SURFACE ACTIVATION OF CONCORDE BY ^{7}Be

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SUMMARY

Activation analysis of two airframe components from Concorde aircraft has identified the presence of ^{7}Be, a nuclide found by other investigators to have been deposited on the forward edge of the LDEF structure. The results of the Concorde analysis indicate that this phenomenon is very much a surface effect, and that the areal densities of the ^{7}Be are comparable to those found for LDEF. The collection of ^{7}Be by the aircraft must be greater than in the case of LDEF (since the duration for which Concorde is accumulating the nuclide is shorter) and is of the order of 1.2 to 41 nuclei-cm^{-2}s^{-1}, depending upon assumptions made regarding the altitude at which collection becomes appreciable, and the efficiency of the process which removes the radionuclide.

INTRODUCTION

Post-flight measurements of the Long Duration Exposure Facility (LDEF) have identified the presence of radioactive contamination by the beryllium isotope ^{7}Be (refs. 1-3). For the LDEF spacecraft the areal densities of the radionuclide were found to vary between 0.9×10^5 and 6.7×10^5 nuclei/cm^2, depending upon the material which had been contaminated. The source of this contaminant is believed to be cosmogenic, *ie* the spallation products of the interactions of primary and secondary cosmic rays with atmospheric nitrogen and oxygen. These spalled nuclei are then 'swept-up' by the spacecraft as it passes through the tenuous atmosphere at orbital altitudes. In support of this theory is the fact that the contamination is superficial, and only observed on the leading edges of the spacecraft.

RAE Farnborough initiated a similar activation analysis as a direct result of the LDEF findings, this time searching for ^{7}Be contamination in airframe components of Concorde aircraft. The normal cruising altitude for these aircraft (between 50,000 feet and 60,000 feet, or approximately 15 km and 18 km) is significantly higher than those of other commercial aircraft, and lies just below the Pfotzer maximum (at 18 km), where the cosmic-ray secondary particle flux peaks (ref. 4). At Concorde altitudes therefore the production rate for ^{7}Be is expected to be at or near its maximum (ref. 5).

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The study of ^7Be deposition on high-altitude aircraft is not of isolated interest and has relevance to the LDEF analysis, since, as suggested by Parnell (ref. 6), aircraft studies may also provide a method of investigating proposed solar flare enhancements of this cosmogenic nuclide.

ACTIVATION ANALYSIS OF CONCORDE SAMPLES

Two samples of Concorde airframe were provided by British Airways for analysis, both of which had been exposed to the external airflow during flight:

(1) Strip of engine cowling, approximately 0.2cm x 1cm x 10cm.

(2) Access door from the upper port-wing of G-BOAB, approximately elliptical in shape, 61.2cm x 31.2cm. When affixed to the aircraft, the door is located above the port engine towards the centre of the wing (fig. 1).

γ-ray analysis of these samples using a high-resolution germanium detector has identified the presence of ^7Be in both cases. For the access door, the 477.5 keV γ-ray peak was found to decay with a half-life of 52±2 days, which agrees well with the half-life which is expected for ^7Be (53.29 days). The analysis also showed no other radionuclides in quantities exceeding nominal background levels.

After analyzing the decay of the radionuclide in the access door over the period of 1.5 months, the door was swabbed with a solution of mild detergent and water. This swabbing process was found to remove 47±4% of the ^7Be contaminant, transferring it to the swabs. A control sample of swabs (containing an identical detergent/water solution) did not identify any sources of 477.5 keV γ-rays. This indicates that the contaminant was from the door and, as with the LDEF analysis, is very much a surface effect. The high efficiency with which the contaminant was removed is believed to be because of an oil/grease layer on the door which collected a significant amount of the ^7Be during flight.

Based upon the γ-ray count rate observed, and estimates of γ-detection efficiency (refs. 7 and 8), it is estimated that the ^7Be activity from the door before it was removed was 219±22 decays/s, which equates to an areal density of $(9.6\pm0.9)\times10^5$ nuclei/cm^2 †. This density is of the same order as those found in the LDEF analysis (ref. 1) of the polished aluminium plate in Experiment A0114 ($(6.7\pm1.0)\times10^5$ nuclei/cm^2) and an anodized aluminium experiment tray clamp ($(4.6\pm0.5)\times10^5$ nuclei/cm^2).

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†It should be noted that these levels of radioactivity are extremely low; this areal density equates to an activity from the access door surface of 3.9 pCi/cm^2, which is less than the background activity in ordinary window glass alone (4.2 pCi/cm^2).

^{7}Be ACCRETION RATE

Estimation of the accretion rate of the radionuclide is largely dependent upon the assumptions made regarding the altitude at which ^{7}Be collection becomes significant, and the efficiency with which the nuclide is removed when the aircraft is washed, approximately every month, using high-speed water-jets. The accretion rates (in nuclei-cm^{-2}s^{-1}) shown in Table 1 have been estimated based upon the best and worst case situations for collection and removal efficiencies. These values were calculated using specific information about the times and durations of the flights (from take-off and above 50,000 feet) before the door was removed, and the date the aircraft was last washed prior to analysis. Naturally the largest value for the ^{7}Be collection rate (41 nuclei-cm^{-2}s^{-1}) relates to when the nuclide has the least opportunity to accumulate on the surface; *i.e.* collection is only finite (and constant) above 50,000 feet, and the cleaning process is 100% efficient. Conversely, if both these factors are in favour of prolonged accumulation (deposition of ^{7}Be begins just after take-off, and washing removes none of the contaminant) the value becomes 1.2 nuclei-cm^{-2}s^{-1}. It should be noted that the assumption that the airframe begins to accumulate an appreciable amount of ^{7}Be immediately after take-off is clearly unrealistic (ref. 5), and this value is only given to indicate that changing the altitude at which collection starts is not as important to the accretion rate as the effects of surface-cleaning.

DISCUSSION

In Table 1, for two of the cases the percentage efficiency of the collection mechanism is given in parentheses. To calculate these values it was assumed that the ^{7}Be concentration above 50,000 feet was ~0.1 nuclei/cm^{3} (ref. 1). It can be seen that in both instances the efficiency is significantly less than 100%. Therefore, unlike in the case of LDEF, there appears to be a sufficient concentration of the radionuclide at Concorde altitude to explain the high accretion rate, although this is dependent upon the exact mechanism by which the ^{7}Be attaches itself to the aircraft, a process which is as yet to be explained.

Any mechanisms which are hypothesized to explain ^{7}Be accretion on high-altitude aircraft must be capable of explaining the collection of the radionuclide on surfaces which are almost tangential to the velocity vector of the aircraft (and hence to the mean airflow), since the access door from Concorde was located towards the centre of the wing and not on a leading edge. Indeed any future experiments which investigate this process should be aimed at determining the collection rate as a function of the air velocity local to the sample, and the ^{7}Be depth profile in the sample, as well as the atmospheric density of the nuclide. Such experiments could involve, for example:

(1) Placing foil patches on various locations of the aircraft surface which may be frequently replaced (so that they do not build up deposits of oil or get washed), and which may then be electrochemically etched to obtain the depth profile.

(2) Flying an active γ-ray detector in the cabin area (such as the Shuttle Activation Monitor (refs. 9 and 10), or a germanium detector) to measure the ^{7}Be density in the atmosphere -

although careful consideration will obviously have to be given to the high γ-ray background expected from being near the Pfotzer maximum.

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TABLE 1

^{7}Be accretion rate (nuclei-cm^{-2}s^{-1}) and accretion efficiency, in parentheses

Efficiency with which nuclide is removed during cleaning:	Altitude at which collection starts:	
	>50,000 feet	Immediately after take-off
All contaminant removed	41±4 (~0.7%)	26±0.3
No contaminant removed	1.9±0.2 (~0.03%)	1.2±0.1

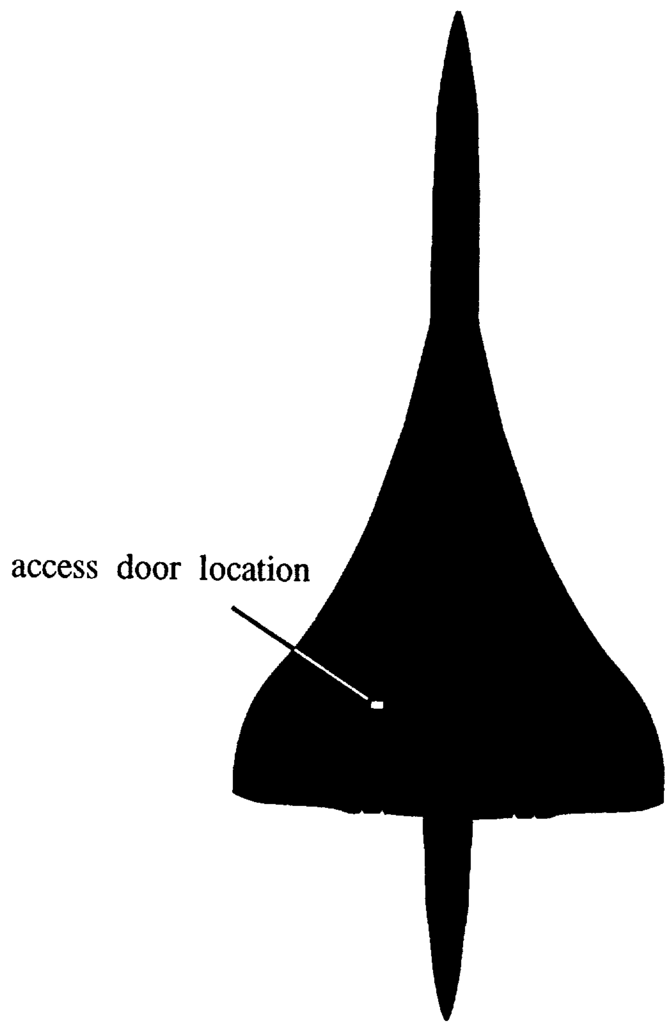

FIGURE 1

Plan view (silhouette) of Concorde indicating location of access door used in activation analysis