Return of the space hoppers: more measures on dH Comet G-BDIX

O regresso das bolas saltitonas: mais ações no avião dH Comet G-BDIX

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Abstract

De Havilland Comet 4C "G-BDIX" arrived at the National Museum of Flight (NMoF) in Scotland in September 1981 and has been displayed outdoors and fully exposed to the environmental conditions ever since. In 2018, National Museums Scotland (NMS) set a development in motion at its NMoF site with the aim to display the dH Comet, amongst other aircraft, in a new, environmentally controlled hangar. Due to planning permission issues the project was cancelled, and the museum is now scoping out alternative options. This led to focus on the outside of the aircraft and provided the opportunity to revisit the work carried out during a project in 2012/13, at the time making the passenger cabin watertight and rectify interior damage.

KEYWORDS
Aeroplane
Aviation
Industrial heritage
In situ
Outdoors

Resumo

O avião De Havilland Comet 4C "G-BDIX" chegou ao Museu Nacional do Voo (*National Museum of Flight*, NMoF), Escócia, em Setembro de 1981 e, desde então, está exposto ao ar livre, sujeito às condições ambientais exteriores. Em 2018, os Museus Nacionais da Escócia (*National Museums of Sctoland*, NMS) desenvolveram um projeto com o objetivo de expor no espaço do NMoF o dH Comet, entre outras aeronaves, num novo hangar com controlo ambiental. Devido a problemas de autorização, o projeto foi cancelado e o museu está agora a estudar soluções alternativas para a conservação do avião. Esta situação levou a que a atenção se centrasse na conservação do exterior da aeronave e proporcionou a oportunidade de revisitar o trabalho realizado durante um projeto desenvolvido em 2012/13 que tinha como principais objetivos tornar a cabina de passageiros estanque e retificar os danos interiores do avião.

PALAVRAS-CHAVE
Avião
Aeronáutica
Património industrial
In situ
Exterior

Introduction

The dH Comet has an important place in aviation history. The Comet 1 was the first commercial jet-powered airliner in the world, entering service in 1952 [1, p. 25]. Only seven complete airframes of different marks are preserved in museums [2-3].

The dH Comet presented in this article was delivered to the Royal Air Force in April 1962 as XR399 [4]. From 1975 until 1980 it was operated as G-BDIX by Dan Air London [5]. Dan Air was the largest operator of the aircraft type and the last one to retire it [6, p. 146]. The Comet landed at the museum in September 1981 (Figure 1). The flight to the museum was the last of a civil dH Comet.

In the 1990s, the exterior of the aircraft was completely repainted by a group of volunteers. At the same time, gaps between panels and around access hatches on top of the wings were covered with sheet aluminium alloy, bitumen based flashing tape and aluminium foil adhesive tape to stop water ingress into the structures beneath.

With some exceptions, the materials used for the long-term preservation of the airframe while being displayed outdoors are not selected by their reversibility, as common practice in conservation [7]. Instead, materials for the measures described in this article are primarily chosen which have been tested and are being used in the aviation industry because of their suitability, durability and compatibility with aluminium alloys and acrylic glass under harsh environmental conditions [8].

Figure 1. dH Comet 4C G-BDIX at the National Museum of Flight.

Emergency measures

Between 2005 and 2012, no major work was carried out on the Comet because other projects had to be prioritised.

In 2011, the Comet was closed to the public because of water ingress into the passenger cabin and an unstable cabin floor.

From September 2012 to March 2013 the conservation team (Mike Loftus and myself) and volunteers carried out short-term emergency measures to enable a reopening of the aircraft to the public. The cabin interior, the over-wing emergency exit hatches and all 36 passenger windows were removed. After removal of the interior, it transpired that the water ingress was caused by failing rubber seals of the emergency exit hatches.

The exit hatches, made of a magnesium alloy, had their paint removed to bare metal with Langlow Strip Away Pro and 320 grit sandpaper to identify even the smallest areas of corrosion. The corrosion was ground away with Dremel aluminium oxide grinding stones and affected areas coated with LAS 4853/ 4854 zinc chromate 2 Pack etch primer. The holes and cavities were filled with Fixtpro J032 aluminium epoxy putty. The hatches received a complete coat of zinc chromate 2 Pack etch primer and two coats of aviation grade two-pack polyurethane paint (PPG Aerospace CA8000-707).

The pressure seals of the emergency exits were badly deteriorated and needed replacing. Because off-the-shelf rubber seals were not available, PPG Aerospace PR1422B2-1150 fuel tank sealant, a two-part, manganese dioxide cured polysulfide compound, was used instead to create bespoke seals. The recess for the original seal was filled with the fuel tank sealant. Upon installation of the emergency exits, another bead of fuel tank sealant was added between hatch and aperture.

Most of the passenger windows, each made of an outer and inner pane of acrylic glass with a vulcanised rubber spacer in between, were starting to separate along the spacer. The panes were joined back together with silicone-free No Nonsense Anti Crack acrylic sealant. Upon re-installation, a bead of PPG Aerospace PR1425B1/2-1001 windshield and canopy sealant, a dichromate cured polysulfide compound, was applied between window and window aperture.

Figure 2. John and the Retro Space Hoppers: *a)* partly inflate; *b)* insert; *c)* completely inflate; *d)* check.

While exit hatches and windows were treated in the workshop, the apertures in the fuselage needed to be protected. The over-wing emergency exits were covered with blanks out of wooden frames, covered with Irish linen, cellulose nitrate dope and Plastazote foam padding. These blanks formed a good seal, even in high winds and heavy rain. For unknown reasons, that same system did not work for the passenger windows. Instead, our volunteer John suggested retro space hoppers to fill the window apertures. Ten adult-sized retro space hoppers were purchased and inserted into the open window apertures, which kept most of the rain out of the passenger cabin. As most of the interior has been removed during the project, a small leakage was acceptable. When sufficiently inflated, the space hoppers took on the shape of the oval windows, and bulges formed on the in- and outside, which prevented the space hoppers from falling out (Figure 2). Only occasionally, a space hopper was dislodged by very high winds.

The floor panels in the cabin aisle were also damaged. They were made of sheet aluminium with strengthening ribs riveted to the underside. Many of the ribs were broken and rivets had failed because they were constantly walked upon by visitors. In the galley areas the floor also had corroded. Repairing the floor panels could not have been achieved within the restricted deadline of the project. Instead, all floor panels in the aisle and galleys were replaced with 13.9 mm aluminium honeycomb centred, glass fibre skinned panels, also known as Aerolam, a material used in modern airliners as flooring. The original floor panels were placed in storage.

Water, which was standing in the aileron servodyne and hydraulic equipment bay under the cabin floor, was not coming from the windows but from other areas we were not able to access. To prevent water accumulating in the lower fuselage, two 10mm drain holes were drilled through the skin in each bay. This will prevent corrosion and the possible development of legionella bacteria.

At the end of the project, an annual outside clean of the Comet resumed by the Preventive Conservation Team of National Museums Scotland.

Aim of the current measures

In 2018, National Museums Scotland (NMS) started the development of a new hangar to move de Havilland Comet "G-BDIX" and two other aircraft inside. The opening of the new hangar was planned for April 2022 but was delayed indefinitely because the museum did not get the required planning permission.

With the prospect of the Comet moving indoors, and two other capital projects, no major work has been carried out on the exterior of the Comet between 2012 and 2021. When it became unclear how much longer the Comet and the other two outdoor aircraft must remain outside, funding was made available to carry out thorough condition assessments and some urgently required work until 2025.

The aim of the current project is to reduce the rate of degradation and stabilise the condition of the aircraft until they can be moved indoors and fully restored by:

- Determining the condition of the more inaccessible but structurally important areas of the aircraft.
- Making the wings watertight.
- Treating corrosion in areas of the upper wing surfaces, on the undercarriages and undercarriage the attachment points (Figure 3).
- Revisiting the measures undertaken in 2012/13 on the outside of the fuselage.

Figure 3. Corroded main undercarriage attachment point.

Current measures

By 2020, leaks had developed in the flight deck of the Comet, originating from the sextant aperture in the ceiling and the windows. A mobile elevated platform (MEWP) was hired to enable us to seal the leaks with non-corrosive, neutral silicone sealant and 3M Aluminium Foil Adhesive Tape 425. The MEWP was also used to inspect and preventively apply sealant to other areas of potential leaks on top of the Comet, as well the other two outdoor aircraft at the National Museum of Flight.

In November 2020, new bird spikes were attached to the top of the fin and two antennas to slow down the degradation of coatings and fuselage skin by acidic bird droppings. The old spikes, which have been applied in 2007, had failed over the years.

In the years 2021 and 2022, drain holes were inspected to ensure they are free, and no water is collecting inside the aircraft and corrode skins from the inside.

Furthermore, ten out of the 36 passenger cabin windows started to take in water again. Five of those were removed, dismantled, re-sealed and reinstalled. The acrylic sealant used during the 2012/13 project did not prove to be durable enough for this application and was therefore replaced with neutral silicone sealant Soudal Silirub LMN. Retro space hoppers were taken out of retirement to protect window apertures again while the windows were resealed (Figure 4). The procedure for the use of space hoppers, when used first time, was successful and has not been changed, please see previous section “Emergency measures”. As described, a small amount of water ingress into the passenger cabin was acceptable in 2012/13 because most of the cabin interior had been removed. Within the last two years, windows were only removed when the weather forecast did not predict any rain as the cabin interior remained in situ. Covering the openings was still essential to prevent birds, dust and direct sunlight entering the cabin, especially because of textile covered seats and carpets beneath the windows.

Figure 4. Retro Space Hoppers in window apertures.

Figure 5. Failed bitumen based flashing tape from the 1990s.

Tape, which had been applied during the 1990s over gaps and openings on the wings, started to fail in many areas, partially by peeling off and partially by developing holes (Figure 5). The tape on the right-hand wing was replaced in most areas with new 3M Aluminium Foil Adhesive Tape 425. Tre Emme SPA Geko bitumen based flashing tape was applied where larger areas needed to be covered (Figure 6).

Figure 6. New bitumen based flashing and aluminium foil adhesive tape covering openings and gaps on top of the right wing.

The wings of the Comet are more than two metres above ground. To safely access and work on the wing, a work platform and "Airdeck" inflatable fall arrest bags come into use. For safety, work on the wings can only be carried out in dry weather and with winds below 18 miles per hour (29 km/h).

A different programme of work was carried out in unfavourable weather conditions. Due to the previous leaks in the cockpit, mould had developed on the leather seats and corrosion had built up on light alloy components, with the lower rails of the opening windows being particularly affected. The mould was removed with a soft brush, Numatic HZQ370 HEPA filter vacuum and 10 % isopropanol in deionised water, applied with damp cloths, and with a toothbrush in seams and other crevices. A low concentration of isopropanol has proved effective during previous other projects in similar circumstances and reduced the accumulation of harmful fumes. The limited space in the cockpit did not allow the use of an extraction unit in the required location and the windows could not be opened for ventilation, but a Sundström half mask with SR 217 A1 gas filter was donned for additional safety. Corrosion was reduced with steel wire wool, lubricated with Kremer Pigments 70400 special boiling point spirit 100-140 °C and a Dremel rotary tool with brass and steel wire brush attachments. Since the treatments in the cockpit have been completed, a dehumidifier has been placed inside to reduce the possibility of mould and corrosion reappearing. Inside the passenger cabin, many rubber bungees at the top and bottom of each seat pocket had severed. These were replaced with new ones as the original ones could not be restored.

Paint samples were taken from the exterior of the Comet. There is no question that the aircraft will get fully repainted in the livery it is in, if a full restoration will get carried out, as this was the paint scheme it was in when it left active service. But from the results of the analysis and the condition of the paint and metal substrate it will depend on whether the existing layers of paint will be preserved or removed during the restoration.

In 2013, most of dH Comet C2 XK699, a Gateguard at the Royal Air Force base at Lyneham, had to be scrapped due to high levels of corrosion [9]. To determine whether the work that is being carried out on "our" Comet is worthwhile, more inaccessible areas of the aircraft were inspected. Hatches were opened which provide access to the main spars of the wings to ensure their structural integrity. The front main spars did not show any signs of corrosion (Figure 7). At a later stage, lining in the luggage holds was removed to inspect the structural integrity of the lower fuselage. Only a small amount of surface corrosion was found.

Figure 7. View of the right front main spar.

Areas of corrosion on the main undercarriage legs were treated by reducing the corrosion with brass wire brushes, 3M Flap Discs 769F, a coat of LAS-656 barium chromate primer and one coat of Akzonobel Aerospace Eclipse Topcoat, a two-pack polyurethane paint. Brass wire brushes reduce the risk of galvanic corrosion, as the elements copper and zinc are already existing in aluminium alloys. For the same reason 3M 769F discs were chosen, with a grain made of aluminium oxide and ceramic [10]. The use of barium chromate is essential because of its inhibitive characteristics.

Barium chromate is highly toxic and carcinogenic. During application and drying, half masks with gas filters were worn. During the removal of corrosion, Sundström half masks with SR 510 P3 particle filters were used. Dust and debris were removed with a Numatic HZQ370 HEPA filter vacuum because the undercarriage has been previously painted with a zinc chromate etch primer. Waste material is being collected and disposed of by the waste management company Veolia UK.

In 2018, the right main undercarriage bogie of the Comet collapsed. Presumably, a seal had failed. Therefore, a full set of spare undercarriages was acquired in 2021 to enable the aircraft to be moved into a new hangar one day. One of our volunteers, an active aircraft engineer, reinflated the leg with nitrogen, levelling the aircraft once more. The seal had not failed but only slowly released the nitrogen over the years. A replacement of the complete legs might not be necessary anymore, should the aircraft be moved in the future. Our volunteer determined the condition of the charging point on the aircraft and is experienced and trained in the use of nitrogen bottles and regulators. For safety, this work was carried out while the museum was closed to the public.

Plastic facia panels on the passenger seat's arm rests have degraded over time and broke, also due to visitors constantly brushing against them when walking through the narrow aisle of the aircraft. One of our other volunteers, a retired boat builder, is currently producing replica panels out of fibre glass. The original panels will be placed in storage without risk of further damage.

Planned future measures

This year, in 2023, it is planned to treat corrosion on the nose undercarriage in the same way as the main undercarriages. All tyres of the aircraft will receive a coating of Autotek AT00TWB250 black tyre wall paint for UV protection.

The remaining five passenger cabin windows, which started to take in water again, will be removed and resealed.

The left wing will have new bitumen based flashing tape and aluminium foil adhesive tape applied. When this task will be finished the tape on both wings will be coated with Upol Acid #8 Etch Primer and two coats of two-pack polyurethane paint to protect it from corroding and to reduce the possibility of peeling in high winds.

On top of the wings are reinforcing panels made of magnesium alloy. Those panels suffer from severe exfoliation corrosion (Figure 8). The corroded layers will be mechanically removed. The remaining panel will be inhibited with barium chromate primer and painted.

The over-wing emergency exit hatches started to corrode again (Figure 9). The corrosion will be ground out with a rotary tool and the holes filled with aluminium epoxy putty. In 2012/13 there was only grey aviation grade paint available. This time, the hatches will be repainted with Akzonobel Aerospace Eclipse Topcoat in their correct red and black colours.

From 2025 onwards, a rolling programme of routine checks and corrosion treatments will be implemented. Failing measures can be renewed or improved.

Whether the aircraft remain outside or move into a new hangar one day, a full exterior restoration is envisaged by National Museums Scotland at some point in the future.

Figure 8. Severe exfoliation corrosion on magnesium alloy panel.

Figure 9. Recurrent corrosion on emergency exit window.

Conclusion

The inspection of vital, structural components and areas proved that the resources spent on the aircraft are justified because the general condition of the Comet is not as poor as the corrosion of some external areas might suggest. BAC 1-11 G-AVMO (Figure 10a) and Avro Vulcan XM597 (Figure 10b), the other two aircraft on display outdoors at the National Museum of Flight, will undergo similar inspections before any treatment will be carried out.

Figure 10. Aircrafts on display outdoors at the National Museum of Flight: *a)* BAC 1-11 G-AVMO and *b)* Avro Vulcan XM597.

Replacing the tape on top of the wings is very effective to prevent water entering internal structures. In heavy rain, the undercarriage bay of the right-hand wing remains dry. The undercarriage bay in the left-hand wing, which currently awaits the replacement of its tape, still suffers from water ingress. This measure might also prevent water from entering the aileron servodyne and hydraulic equipment bay (section "Emergency measures").

Windows, which have been resealed during 2021/22, are still watertight. They will be closely monitored to ensure that the recently used sealants are more durable than the acrylic sealant from 2012/13.

Especially the leaking windows and recurrent corrosion on the emergency exits show clearly that outdoor aircraft are a constant, ongoing project which requires planning and resourcing on an annual basis.

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