Design Approach to Cold Weather Clothing Systems
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RFD Beaufort
Introduction

- A Brief Explanation of Hypothermia
- Consequences of Hypothermia for Pilots and Aircrew
- Challenges of Designing Cold Weather Clothing Systems for Aircrew
- Material Considerations
- Future Technologies
- Qualification Requirements
- RFD Beaufort Cold Weather Protection Garment Developments
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A Brief Explanation of Hypothermia

Normal Body Core Temp = 36.5° C to 37.5° C (98° F to 100° F)

Hypothermia = Body Core Temp falls below 35° C (95° F)
## Consequences of Hypothermia for Pilots and Aircrew

<table>
<thead>
<tr>
<th>Core Temp</th>
<th>Definition</th>
<th>Symptoms</th>
<th>Consequences</th>
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</table>
| 35°C      | **MILD**    | • Shivering  
            • General Discomfort | • Distracted – Concentration Reduced  
                                                                          • Co-ordination Reduced  
                                                                          • Responses slowing down |
| 32°C      | **MODERATE**| • Violent Shivering  
            • Mild Confusion  
            • Stumbling Gait  
            • Pallor obvious | • Lack of Co-ordination  
                                                                          • Slow and Laboured Movement  
                                                                          • Poor Response – inability to concentrate |
| 28°C      | **SEVERE**  | • Heart Rate Decrease  
            • B.P. Decrease  
            • Respiratory Rate Decrease  
            • Exposed Skin blue and swollen | • Sluggish mental capability  
                                                                          • Amnesia  
                                                                          • Walking Impossible  
                                                                          • Irrational Behaviour and Mental Confusion |
| 20°C      | **PROFOUND**| • Brain Function Ceases  
            • Heart Stops | • Death Occurs, Rate Dependant on:  
                                                                          • Age  
                                                                          • Physical Condition (Drugs/Alcohol)  
                                                                          • Physiology  
                                                                          • Gender |
Challenges of Designing Cold Weather Clothing Systems for Aircrew
Challenges of Designing Cold Weather Clothing Systems for Aircrew

1. Integration into the cockpit environment on different aircraft platforms (Fast Jet / Non Fast Jet)
2. Integration with other clothing and equipment worn by Air crew
3. Thermal burden – when not operating in cold environments - FJ
4. Thermal Burden – when not operating in cold environments - NFJ
5. Anthropometric considerations
6. Escape and Evasion considerations post Aircraft abandonment
7. The Modular Clothing System
Challenges of Designing Cold Weather Clothing Systems for Aircrew

1. **Integration into the cockpit on different Aircraft platforms (Fast Jet / Non Fast Jet)**

   - Maximising Comfort
   - Maximising Mobility
   - Minimise Bulk due to space constraints
   - Consideration of Emergency Escape procedures
   - Minimising Thermal Burden
   - Harness Integration
   - Seat Integration
   - Facilitate in-flight urination
   - Ergonomics
2. Integration with other clothing and equipment worn by Air Crew

- Bulk around neck – Helmet interaction and head mobility
- Bulk underarms – Flight jacket interaction
- Bulk underarms – Pocket interaction
- Bulk below waist – reduced G protection offered by the Anti G Trouser
- Integrate urination facility
Challenges of Designing Cold Weather Clothing Systems for Aircrew

3. Thermal burden in *Fast Jets*—when operating through a wide temperature range
Challenges of Designing Cold Weather Clothing Systems for Aircrew

4. Thermal burden in *Non Fast Jets* – when operating through a wide temperature range

- Pilot – seated and relatively sedentary throughout flight
- Rear Aircrew
  - Require more mobility to carry out operational activities
  - Constant change between hard physical work and sedentary periods of inactivity (e.g. seated during transit)
- Operations with open doors - Wind Chill Factor
  - Rotor Down draft
Challenges of Designing Cold Weather Clothing Systems for Aircrew

5. Anthropometric considerations

- Male and Female Aircrew
- Large anthropometric size range
- Size roll development to accommodate full range of Male and Female sizes with consideration of unisex sizes
- Wide size range minimises the need for Special Measure garments and optimises wearer fit.
Challenges of Designing Cold Weather Clothing Systems for Aircrew

6. Escape and Evasion considerations post Aircraft abandonment

• Environmental Protection –
  • Wind Chill
  • Water Penetration
  • Thermal Protection

• Comfort and Mobility

• Camouflage and concealment

• Low Noise Signature
Challenges of Designing Cold Weather Clothing Systems for Aircrew

**Escape and Evasion considerations post Aircraft abandonment**

- Ability to vent garments during periods of high activity
- Facilitate urination/toilet provision with the minimum of doffing
- Quick Drying
- Head, Hand and Foot protection
- Survival Equipment storage
Challenges of Designing Cold Weather Clothing Systems for Aircrew

Potential Operational Scenarios

- Cold Wet conditions and effects of Wind-Chill
- Cold Dry conditions and effects of Wind - Chill
- The Cold Wet Environment – Rain, Snow and Sleet
- Extremes of environment – Hot to Cold
Challenges of Designing Cold Weather Clothing Systems for Aircrew

Cold Air and Effects of Wind-Chill

![Graph showing wind chill index and temperature relationship](image)

- **Very cold**
- **Danger of frostbite**
- **Great danger of frostbite**

Temperature, $\degree C$:
- 0
- -5
- -10
- -15
- -20
- -25
- -30
- -35
- -40
- -45

Wind speed, m/s:
- 2
- 4
- 6
- 8
- 10
- 12
- 14
- 16
- 18
- 20

Wind chill index, $\degree C$:
- -25
- -35
- -60
Challenges of Designing Cold Weather Clothing Systems for Aircrew

7. The Modular Clothing System

- Layering can improve thermal protection by the entrapment of air between layers.
- Modularity within the clothing system can optimise the comfort of the Aircrew by enabling clothing combinations to be selected in accordance with the operational conditions and mission requirements to be encountered.
- A typical clothing ensemble will require:
  - Outer Shell
  - Mid Layer
  - Base Layer / Underwear
  - Accessories
## Challenges for Cold Weather Protection Systems for Aircrew

<table>
<thead>
<tr>
<th>LAYER</th>
<th>BASIC REQUIREMENT</th>
<th>REQUIREMENTS SPECIFIC TO AIRCREW</th>
<th>DESIGN CONSIDERATIONS</th>
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<tbody>
<tr>
<td>Outer Shell</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Durable</td>
<td>• Flame retardant</td>
<td></td>
<td>• Equipment Stowage</td>
</tr>
<tr>
<td>• Waterproof</td>
<td>• Anti –Static</td>
<td></td>
<td>• Wind and water proof with venting to reduce thermal burden during exertion</td>
</tr>
<tr>
<td>• Windproof</td>
<td>• Low noise signature</td>
<td></td>
<td>• Ease of donning / doffing</td>
</tr>
<tr>
<td>• Breathable</td>
<td>• Camouflage pattern/colour</td>
<td></td>
<td></td>
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<tr>
<td>Mid Layer</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Lightweight</td>
<td>• Flame retardant</td>
<td></td>
<td>• Modular / Scaleable approach to vary insulating characteristics based on conditions and operational requirements</td>
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<tr>
<td>• Insulating</td>
<td>• Low noise signature</td>
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<tr>
<td>Base Layer / Underwear</td>
<td>• Breathable</td>
<td>• Non melt /drip hazard</td>
<td>• Sanitary layer requiring frequent washing</td>
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<tr>
<td></td>
<td>• Insulating</td>
<td></td>
<td>• Modular approach to vary insulating characteristics based on conditions</td>
</tr>
<tr>
<td></td>
<td>• Wicking – moisture management</td>
<td>• Low noise signature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Comfortable against the skin</td>
<td>• Bio-static / Hygiene considerations</td>
<td></td>
</tr>
<tr>
<td>Accessories</td>
<td>• Hand Protection</td>
<td>• Maximum dexterity and tactility required to fly the aircraft</td>
<td>• Gloves or Mittens (or combination)</td>
</tr>
<tr>
<td></td>
<td>• Head protection (thermal)</td>
<td>• Minimal packed bulk</td>
<td>• Balaclava or Head Over (no requirement to be FR as only worn outside the aircraft)</td>
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<tr>
<td></td>
<td>• Head Protection (wind and water)</td>
<td>• Minimal packed bulk</td>
<td>• Rain Hood (no requirement to be FR as only worn outside the aircraft)</td>
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Material Considerations
Material Considerations

Outer Shell –

- **Durable** – highly abrasion resistance and resistant to laundering
- **Waterproof** - MVP membranes - 100% waterproof

Differing pressure loads affect the knee and posterior depending on body posture and weight - Data based on a human 1.7m tall and circa 70kg)
Material Considerations

Outer Shell –

- **Windproof** - MVP membranes -100% windproof
- **Breathable** – MVP materials (Vent panels)
- **Lightweight** - Circa 180g/m²
- **Flame retardant** - Inherently flame retardant or improved FR surface finishes
- **Anti static** - Carbon fibres in weave construction to reduce ESD
- **Camouflage / Colour** - Multiple dying processes – producer coloured to improve colour fastness and reduce IRR
- **Low noise signature** - Flexible materials with good drape and handle
- **Maintainable** – Easy to repair
Material Considerations

Mid layer –

- **Light weight** – materials circa 180g/m² but will increase as insulation values increase

- **Insulating** – High or Low loft materials - levels of insulation can be varied dependent on expected environmental conditions

- **Breathable** – Air Permeable

- **Flame retardant** - the level of FR resistance can be dependent on the garments worn over the top

- **Minimal Bulk** – Low surface friction and flexible

- **Ability to be laundered**
Material Considerations

Base Layer / Underwear –

- **Breathable** – Air Permeable
- **Wicking / Moisture management** – hydrophilic fibres
- **Comfort against skin** - Surface finish of materials and seam construction
- **Light weight** – circa 100g/m²
- **Flame retardant** - Non Melt or Drip Hazard
- **Bio-static / Hygiene considerations**
- **Ability to be laundered**
Future Technologies
Future Technologies

• Heat Storage Technologies – “Phase Change Materials” (PCM) – Latent Heat Stowage
  • A Phase-Change Material (PCM) is a substance which melts and solidifies at a certain temperature. The material is capable of storing and releasing large amounts of energy.
  • Heat is absorbed or released from micro encapsulated beads when the material changes from solid to liquid and vice versa.

• Powered Heat Generating Systems
  • Electrically heated stainless steel or carbon fibre threads powered by rechargeable Lithium Ion battery technology can provide localised heating to the body.
  • Technology originally used in 1940’s but new wiring and battery technologies have improved the performance, duration, durability and reliability of the heating systems.
Future Technologies

• Power Capture Technologies
  • Biomechanical energy harvesting from human motion to provide electrical power normally supplied by batteries to power portable heating system and is harvested from body heat and from motions of various parts of the body during walking, such as heel strike, ankle, knee, hip, shoulder, and elbow joint motion

• Inherent Air Insulation – High loft / Low compression
  • High loft materials with excellent resistance to compression are being continuously developed. The high lofting provides improved insulation performance whilst the low compression characteristics maintain thermal insulation when, for example lying down or seated.
  • The material can be manufactured to be inherently windproof and waterproof and have sweat management / wicking characteristics
Future Technologies

• **Inflatable Air Insulation Technology**
  
  An adjustable insulation system that uses the introduction of air to meet the thermal needs of the wearer by simply inflating the system by blowing into a non return valve.

  Adapting to changing conditions can be accomplished without removing layers.
Qualification Requirements
Qualification Requirements

Equipment Level Testing to include:

- Smoke density
- Flame resistance
- Effect of Temperature
- Solar
- Colour fastness to light
- Abrasion
- Fungus resistance
- Sand and Dust
- Temperature Shock
- Contamination resistance
- Thermal testing
- Comfort and mobility
- Anthropometric sizing
Qualification Requirements

System Level Testing to include:

- Ejection Tests*
- Man /Seat inversion*
- Man seat separation*
- Man rating*
- Flame Trial
- Emergency Cockpit Operations
- Rescue egress
- Cockpit Integration and Habitability
- Rain
- Electro static discharge
- Crash deceleration
- Period of wear
- Normal Ground Egress
- Emergency Ground Egress
- Man Machine Interface
- Parachute Suspension
- Land Dragging

* Applicable to Fast Jet only
RFD Beaufort Cold Weather Protection Garment Developments
RFD Beaufort are currently developing Cold Weather clothing systems to provide Cold Weather Clothing which provides the highest level of performance and the best value for money – by using advanced design and experience from existing proven product.

- Offer improved performance and durability through enhanced material and design features.

- Provide great value by meeting both FR and non FR product needs based on a common design. Military needs FR clothing for high-risk events e.g. refuelling and flight operations, and non-FR for lower-risk tasks without additional logistics and maintenance burden.

- Provides the lowest lifetime costs through improved material selection and design with the same maintenance and replacement schedules.

- Improve aircrew performance by optimising comfort and mobility through experienced garment design, material selection and integration with other flight equipment.
RFD Beaufort Cold Weather Protection Garment Developments

• **Reduce total lifetime costs** through selecting robust durable materials and reducing the complexity and cost of repair and replacement parts through simple design

• Ensure peace of mind by drawing on RFD Beaufort’s extensive capabilities and experience:
  
  • >90 years experience designing customised military solutions partnering with UK MoD and other International Defence Authorities.
  
  • RFD Beaufort’s PFE products are in use worldwide in **active combat situations**
  
  • RFD Beaufort products undergo rigorous **full Air-Worthiness** testing and qualification
RFD Beaufort Development History
RFD Beaufort World Firsts

- 1940: Mae West - Life Preserver
- 1950: Fast Jet Anti-G Trousers
- 1976: Welded Life Raft
- 1989: Marin-Ark Marine Escape System
- 1992: Full Coverage Anti G Trouser
- 1994: SEIE Mk10
- 2001: Mk60 Armoured Life Preserver
- 2003: HAPLSS
- 2004: VCLJ/ Rebreather
- 2006: Fascines
- 2007: Fragmentation Vest; SEIE Mk 11
- 2008: Liquid Cooling Garment and PCU
- 2009: Flexible Hyperbaric Chamber
- 2012: Wave Energy Conversion Development
QUESTIONS