INSULATION CONCEPT & MATERIAL OPTIMISATION IN BUSINESS AIRCRAFT

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Keywords:*thermal, acoustic, insulation, Polyimide, Polyethylene, foam,FST*

Abstract

Available energy for cabin heating power in large cabin single engine A/C is limited. Thus, the thermal performance of the insulation and its concept are of high importance. Pilatus Aircraft Ltd. together with illbruck Special Products initiated an improvement program for the PC12 insulation (10-seater). The goals were to improve thermal and acoustic performance, to cut down installation time, to reduce water ingress in the insulation material, to simplify inspection and consequently, to reduce overall costs.

The insulation concept for the cabin and cockpit consists of cushions clamped between profiles (above floor) and foam plates (under floor). Cushions were manufactured with open-cell PI foam blocks bagged in two different polymeric foils. The first is a conventional vapour barrier (inwards) which is heat sealed with the second, a newly developed illbruck foil (outwards). Longerons and frames are insulated with clipped foam profiles, which serve as fasteners for the cushions. Closed-cell foam plates were used in the under floor. All materials and their combination demonstrate FST compliance of FAR 25.853(a) or (b).

In-service experience showed significant benefits in insulation manufacturing, installation as well as in maintenance and inspection. Acoustic and thermal performances were improved without notable weight increase. Ongoing developments are devoted to further acoustic and weight reduction, as the modular design of the new insulation concept allows further materials or detail optimisation.

1 Introduction

In regions of extreme climatic conditions, some PC12 customers experienced water ingress within the thermal/acoustic insulation material. This was due to an insufficient drainage and ventilation as well as to the use of un-bagged foam material. An improvement program was started to review the insulation materials and concept. The results are implemented in a large percentage of the PC12 fleet today.

2 Materials

2.1 Generalities

Airliners generally use fibrous glass bagged in metallized polyvinyl-fluoride foils. The foils are reinforced by a nylon mesh. Cushions of this type do not provide a defined and stiff shape and tend to collapse with time due to vibrations. The cancerous potential of short glass fibers remains an open issue. Further, this concept requires punctures of the bagging foils (or clips) for fastening or ventilation. Therefore, this concept is prone to water ingress and operators are forced to replace water swelled cushions after 3-4 years. [1]

Foam has numerous inherent advantages: cushions made out of foam are easier to handle and to manufacture. Foam is made of a hydrophobic material which does not need binders used in fibrous glass and is not a hazardous material. It has a stiff shape which ensures durable insulating properties. [2,6]

Foam showed to be advantageous over fibrous glass in water ingress considerations. During manufacturing and installation, the cushions are locally crushed. This severely increases their tendency to pick up water, independently of the hydrophobic character of the material. Foam is much less sensitive to this effect than fibrous glass. Further, foam dries quicker than fibrous glass once swelled with water, as water remains homogeneously distributed in the open-cell structure. In the case of fibrous glass water accumulates in the bottom of the cushion and is thus more difficult to dry. [3,4,6]

2.2 PC12 Insulating Materials

The insulating materials used for the PC12 are different for above and below the floor. Bagged open-cell foam blocks are used above the floor. Closed-cell foam (un-bagged) plates are preferred in the bilge as they are inherently resistant to water ingress.

Tested separately and together, all materials comply with FST requirements FAR25.853 a or b.

2.2.1 PI Open-Cell Foam

The insulation blocks are made of polyimide (PI) open-cell foam (illbruck Solimide AC530). Its density is 5.0 kg/m^3 ±15%. Compared to fibrous glass, PI foam is generally lighter but shows a slightly higher thermal conductivity of 0.049 W/mK (against 0.04 for fibrous glass). [2]

2.2.2 Bagging Foils

The PI blocks are bagged within 2 different foils (inward and outward sides) to build a cushion. Both foils are heat sealed together to a ca. 8 mm seal bead, achieving a min. of 2.5 N/m tear strength.

For the inward side, the foil must have the properties of a vapor barrier to minimize humid air generated in the cabin from penetrating and condensing within the PI-foam. Metallized Orcofoil AN-16R or Jehier Terul 11 reinforced with nylon mesh are used (46 g/m^2).

For the outward side, the foil must be water tight to avoid ice melting from the structure from entering the cushion. Further, extant liquid water in the PI-foam shall be allowed to diffuse outside of the cushion.

This dual function is provided by a newly developed, specially filled, PE-foil from illbruck Special Products (illfoil AC101/20 R). Its water tightness is 10 m water pressure, while its water vapor permeability to DIN53122 is 6.6 l/24h/m^2 (conventional films like Gore-Tex: have a permeability of 6-6.5 l/24h/m²). The illfoil is ca. 20 µm thick, is reinforced by a nylon mesh and weighs 36 g/m^2. [2,3,4,5]

2.2.3 PEX closed-cell foam

For the bilge, longerons, frames or zones prone to trap water, a closed-cell PEX (cross-linked polyethylene) foam is used. Its density is 24 kg/m^3 and thermal conductivity is 0.038 W/mK.

A lighter 15 kg/m^3 version is being qualified. [2]

3 Insulation Concept

The PC12 insulation concept now uses the arrangement:

1. Above floor: *outer (alu) skin – air gap – bagged insulation cushion – interior liner.*
2. Under floor: *outer skin – air gap – foam plate.*

3.1 Above Floor Concept

The above floor concept is based on two modules (fig. 1):

1. surface insulation with bagged foam blocks (= cushions) and
2. longerons/frames/bulkheads insulation with foam profiles.

To insulate longerons and frames, profiles were used which were cut out of PEX foam blocks. Their design allows them to be clipped directly onto longerons and frames. Few positions need to be additionally taped. Further advantage: these profiles replace all pins, clips or through-punctures to fasten the cushions, as these are clamped between the PEX profiles (fig. 2).

fig. 1: above floor PC12 insulation concept.

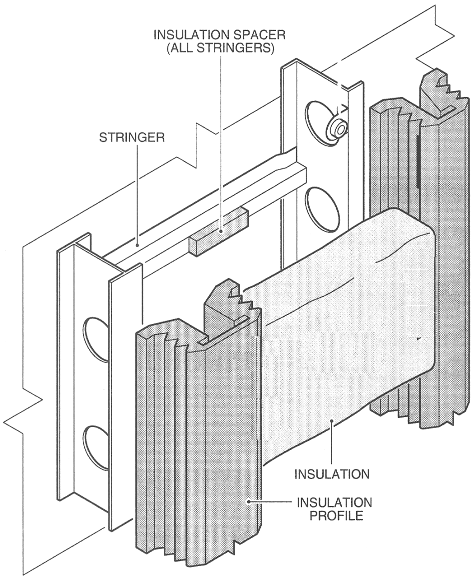

fig. 2: detail of the PEX profiles and bagged PI cushions.

This concept aimed at providing an air gap between the cushion and the outer alu skin to allow ventilation of the structure and of the cushions. In providing adequate heating and ventilation flow in the PC12 cockpit & cabin, the insulation concept formed and important role equal to that of the heating system itself.

Vent holes installed onto the illfoil avoid a pressure build-up in the cushions during flight. They also simplify installation as they allow entrapped air to escape. Positioning vent holes on the outer side of the insulation allows the cushion to expire extant humid air and inspire dry air. Thus, a drying effect is expected during operation.

3.2 Under Floor Concept

Under the floor, 15 mm thick PEX plates are used. They are placed directly onto the stringers and clamped between the frames/bulkheads. Their installation provides a gap for ventilation which also allows liquid water to reach the drain valves.

Drainage holes were added and their diameter increased from 6 mm to 8. The reason is that the CPC (corrosion protective compounds) sprayed in the bilge over the primer negatively influenced the flow of water within the drain hole, due to its hydrophobic character.

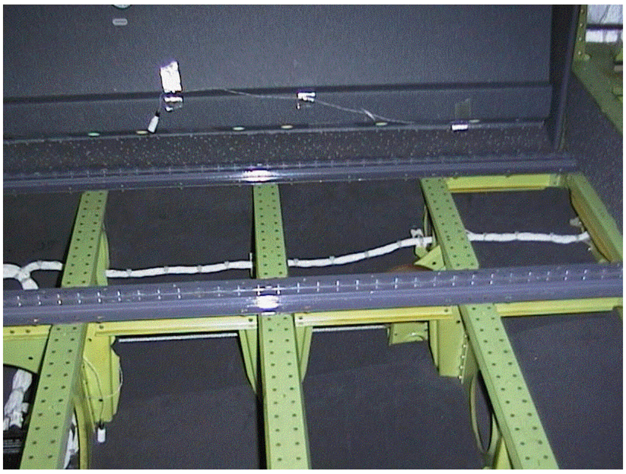

fig. 3: under floor PEX plates insulation.

4 Results and In-Service Experience

Based on about 15 months of in-service world-wide experience, the concept has so far showed several benefits.

4.1 Benefits

The modular concept used above the floor, using clipped profiles and cushions clamped between them greatly facilitates manufacturing and installation of the insulation. No fasteners are necessary. Installation time was severely cut down. Logistic was reduced as the cabin insulation is now installed later in the production line, living the structure fully accessible for systems installation. Maintenance and inspection are simplified which will lead to further savings in operation.

Due to the stiff shape of the foam blocks, direct contact of the cushions with the cold structure is reduced and on stringers, contact is restricted with spacers (fig. 2). Thus water ingress is minimized. No water ingress is reported so far, despite that some bags were found open due to defect seal beads. In the mean time, the heat sealing process was improved.

The gap between the outer skin and the cushions proved efficient to remove condensed water and allow the structure to dry quicker, which will substantially delay the onset of corrosion.

The long-term advantage of foam against fibrous glass is no more to be proven [1,3] while the long-term behavior of the PC12 concept is subject to ongoing control.

4.2 Weight Consideration

Weight of the investigated insulating materials for the passenber cabin (above and below floor) and the final weight (with cockpit) of the PC12 is given in the following table:

PC12 – Cabin only (measured)	kg
Fibrous Glass (6.4 kg/m^3) + fasteners	14.9
Former Concept (unbagged PI foam, 6.4 kg/m^3)	5.5
New Concept (bagged AC530 + PEX profiles)	9.75
PC12 – Cabin + Cockpit insulation	**kg**
Fibrous Glass + fasteners (calculated)	20
Former Concept (calculated)	13.0
New Concept (measured)	14.9

The choice of foam instead of fibrous glass was easy to make. The increase in both acoustic and thermal performance was achieved with a negligible weight increase. In-service, weight increase is expected to be minimal as the bilge material does not absorb water. This, together with the improved drainage drastically minimize water pools and weight take-up.

4.3 Performances

Thermal performance was measured in combination with improvements to the heating system. Results indicated that the new insulation showed a positive improvement in term of performance (ca. +3°C on cabin temperature).

The interior liner surface temperature was found to be higher.

Acoustic performance was also improved by about –3dB compared to the previous insulation concept.

5 Outlook

The use of foam of higher density or adequate modification of its shape may achieve further improvements in acoustic performance in the cabin, as already proven in lab tests.

illbruck works in a ongoing process to improve the flammability properties of the materials to fulfill the future FAA requirements.

The PC12 insulation concept allows a wide range of further improvement. A lower density closed-cell PEX foam shall be used soon for further weight savings.

As a result of this development, the PC12 cabin environment and longevity of the airframe has been significantly improved. With continuous research & development illbruck and Pilatus are well prepared for the future.

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