

Approved and Suitable— A Model for the Future?

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Abstract

In the United Kingdom, the Control of Substances Hazardous to Health (COSHH) Regulations call for Respiratory Protective Equipment to be suitable for its intended use and approved (or conform to a standard approved) by the Health and Safety Executive (HSE). A number of standards have been approved by the HSE for gas and combined gas/particulate filters, these being EN141, prEN371, and prEN372. However, there are many applications where mixtures of toxic compounds exist such that the choice of a filter that conforms to one of the standards is not "Approved" for use against one or more of the other substances in the mixture. An HSE Type Approved filter for use against dichloromethane was shown to be suitable for use against a number of toxic materials. The methodology for demonstrating such suitability is presented.

Introduction

The Royal Air Force have identified two principal groups of personnel who need protection from airborne hazards at work. The first group are the painting and finishing tradesmen who are involved both with spraying paints and with applying paint stripping compounds. The second group are personnel operating inside hardened aircraft shelters (HASs). Aircraft exhaust is known to contain a number of toxic compounds. The original filter procured for use by the Royal Air Force was designated as a CC filter, as defined in

British Standard 2091. This filter was claimed to be effective against a whole range of organic compounds including: organic substances that boil above 60°C, acetaldehyde, acetone, acrolein, amyl acetate, benzene, ethylene oxide, formaldehyde, hydrogen fluoride, isocyanates, mercury and its compounds, phenol, phosgene, and the oxides of sulphur.

The Royal Air Force currently have two filters to meet the two major areas of protection. Firstly,

there is an A2-P3 filter (Protector Safety RC220) that gives approximately 75 minutes of cumulative use. This equates to about two weeks of operational use by a painter. This A2-P3 filter has, however, only been procured for trial purposes. Secondly, the Royal Air Force has purchased, but not yet issued, a supply of single-use AX-P3 filters for personnel working in HASs. Such personnel are liable to exposure to the toxic exhaust products of jet engines whilst they are working round aircraft that are taxiing out of the shelter to fly, or being winched back into the shelter at the end of a sortie. It was originally hoped that the Royal Air Force would be able to use the AX designated filter for protecting painters and finishers instead of the A2-P3. This would achieve the aim of obtaining a single type of filter for Royal Air Force use.

With the inception of the COSHH regulations in the United Kingdom, the European Standard EN141 was adopted for gas and combined filters. The CC filter did not meet the requirements of this standard and this is what led to the RAF changing the filters issued to personnel. For painters and finishers an A2-P3 designated filter was chosen as being suitable for removing the range of solvents and other hazardous compounds such as isocyanates commonly encountered in paint or paint strippers. The suitability of this filter was confirmed by a trial undertaken at Royal Air Force Kinloss in 1988/89 (Farmer et al., 1989). Although this trial showed that the A2-P3 filter was suitable for use in all painting and finishing tasks, including those tasks where dichloromethane paint stripper was used, the definition of an A2-P3 filter as being for use against organic compounds with a boiling point above 65°C, precluded its use against dichloromethane. Thus the Royal Air Force sought to purchase a filter designated AX-P3, which is defined in prEN371 as being for use against certain organic compounds with a boiling point less than 65°C as specified by the manufacturer. Such a filter can be used against dichloromethane. Elements of personal protective equipment used in the United Kingdom must be declared suitable for use by the Health and Safety Executive (HSE). Normally the HSE will issue a Type Approval for an item of equipment that meets the specifications laid down either in the British Standards or more recently in the European Standards. The HSE-approved AX filter, by definition is used for only one shift. For Royal Air Force purposes this means that the filter would probably only be used once for

about 10 minutes and then it would have to be discarded, which would be costly.

In collaboration with a number of companies, a painters and finishers respiratory protective assembly—which includes a supplied-air positive-pressure dual-port respirator—has been developed by the Royal Air Force. The intention of this system is to allow the painter to transit from the changing area to the workstation using negative-pressure breathing through an HSE-approved filter. Once at the workplace he connects to an air-fed positive-pressure breathing hose and blanks off his filter. Transit back to the changing room is the reverse of the transit to the workplace. This means that the painter is breathing possibly contaminated air through a filter for approximately 10 minutes per working shift.

A substance-specific filter is defined in prEN372. In essence, this standard defined the challenge test to allow a filter to be designated for use more than once against a specific contaminant. Currently the SX-P3 filter has HSE approval (CA/35/91) for use against dichloromethane. Challenging an approved filter against other compounds, using an approved challenge regime, could allow an SX filter to become Type Approved for use against more than one compound. Since the SX-P3 filter has a deeper charcoal bed than the A2-P3 filter, and the Kinloss trial showed that the A2-P3 met all the Royal Air Force painters' and finishers' needs, logic dictated that the newer SX-P3 will also satisfy these needs. It is suggested that the SX-P3 filter would prove a suitable replacement for the previously trialed A2-P3 as a multi-use filter for painters and finishers.

However, the SX-P3 filter is unlikely to ever meet the requirements of the SX designation for formaldehyde, the most important HAS contaminant, simply due to the difficulties in generating a 5000 ppm challenge concentration required by the standard.

It was decided that, if a suitability trial could prove that the SX-P3 filter worked in a HAS environment and maintained safety for the wearer with a reasonable filter life, then this SX filter would be suitable for all the Royal Air Force's main respiratory protective equipment filtration requirements.

Experimental

There were two phases to the trial: an initial stage measuring the contaminant levels during typical HAS operations; and a second stage to test a filter against levels of formaldehyde well in excess of those normally expected in an operational HAS.

Previous research into levels of contamination had been conducted with Tornado aircraft under usual operating conditions (Farmer, 1988). In Phase 1 of this trial, the conditions were such that higher than normal winds were encountered blowing towards the efflux vent; it was believed that this may contribute to the worst case pattern that was being sought.

Formaldehyde was chosen as the test substance in the second stage as its possible carcinogenicity makes it potentially the most dangerous of the HAS contaminants. Polycyclic aromatic hydrocarbons (PAH) are known to be present in jet efflux; however, PAHs can be considered to be standard organics and are filtered by the SX-P3. As a low-boiling-point organic, formaldehyde may be less easily adsorbed, a second reason for its use in the second stage of this trial.

Stage One

Monitoring was undertaken within a HAS during two normal operations: a startup/taxi-out manoeuvre, and a winch-back with engine run-

ning. Another operating procedure may require prolonged engine runs within the HAS, so levels were monitored whilst the Tornado kept its engines running over a period of some 20 minutes. Atmospheric monitoring for formaldehyde, sulphur dioxide, carbon monoxide, nitrogen monoxide, and nitrogen dioxide was undertaken with a series of Sabre InterScan instruments. The InterScan meters were fitted with fresh batteries; they had all been calibrated by the manufacturer at annual service immediately prior to this trial. Additionally, the formaldehyde level in the HAS exhaust tunnel was measured to simulate a worst-case exposure, and measurements of formaldehyde levels were taken from within a specially modified respirator.

The wearer of the modified respirator shadowed the movements and actions of the aircraft ground-handling party to ensure that representative exposures were measured. Similarly, the static instruments were mounted on a medical trolley which allowed them to be positioned close to the ground handling crewman and moved with him to allow representative samples of atmospheric levels close to the worker. The instruments readings were recorded at 60 second intervals throughout the trial. A diagram of the HAS showing the monitoring positions is shown in Figure 1.

Prior to the aircraft run, the fit of the modified respirator was checked for comfort, and for a satisfactory seal by using a TSI Portacount Fit

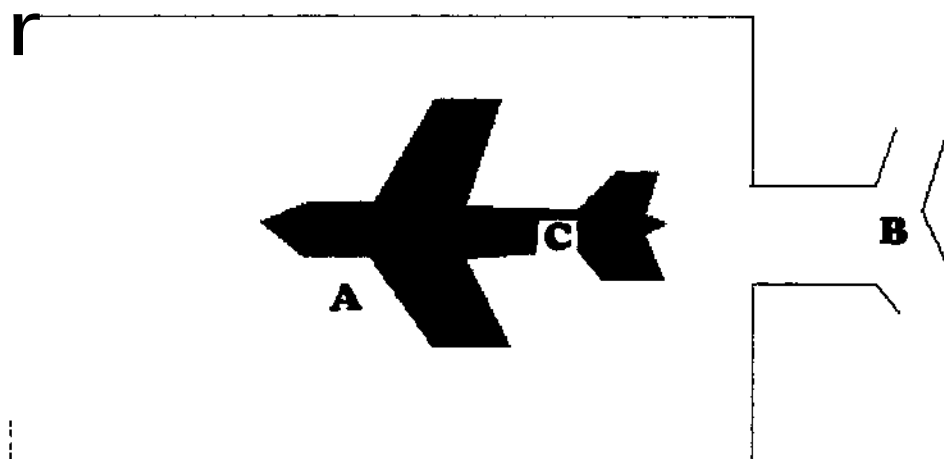


Figure 1. A diagrammatic representation of a hardened aircraft shelter (not to scale). (A) = position of test subject for startup; (B) = position of wearer of filter TF for maximum jet exhaust exposure; (C) = position under aircraft during sustained engine run.

Test instrument. The modified respirator used had been Type Approved by the HSE for use in this trial (CA/156/89 Supplement No. 1). Figure 2 shows the modified respirator worn by the test subject. During the trial three other team members wore respirators fitted with trial canisters. At the conclusion of the aircraft-handling task, the filters were immediately removed from the masks, sealed with blanking plates, and returned to the Protector Safety Laboratory for residual life testing. Residual life testing was carried out using previously validated gas testing procedures (Littleton and Feeney, 1991).



Figure 2. Photograph showing the test subject wearing his modified respirator, before the InterScan monitor was connected.

Stage Two

In order to further test the ability of the SX-P3 filter to remove formaldehyde, an enclosure was constructed to allow a controlled exposure of the filter during simulated conditions. The enclosure was constructed (Figure 3) to allow an atmosphere to be generated and controlled within which the wearer of the modified respirator was exposed to formaldehyde levels up to 20 ppm for a total of 40 minutes. Throughout the experiment the test subject undertook random upper torso, head, and arm movements as well as engaging in conversation in an attempt to simulate the type of exposure a ground handler may have experienced had the HAS exposure been at these levels. Continuous formaldehyde monitoring both "in-mask" and of the enclosure atmosphere close to the filter intake was performed using two Sabre InterScan formaldehyde meters.



Figure 3. Photograph showing the test subject inside the controlled exposure enclosure.

Results

The Tornado F3 aircraft performed a dual-engine start-up and taxi-out followed by a single engine hot winch-back. Finally the aircraft continued to maintain a single engine running for a further 20 minutes. The environmental conditions at the time of the trial were: wind 260° at 24 knots gusting to 35 knots, temperature 9°C, RH 52%, and barometric pressure 995.2 mB.

Carbon monoxide levels reached a maximum of 30 ppm, and this was a single reading as the aircraft exhaust passed the monitoring point. Formaldehyde, sulphur dioxide, and nitrogen monoxide reached peak levels of 0.6, 0.6, and 0.4 ppm, respectively, at the same time. Nitrogen dioxide was not detected at any time. The results are shown in Table 1, and represented graphically in Figure 4. For comparison purposes, the appropriate results from the previous survey are reproduced in Table 2, whilst at Table 3 the peak readings from this trial are shown.

Within the test respirator no formaldehyde was detected until the trial was well advanced. At this stage, the wearer was moving round beneath

the aircraft, so facesal leakages were quite possible. A level of 0.04 ppm was indicated. The highest indicated value, 0.06 ppm, occurred when the test subject was standing in the jet efflux during the winchback manoeuvre, and this was highly likely to have moved the mask on the face and compromised the seal.

During Phase 2 of the trial, the formaldehyde level in the test area exceeded 15 ppm after seven minutes, and then remained between 15 and 20 ppm until the experiment's conclusion. Within the respirator, levels were consistently noted between 0.01 and 0.02 ppm; these were regarded as zero values. The results are tabulated at Table 4 and shown graphically in Figure 5.

Residual life testing showed that two new filters—controls—had a life of 92 and 94 minutes, respectively, against an acetone challenge of 5000 ppm. The HAS-exposed filters had residual lives ranging from 82 to 88 minutes. The filter exposed to the experimentally high concentration in Phase 2 of the trial had a residual life of 84 minutes. Residual life values are shown in Table 5.

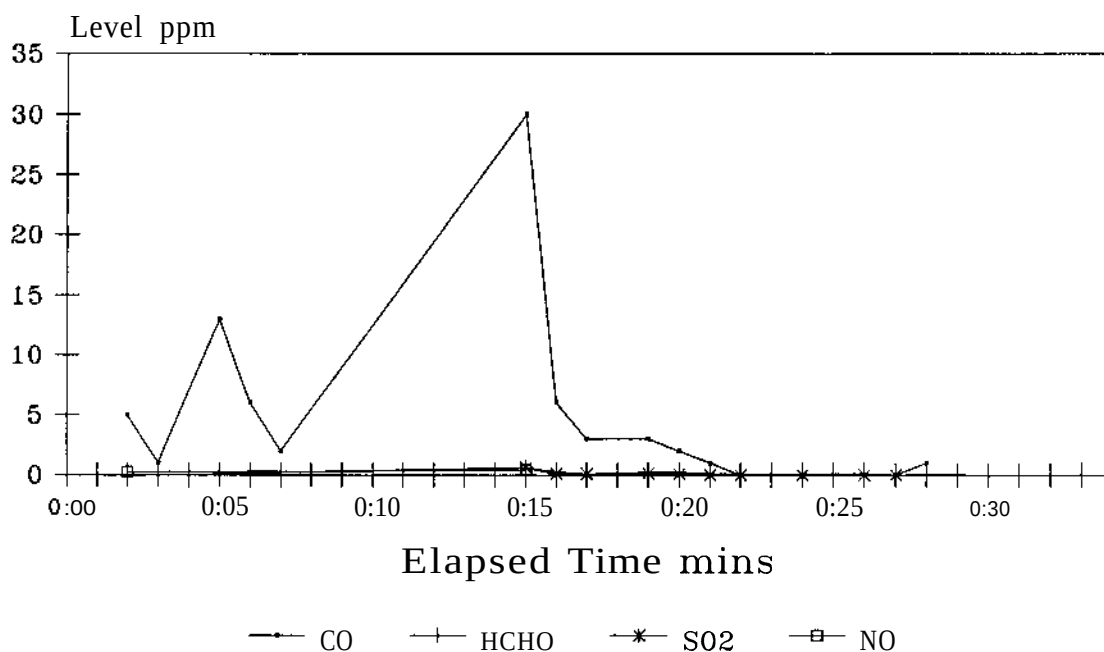


Figure 4. A graph showing the levels of pollutants measured in the hardened aircraft shelter throughout the trial.

Elapsed Time mins	CO ppm	HCHO ppm	In mask HCHO ppm	SO ₂ ppm	NO ppm	Comment
0 1 2 3 4 5	5 1 13	0.1	0	0	0.2 0	Start-up and Taxi -out
6 7 8 9 10	6 2 - -	- -	0.04 0.02 0.06			Outside HAS under ac wing In jet blast fitting winch
11						
15	30	0.6	0	0.6	0.4	Inside HAS as exhaust passed the monitor
16 17 19 20 21 22 23 24 26 27 28 29	6 3 3 2 1 0 0 0 0 0 1 0	0.25 0.1 0.2 0.2 0.1 0.1 0 0.1 0 0 0.1	0 0 0.02 0 0.02 0.02 0.06 0.02 0.01	0.1 0.1 0.1 0.05		Engine Run In work position A Move to Position C
30 31 32 33 34			0.01 0.02 0.04 0.04 0.02			Only levels inside mask were measured for this period - aircraft stopped.

Table 1. Contaminant levels measured inside HAS during SX canister trial.

Manoeuvre	HCHO ppm	CO ppm	SO ₂ ppm	NO ppm
Start	1.2	5	0.4	0.3
Wtfinch	0.3	0	0.2	0.2
Sust Run	0	2.0	0.2	0.2

Table 2. Peak contaminant levels from Tornado aircraft, as shown in 1988 trial (ICOM/22/88).

Manoeuvre	HCHO ppm	CO ppm	SO ₂ ppm	NO ppm
Start	0.1	13	0	0.2
Wtfinch	0.6	30	0	0
Sust Run	0.25	6.0	0.6	0.4

Table 3. Peak contaminant levels from Tornado aircraft, as shown in 1991 survey.

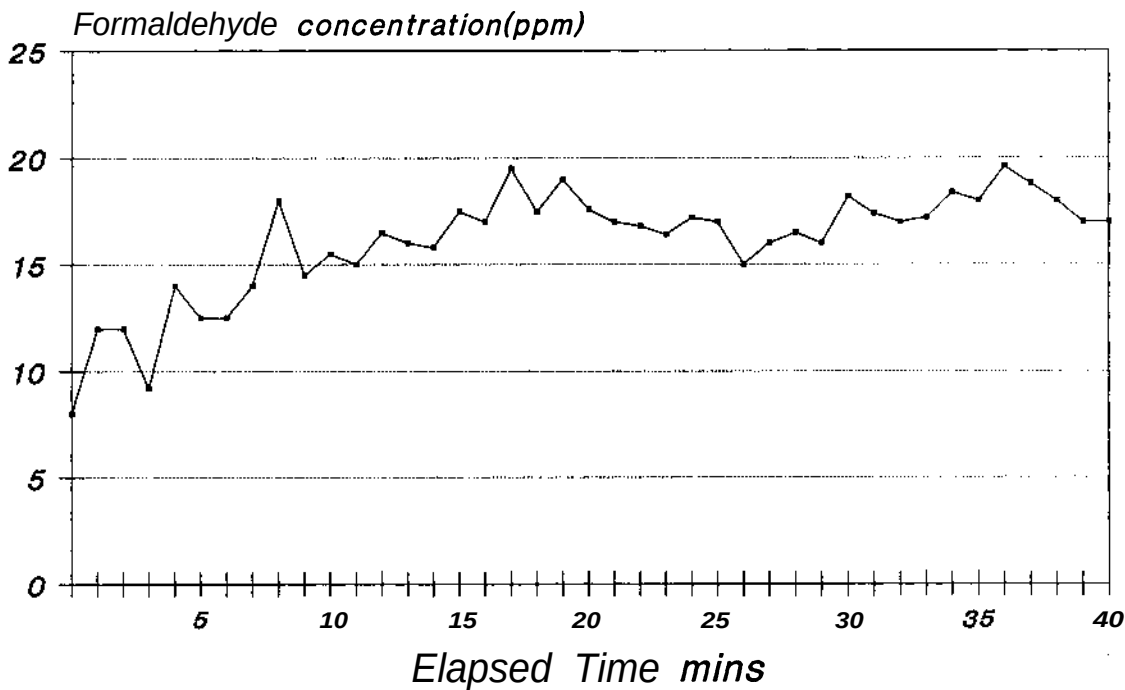


Figure 5. A graph showing the levels of formaldehyde in the experimental enclosure during Phase 2 of the trial.

Discussion

The peak values of carbon monoxide and formaldehyde contamination measured in the HAS were greater in this survey than those recorded in 1988, whilst the levels measured at the HAS entrance were lower. This supports the contention that the higher wind speed blowing into the HAS exhaust port reduced the clearance time for these contaminants from within the HAS. The exposures to ground personnel within the HAS were therefore higher than occurred in the 1988 survey. Conversely, outside the HAS the wind speed dispersed the contaminants much faster.

Contaminant levels within the HAS would be expected to fall once the aircraft was positioned against the chocks directing the exhaust along the efflux tunnel. The aircraft exhaust then acts like a venturi drawing a high air flow through the HAS to disperse the contaminants rapidly. The results in both this survey and the 1988 survey showed the sustained engine-run contamination levels to be lower than the **start-up/taxi-out** and **winch-back** levels. During the taxi-out the aircraft's exhaust moves away from the tunnel, and on the turn directs the exhaust towards the HAS side wall, so this probably accounts for the higher levels of contamination within the HAS for the taxi-out. Similarly, during the winch-back the exhaust enters the HAS some distance from the efflux tunnel until the aircraft comes close to its parked position. The higher peak levels recorded in this survey than in 1988 (Table 3) support the case for the external wind speed and direction sustaining the contamination within the HAS.

Both during operational use in a HAS and in the artificially generated high formaldehyde environment, the SX-P3 filter protected the wearer against formaldehyde exposure. The small intra-mask levels recorded occurred at times when the test subject was climbing beneath the aircraft or when exposed to the force of the jet exhaust. In the first case excessive and unusual movement may

Elapsed time mins	Level ppm
0	8
1	12
2	12
3	9.2
4	14
5	12.5
6	12.5
7	14
8	18
9	14.5
10	15.5
11	15
12	16.5
13	16
14	15.8
15	17.5
16	17
17	19.5
18	17.5
19	19
20	17.6
21	17
22	16.8
23	16.4
24	17.2
25	17
26	15
27	16
28	16.5
29	16
30	18.2
31	17.4
32	17
33	17.2
34	18.4
35	18
36	19.6
37	18.8
38	18
39	17
40	17

Table 4. Formaldehyde levels measured inside enclosure during Phase 2 of the SX canister trial.

Filter	Residual Life mins
New Filter Control 1	94
New Filter Control 2	92
Test Subjects Filter	82
Exposed Filter JL	82
Exposed Filter TF (in efflux tunnel)	88
Phase 2 Filter	84

Table 5. Residual life of RC240 filters as tested against a 5000 ppm acetone challenge.

have breached the respirator seal, whilst in the second case the force of the exhaust stream alone may have lifted the mask from the face. In either case the level of recorded contamination inside the mask was very small; the mask obviously provided an excellent level of protection. In reading the Sabre InterScan Formaldehyde meter, values below 0.02 ppm were regarded as zero, for it was considered that changing the angle of view of the scale may have been sufficient to introduce an error. As the same operator monitored the instrument throughout the trial deflections over 0.02 ppm (accepted as representing some detected contaminant)—such a needle movement was thought to have been detectable without error, although the actual value may not have been accurately measured.

Water vapour on the charcoal of the filter may enable the filter to adsorb more water-soluble contaminants—such as formaldehyde—than could be adsorbed by a dry canister. This could explain why the residual life of the filter deliberately exposed to jet efflux was longer than the life of the filter normally exposed to HAS contaminants. In all test filters about 10% of the filter life had been used. Given that there are a variable number of aircraft operations on any working day, but assuming a number of constants from the normal operating practices of the Tornado F3 squadrons, and incorporating a safety factor, the in-use life of an SX-P3 filter in the HAS environment may be taken as 20 working days.

Conclusions

During normal operations the level of HAS contaminants from a Tornado F3 aircraft does not exceed the Maximum Exposure Limit (MEL).

The SX-P3 filter tested is suitable for use against HAS contaminants

In order to comply with the Health and Safety at Work Act and/or COSHH, an employer has a

duty to reduce the exposures of his workers to substances Hazardous to Health to the lowest level reasonably practicable. Use of a full-face respirator and filter canister provides a means of lowering the workplace exposures of aircraft ground handling crews to very low levels.

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References

- British Standards Institute, *Specification for Respirators for Protection Against Harmful Dusts and Scheduled Agricultural Chemicals*, BSI2091, 1969.
- European Standard, *Respiratory Protective Devices: Gas Filters and Combined Filters; Requirements, Testing, Marking*, EN141, 1990.
- Farmer, T.P., *An Investigation of Contamination Levels in Hardened Aircraft Shelters*, ICOM/22/88, 1988.
- Farmer, T.P., Kelly, P.N., and Sharpies, C.J., *A Report on the COSHH Assessment of Phenol Paint Stripper at RAF Kinloss 7-11 December 1989*, ICOM/77/89, 1989.
- Littleton, C.J. and Feeney, J.R., "The Effect of Challenge Concentration on the Gas Life of Respirator Filters," *JISRP*, (9)4, p 6.
- Provisional European Standard, *Respiratory Protective Devices: AX Gas Filters and Combined Filters Against Low-Boiling Organic Compounds; Requirements, Testing, Marking*, prEN371, 1991.
- Provisional European Standard, *Respiratory Protective Devices: SX Gas Filters and Combined Filters Against Specific Named Compounds; Requirements, Testing, Marking*, prEN372, 1991.