1. Effectivity

Aircraft fitted with B/E Aerospace 119003-11 Protective Breathing Equipment (PBE) also known as smoke hoods.

2. Purpose

This AWB highlights recent self-ignition problems with a type of PBE. PBE are required under section 20.4 of the Civil Aviation Orders.

3. Principle of operation

During the donning sequence, the chlorate candle is actuated when the adjustment straps are pulled to secure the orinasal mask cone against the face. The chemical reaction of the candle is:

$$2NaClO_3 \rightarrow NaCl + 3O_2$$

The reaction does not take place until the temperature is above 250°C; therefore iron powder is added to the mix to provide the heat for the reaction to proceed. The small chlorate candle (starter candle) produces about 8 litres of oxygen by the chemical decomposition of sodium chlorate.

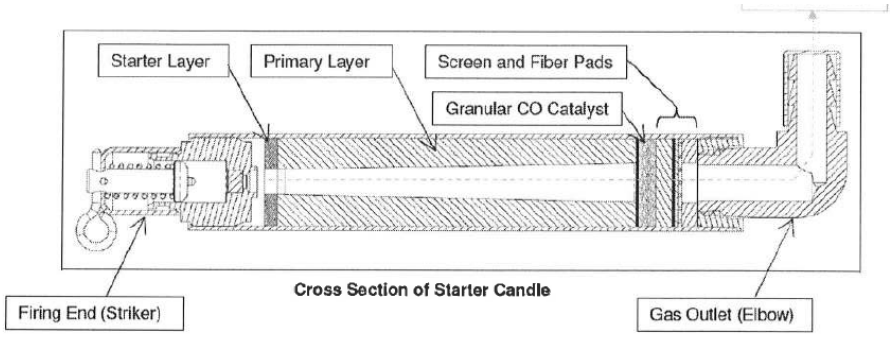

Figure 1 - Starter candle

This candle is mounted to the bottom of the KO_2 canister see Figure 1.

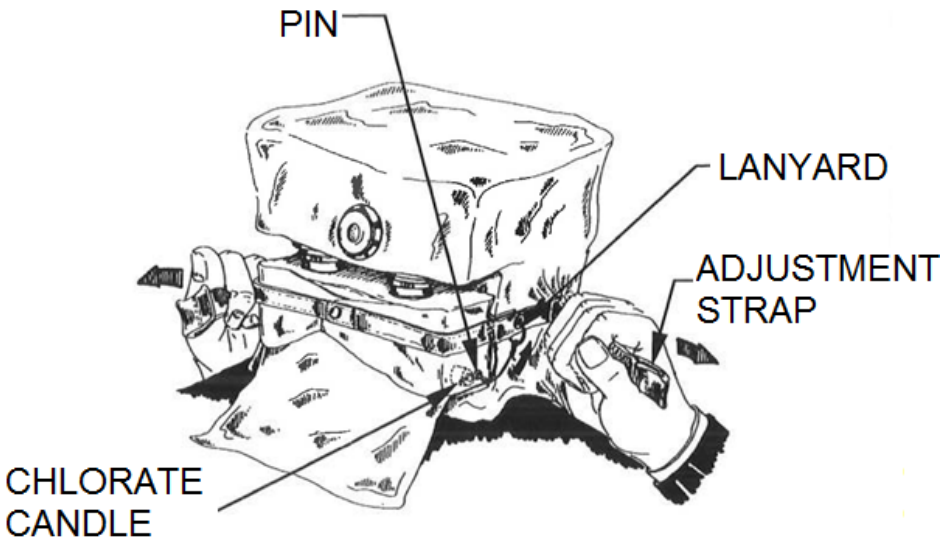

Figure 2 - Starting the candle

The outlet of the starter candle discharges into the KO_2 canister on the side where exhaled breath enters the canister from the exhalation duct. Some of the oxygen from the starter candle provides an initial fill of the exhalation duct, while the bulk of this oxygen travels through the KO_2 canister and fills the main compartment of the PBE.

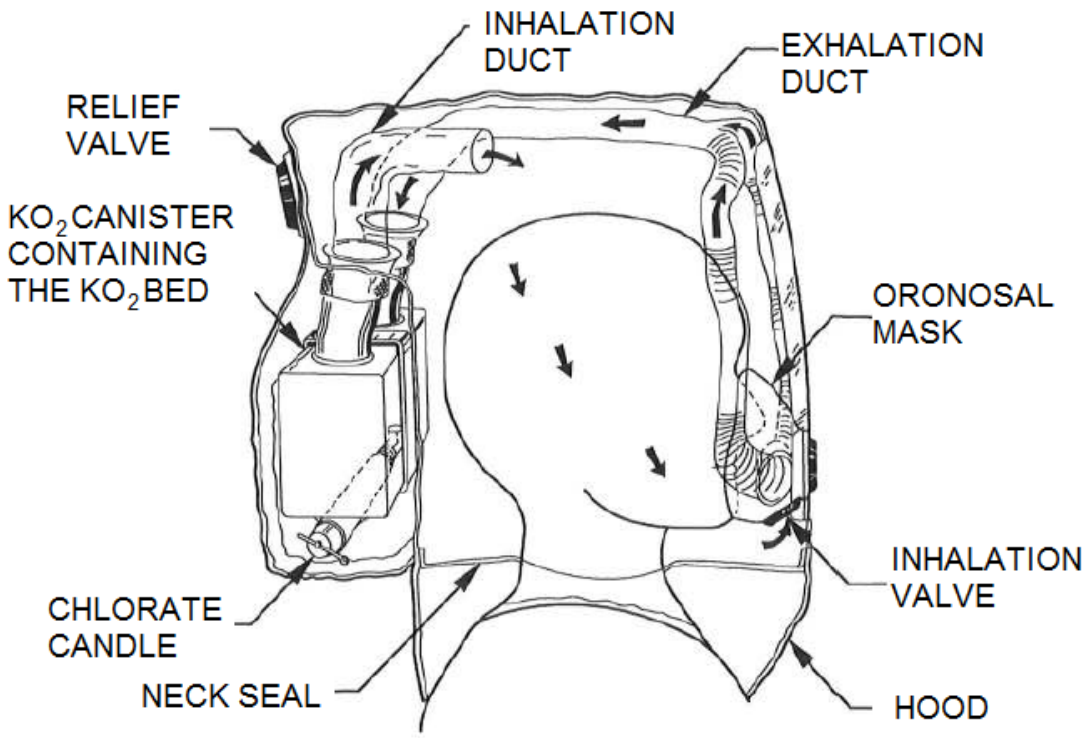

Figure 3 - Operation of PBE

A schematic view of an operating PBE is shown in Figure 3. During operation the user exhales into the oronasal mask. A pair of one-way valves connects the oronasal mask to two branches of the exhalation duct. The exhaled breath travels through the exhalation duct and enters the (potassium superoxide) canister. Here exhaled carbon dioxide and water vapour are absorbed and replacement oxygen is released. This chemical reaction is shown below:

Oxygen generation

$$4KO_2 + 2H_2O \rightarrow 2KOH + 3O_2$$

$$4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$$

Carbon dioxide removal

$$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$$

$$KOH + CO_2 \rightarrow KHCO_3$$

The regenerated breathing gas passes through the inhalation duct and enters the main compartment of the PBE. This interior hood volume serves as a breathing reservoir. When the user inhales, another one-way valve called the inhalation valve allows the regenerated gas to enter the oronasal mask and this travel to respiratory tract of the user. This breathing cycle will continue until the KO_2 canister is exhausted.

4. Reported incidents

a. Case 1

The PBE was removed from service as it had lost its vacuum seal (inflated). The unit was stored in a clean, ventilated store cupboard until several units were collected and discharged as a batch.

During the disposal process, the PBE was removed from the vacuum bag for disposal; it was actuated and then placed in a mesh cooling bin. A loud explosion was heard when the activation pin was released followed by fire from the outlet side of the canister. A fire emanated from the outlet side of the canister see Figure 4, burning the rubber duct and into the plastic tubing leading to the mask see Figure 5. The rubber duct and mask plastic tubing burnt before the fire self-extinguished after approximately 30 seconds. The unit was completely extinguished with water.

Figure 4 - Subsequent fire from outlet

Figure 5 - Burnt tubing

b. Case 2

While discharging a PBE oxygen generator, a pop was heard and smoke was noticed followed by flames coming from the unit located in the PBE discharge. Initial attempts to extinguish the flames with both CO_2 and chemical fire extinguishers were unsuccessful. Due to the amount of black smoke and the activation of the fire alarms, staff were evacuated the building and the emergency services attended. An employee was taken to hospital due to smoke inhalation.

The PBE and KO_2 canister were badly damaged. It is not possible to determine whether there was damage to the PBE or the canister or whether there was any contamination in the PBE before candle actuation. It is also difficult to determine where the ignition started. It appears that all necessary parts of the starter candle were present. Visual examination of the candle assembly revealed some unknown material deposit found inside the candle outlet elbow. The chemical deposit inside the elbow is seen below in Figure 6. It is unlikely that the contamination was inside the candle. An organic contamination inside the candle would have been consumed in pure oxygen and high temperature. It is also possible that it debris could have been carried into the through the hole by water.

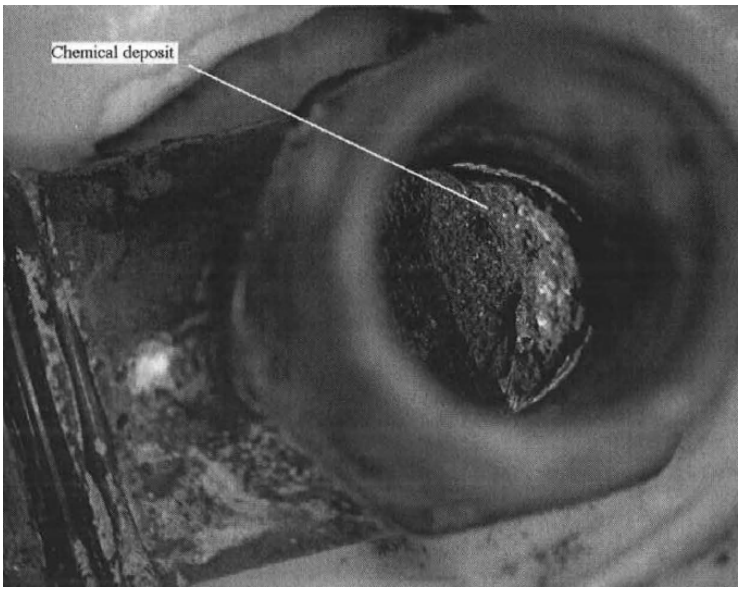

Figure 6 - Unknown material in elbow of candle

A hole was observed in the filter as seen in. The cross sectional area of the hole is about 2mm^2 see Figure 7.

Figure 7 - Hole through filter

The necessary parts in the candle are present and the CT scan shows the gas flow path through the granular CO catalyst bed. Typically, the oxygen produced during operation permeates through the granular catalyst bed and does not create any visible gas flow path through the catalyst bed.

The dark areas are void spaces and the denser areas are lighter colours see Figure 8. The large black void through the catalyst bed is by design. This position shows the orientation of the starter candle in the donned position, with the outlet of the elbow pointing upwards into the PBE.

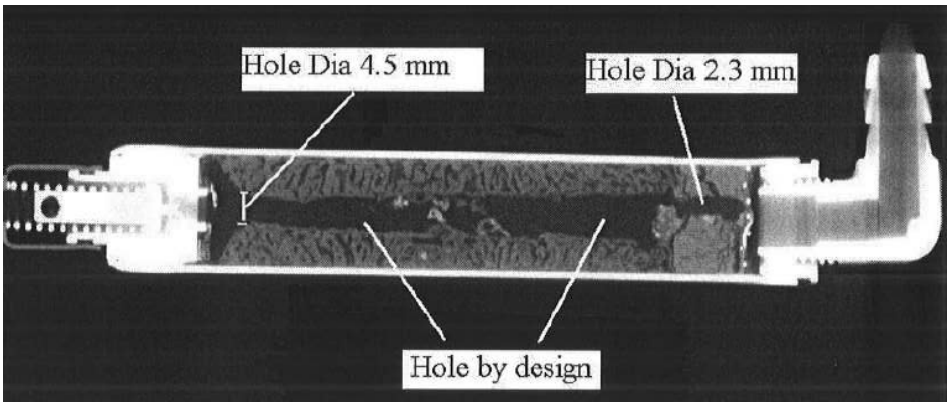

Figure 8 - Starter candle internal voids

The catalyst bed and the particulate filter on top of it help prevent reaction debris from entering the PBE. Once a hole is formed, particles can pass through the hole into the PBE and come into contact with the PBE materials.

c. Case 3

The PBE was removed due to a damaged vacuum seal. During discharge the PBE caught fire when it was put into the disposal container, the entire workshop was evacuated due to the fire extending to other disposed PBEs.

The candle had separated from the generator and blackened soot was observed around the pouch. B/E Aerospace has advised that ejection of the bushing is the pressure relief mechanism for the candle in the event of an over pressurisation situation. The most likely cause of this condition is a restriction that does not allow the oxygen produced to leave the candle as rapidly as it is being produced.

d. Case 4

PBE was removed from the aircraft for use as a training aid see Figure 10. The PBE was in date and considered serviceable. When the PBE was activated, the canister exploded Figure 9 and it caught fire, burning the scalp of the operator.

Figure 9 – Soot from exploded canister

Figure 10 - Burnt hood

Figure 11 - Smoke hood

e. Case 5

An incident occurred with a foreign operator where a cabin fire was reported. The cabin crew member donned the PBE and it caught fire violently.

The cabin crew member was able to take off the PBE and use a halon extinguisher. The incident resulted in a full aircraft evacuation. The General Civil Aviation Authority (GCAA) of the United Arab Emirates has issued an operational directive 09-2014 which required the withdrawal from service of PBE part number 119003-11 serial numbers 003-34983M to 003-35563M. All 119003-11 units require inspection/rejection at every weekly check as per the applicable maintenance data, unless the maintenance program frequency is more restrictive. The inspection should cover the integrity of the PBE vacuum seal, expiry date, moisture ingress or any obvious damage or abnormality. A tight pouch indicates a good vacuum seal; a slack or inflated pouch indicates a degraded vacuum seal.

Operational directive 07-2014 was issued by GCAA to inspect/reject at every pre-departure as per the applicable maintenance data. Operational Directives issued by GCAA are not mandatory by Part 39 of CASR.

f. Case 6

During routine PBE disposal, the unit experienced an explosion and fire. A loud audible explosion was heard, leading to fire emanating from the outside side of the unit that burnt the rubber ducting and tubing. Dense smoke exited the canister during the fire event which lasted for approximately 2 minutes. This event matches the information contained in the relevant Boeing Service Letters:

- 717-SL-35-108A
- 737-SL-35-016A
- 747-SL-35-031A
- 777-SL-35-108A

5. Related Airworthiness Directives

Although GCAA has released Operational Directives on PBE, their requirements are not mandatory in accordance with Part 39 of CASR. The following are provided by the State of Design:

- FAA AD 2011-01-09 serial numbers 003-50730M to 003-51329M – Remove from service defective potassium superoxide canisters
- FAA NPRM AD-2015-2134 – Proposed AD prompted by reports of compromised vacuum seals of the pouch that contains the PBE with part numbers 119003-11 and 119003-21. The proposed AD requires inspecting the PBE to determine if the pouch has the proper vacuum seal

6. Recommendations

- 119003-11 PBE units can remain in service until the end of their 10 year service life; however it is recommended to replace these units with 119003-21 on an attrition basis. The -21 units contain a stainless steel mesh screen on the output of the canister to prevent sparks and debris being exhausted during activation
- If a PBE catches fire during use, immediately move the unit to a safe non-combustible surface, use a water or halon extinguisher and wait at least 4 hours for the canister to cool
- Do not use carbon dioxide extinguisher as it may make the fire larger by accelerating the chemical reaction in the canister
- Potassium superoxide reacts with water to form potassium hydroxide which is caustic and very corrosive; deterioration may occur to nearby aircraft structure and components
- Replace any PBE units with damaged canisters as they are more vulnerable when exposed to shock and vibration

- Replace any PBE units with damaged vacuum seals with serviceable units as moisture can get inside the canister from humidity in the cabin or from aircraft disinsectant chemicals – organic solvents are typically easy to ignite. The seal should feel tightly contracted around the folded PBE contained within the pouch and should not exhibit looseness or bloating. If any amount of compression or spingback is evident, the seal is considered compromised see Figure 12.

Figure 12 - Condition of pouch

- No two PBE units should touch each other during actuation for disposal in accordance with approved procedures
- Keep PBE away from oils and grease due to potential fire hazard; as they contain oxidizing chemicals
- Unless the PBE is rendered inert and unsalvageable, exercise caution when using PBEs as training aids as this is outside of the manufacturer's instructions.

- Dispose PBE in a manner consistent with the manufacturer's instructions or return to manufacturer any PBE that are determined unserviceable.

7. Reporting

Report any issues with PBE to the manufacturer and CASA.

8. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

Airworthiness and Engineering Standards Branch
Standards Division
Civil Aviation Safety Authority
GPO Box 2005, Canberra, ACT, 2601