphones R/T	Integrates the function of inner cloth helmet	Integrates the function of inner cloth helmet

bladder fabrication; and further work is in progress to develop a light-weight bladder. Work has been initiated on the development of a full coverage anti-G suit for improved G protection.

Aircrew helmet

As we all know, the necessity for the protective head gear need not be emphasized, and, in fact, the incidence of head injuries have been reduced with the introduction of aircrew helmets. Over the years, this lab has developed outer protective helmets Mk I, Mk II and integrated helmets. These helmets are currently in service use. The design criteria and various test methods followed for the development of helmets are dealt in detail elsewhere [1].

Outer protective helmets Mk I and II. These helmets are worn along with the cloth helmet, which houses the earcapsules and the earphones. These helmets are fitted with a single tinted acrylic visor and are manufactured in 5 sizes with three fittings in each size. The Mk II visor has a G-loaded mechanism; should the pilot eject, the visor comes down automatically and provides blast protection. The system is so designed that the visor does not come down during G manœuvres. The details of the various helmets developed are listed briefly in Table 1.

Integrated helmet (IH). The IH's shell is fabricated from fibreglass resinate and provides high-degree impact and penetration resistance. These helmets weigh around 1.5–1.8 kg depending upon the size. The helmet has a double visor system consisting of clear and tinted visors. The chinstrap has a quick release buckle and is easy to don and doff. The helmet is made in three sizes – small, medium and large. Individual fitment is achieved by the use of a variable harness system.

Light-weight integrated helmet. In high-performance aircraft, the aircrew pull high G loads of magnitude 9 G. Under these conditions, the weight of the helmet becomes a critical factor in aircrew fatigue. The heavy helmets also cause neck injuries [2, 3]. The light-weight integrated helmet is in an advanced stage of development, to meet the needs of the aircrew.

It is made from kevlar–fibreglass composite and weighs around 1.2–1.3 kg and is made in three sizes. The helmet is provided with a dual visor system. Two versions of the helmets have been developed: one for use with oxygen mask having chain toggle harness and the other for use with oxygen mask with bayonet connector.

Automatic inflatable life jacket (AILJ)

DEBEL has designed and developed various versions of AILJs to suit the operational requirements of aircrew flying over the sea. At the heart of the AILJ is the automatic inflator, which inflates as soon as it is immersed in water, and the wearer surfaces out within 3 s. The jacket provides 18 kg buoyancy and keeps the wearer's head out of the water surface at an angle of 45° to the vertical facing the oncoming waves. The design criteria of AILJ have been dealt with in detail elsewhere [4, 5].

AILJ consists mainly of three subassemblies, viz. collar-type waistcoat, inflatable stoles and automatic inflator. The jacket is worn around the neck.

Waistcoat. The waistcoat consists of stowage for stoles, a waist adjustment belt, and houses survival aids such as miniflare, sea-activated battery and SARBE. The waistcoat and collar for stowage of stoles are fabricated out of heavy-duty nylon or nylon/cotton fabric. The stowage is closed by means of an open-end medium–heavy-duty synthetic slide fastener. The inner of the collar is provided with rescue straps for winching of the crew into a helicopter.

The AILJ has two almost identical stoles. The stoles are fabricated out of butyl-coated nylon fabric for greater carbon dioxide retention. Each stole is fitted with two rubber hoses, one of which is fitted with a non-return valve (NRV) and connected to the automatic inflator, and the other hose is fitted with an oral inflation valve provided with an NRV.

The inflator comprises a rechargeable Ni–Cd battery, an electrically operated explosive cartridge, a housing for battery, a plunger, a lever, a piercing pin and a 34 g CO_2 cylinder.

Recently, a miniaturized inflator which weighs only 350 g has been developed. This system uses lithium battery and a miniaturized sensor.

Futuristic plans on the development of AILJs include the refinement of materials used for making waistcoat and the bladders. Efforts are being made at this laboratory to develop flame-retardant materials for the fabrication of waistcoat.

Pressure clothing

High altitudes expose the aircrew to reduced barometric pressures. The high-altitude pressure suit, gloves and socks developed by DEBEL provide protection to the aircrew for short durations in the event of cockpit pressure failure.

High-altitude pressure suit (HAPS). The HAPS is a flying overall, incorporating the tensioner system, anti-G bladder and abdominal pressure compensator. It provides protection at altitudes above 12,000 m in the event of loss of cabin pressures. HAPS, being a skin-tight garment, is tailored to suit the pilot in seated position. The HAPS developed is compatible with the existing oxygen systems in the aircraft. The suit has been fabricated out of specially developed nylon/cotton fabric.

High-altitude pressure gloves (HAPG). HAPG is a conventional five-finger design gloves provided with 'V' gusset conforming to the shape of the fingers to provide better fitment. The main feature of HAPG is that it contains a blind latex glove holding a fixed volume of air concealed between two layers on the dorsal side of the glove which applies pressure on the wearer's dorsal side of the hand. The gloves are made of soft sheep nappa leather and are made in 10 sizes.

High-altitude pressure socks (HAPS). The socks are made out of nylon/cotton fabric which has low extensibility. The top of the socks is provided with adjustable lacing for individual adjustment. The socks are made in four sizes.

Communication equipment for aircrew. For smooth operations of flights and carrying out the assignments deffectively, intelligible communication is an inescapable requirement. This will help in establishing links between aircraft to aircraft, aircraft to ground and vice versa. The electroacoustic transducers form a part of the communication system. These include the microphone and earphones in transmitter and receiver systems, respectively. However, in aircrew equipment, these form a part of the oxygen mask and helmet, respectively.

The microphone designed and developed is miniaturized, sensitive and of differential type. It makes use of two coils and two ring magnets and a single diaphragm to make it differential type. Utmost care is taken to achieve a sensitivity of −60 db, re of 1 V/Pa and signal-to-noise ratio of 18 db at 1 kHz. The frequency response of the microphone is so adjusted to suit in the oxygen mask, giving high intelligibility in speech transmission. The response is limited from 300 to 3500 Hz and rises 8 db/octave from 300 to 1200 Hz and varies by ±4 db thereafter. The impedance is 600 Ω ±35%. The weight of the microphone is highly critical and is 10 g when used in high-G performance aircraft. Compatible cord connectors have also been developed.

The earphones are of electromagnetic type, weighing 32 g each. These have high impedance of 10 kΩ each and a sensitivity of 115 db SPL/mW. The response of the earphones is restricted to the frequency band of 300–3000 Hz and the maximum variation in output with respect to 1 kHz is ±6.5 db. These can be used in the tropical environment.

Both microphones and earphones have been subjected to various environmental tests and can be used from −10° to 50°C. However, the storage temperature is from −50° to 70°C. These devices have also been subjected to vibration test from 5 to 500 Hz with an amplitude of 0.125 mm or 10 g, whichever is higher.

Aircrew personal clothing

In addition to the protection equipment, the aircrew also require flying clothing, viz. flying overalls, gloves, boots and socks.

Flying overall. Currently, the aircrew of IAF are using flying overalls Mk II fabricated out of 60/40 polyester/cotton blended fabric in mockleno weave. The fabric has been specially developed to meet tropical conditions of flying.

The overall Mk II has been designed based on human engineering requirements. The overall is a single-piece garment having a medium-duty metallic slide fastener running from the neck to the crotch position in front for easy donning and doffing. Slits are provided at the waist for easy access to the inner garments. The overall has been provided with pockets to hold personal and operational-related items. The overall is made in 11 sizes.

Flame-retardant (FR) overalls. Several flame-retardant (FR) materials suitable for tropical flying have been developed. FR materials developed are either a mixture/blend of FR viscose, P-84, polyester or FR viscose alone. FR viscose has been specially developed for this purpose.

The various FR materials developed include 100% FR viscose, 50/50 FR viscose/P-84, 70/30 FR viscose/P-84 and 50/50 FR viscose/polyester. All these developed materials are in the light- to medium-weight range, conforming to BS 3119 or ASTM 2863. The char length (CL) and limiting oxygen index (LOI) of the fabrics developed are given in Table 2.

The results of the strip studies, viz. char length and LOI, do not give any meaningful indication of the protection offered to the wearer in terms of burn injuries [6]. A thermally instrumented mannequin has been developed to study the protection offered by various garments in terms of burn injury. Work is in progress to develop an automated system for classifying the burn injury and to assess the protective performance of fabrics.

Design of overalls. The design of the FR overall was based on the survey conducted among the pilots and the extensive field trials.

The designed overalls were evaluated for thermal stress imposed on the wearer on expo-

Table 2. FR characteristics of fabrics

Fabric	Weight (g/m^2)	CL (cm)	LOI (%)
100% FR viscose	280.0	–	29.0
50/50 FR viscose/P-84	185.0	6.1	34.0
70/30 FR viscose/P-84	185.0	7.4	32.0
50/50 FR viscose/polyester	185.0	–	25.1
80/20 FR viscose/polyester	220.0	–	26.6

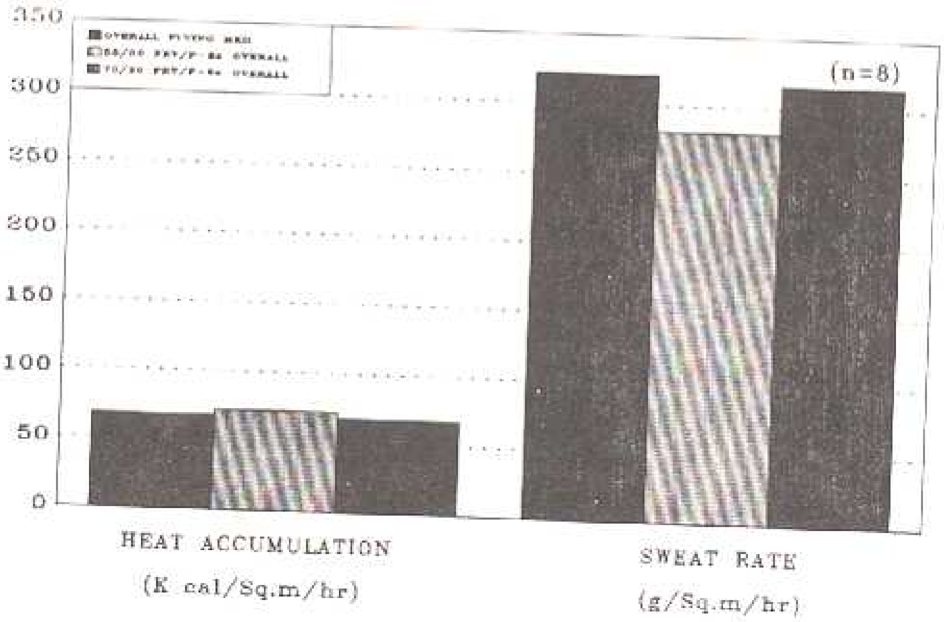

Figure 1. Heat accumulation and sweat rate on exposure to heat stress for 1 h.

sure to simulated conditions (Tdb – 48°C, RH 50%) for 1 h. The physiological evaluation [7-9] revealed that the thermal stress imposed on the wearer was not significant (Figure 1).

Recently, work has been started on the development of FR fabrics using unconventional yarns, viz. core spun yarns. Experiments in this direction have already yielded positive results and the development of fabric using these yarns is being pursued.

Flying gloves. Gloves to meet normal flying needs, survival conditions and parachutists' requirements have been designed and developed. The gloves for flying are made out of thin, soft chromium–zirconium tanned leather for better feel and thermal insulation. The survival gloves and PJI gloves are made out of soft nappa leather, having a lining of acrylic pile to provide adequate warmth under cold conditions.

Boots. Various types of boots for flying have been developed to meet the user requirements and these include flying boots Mk I, II, III, IV, winter flying boots and PJI boots. The boots are fabricated out of water-repellent upper and make use of specially designed anti-skid sole. All the boots are of welt design to prevent the snow or water entering the boots. They are made in 9 sizes, with 3 subsizes in each size. The PJI boots are provided with a thick micro rubber sole for withstanding the impact shocks on landing. The winter flying boots are provided with an interlining of woollen pile fabric all around to provide insulation. Some recently developed flying boots, in addition to the above features, have an additional zipper at the centre for easy donning and doffing.

Conclusions

The recent developments in the field of aircrew protective equipment/clothing have been briefly described. Many of the protective equipment/clothing developed are in active service use. To meet the demanding operational needs, improvements are being carried out in the present design and new products are being developed. The development and use of new materials in the design and development of protective equipment has been given top priority to offer maximum protection along with operational effectiveness.

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