



**Australian Government**

**Australian Transport Safety Bureau**

**ATSB TRANSPORT SAFETY INVESTIGATION REPORT**

Aviation Occurrence Investigation – 200605039

Final

**Smoke event  
80 km west-north-west of Ravensthorpe, WA  
29 August 2006  
VH-NJE  
BAE SYSTEMS BAe 146-100**





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### Acknowledgements

Figure 1. Reproduced with the permission of the aircraft operator

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### Abstract

At 1745 Western Standard Time on 29 August 2006, a BAE SYSTEMS BAe 146-100 (BAe 146) aircraft, registered VH-NJE, departed Ravensthorpe Aerodrome, WA for Perth.

The flight crew recalled noticing a smell on the flight deck as the aircraft climbed through about FL130, but commented that it was different from the oil-like smell historically associated with the operation of the BAe 146, and to the normal smells associated with the operation of the aircraft's galley. The pilot in command recalled that, shortly after, there were a number of 'popping noises' accompanied by a series of bright yellow flashes and some glowing behind the escape rope panel on the copilot's side of the flight deck.

Shortly after, the smoke and related symptoms dissipated and the flight crew donned their emergency oxygen equipment and returned to the departure aerodrome. The crew stated that the aircraft's emergency oxygen equipment adversely affected their communication during the remainder of the flight.

The investigation determined that the aircraft's 'A' windscreen electrostatic filter had failed. That failure was consistent with an electrical arcing event.

In response to this and a number of other similar failures in the UK and in Europe, the aircraft manufacturer undertook a number of safety actions, including issuing a Service Information Letter advising operators to check the correct positioning of the insulation blankets in the vicinity of their aircraft electrostatic filters at the next available opportunity. The Australian Transport Safety Bureau has issued two safety recommendations that seek to reduce the likelihood of electrical arcing events in 'A' windscreen filters in BAe 146 aircraft.

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# THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

## **Purpose of safety investigations**

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

## **Developing safety action**

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

**About ATSB investigation reports:** How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site [www.atsb.gov.au](http://www.atsb.gov.au).

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# FACTUAL INFORMATION

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## History of the flight

At 1745 Western Standard Time<sup>1</sup> on 29 August 2006, a BAE SYSTEMS BAe 146-100 (BAe 146) aircraft, registered VH-NJE, with four crew and 61 passengers on board departed Ravensthorpe Aerodrome, WA for Perth. The pilot in command (PIC) reported that, when climbing through 6,000 to 7,000 ft, he engaged the autopilot and confirmed its IN<sup>2</sup> indication. Shortly after, the PIC noticed that the aircraft was drifting off track and that the autopilot chevron on the mode control panel was not engaged.<sup>3</sup> The PIC attempted to re-engage the autopilot, but was unsuccessful.

As the flight crew continued the climb to the cleared altitude of flight level<sup>4</sup> (FL) 240, they confirmed that the autopilot was on, but that it was not coupled to the flight director, and that its pitch and roll functions were inoperative. The flight crew reported recycling the overhead autopilot master switch, but without effect.

The flight crew recalled noticing a smell on the flight deck as the aircraft climbed through about FL130, but commented that it was different from the oil-like smell historically associated with the operation of the BAe 146, and to the normal smells associated with the operation of the aircraft's galley. The PIC indicated that the proximity of the autopilot problem to the identification of the smell on the flight deck caused the flight crew to link the two events. On that basis, the flight crew decided to isolate the autopilot and for the PIC to hand-fly the aircraft.

The PIC requested the Number-1 cabin crew member (CC1) to proceed to the flight deck after a check of the galley in order to eliminate it as a source of the smell. On arrival on the flight deck, the CC1 confirmed that there was no smell in the galley, and described an unusual smell on the flight deck that was felt to be emanating from above and behind the copilot, and was of varying intensity.

The PIC recalled that, shortly after, there were a number of 'popping noises' accompanied by a series of bright yellow flashes and some glowing behind the escape rope panel on the copilot's side of the flight deck. The PIC thought that he may also have seen sparks in that area, and reported that the smell increased in intensity at that time. The CC1 immediately departed the flight deck and returned with a cabin fire extinguisher, and the PIC requested the copilot to prepare the flight deck extinguisher for possible use.

The CC1 test-fired the cabin fire extinguisher prior to applying it to the suspected smoke source. The cabin fire extinguisher appeared to malfunction and, before the

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1 The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST), as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) + 8 hours.

2 Visual indication of the successful engagement of the autopilot.

3 Indicating the disengagement of the autopilot.

4 Operating altitudes above 10,000 ft above mean sea level (AMSL) are referred to as flight levels. FL240 equates to 24,000 ft.

copilot could activate the flight deck extinguisher, the PIC identified that the glow had dissipated and ordered a pause in the immediate response. The completion of the recall items from the emergency checklist was deferred in order to further investigate the source of the smoke and other indications of a possible fire. An inspection of the area of the escape rope panel confirmed that there were no further signs of fire or smoke.

In order to expedite the aircraft's safe landing, the flight crew decided that the most appropriate course of action was to return to Ravensthorpe. The copilot transmitted a PAN<sup>5</sup> call to air traffic control while the PIC manoeuvred the aircraft and the CC1 prepared the cabin for landing. The PIC recalled directing the copilot to don his oxygen mask and the copilot carried out the recall items from the emergency checklist. Control of the aircraft was temporarily handed to the copilot in order for the PIC to don his oxygen mask.

The crew stated that the aircraft's emergency oxygen equipment adversely affected their communication.<sup>6</sup> That was resolved by the copilot holding the checklist items in the PIC's view and pointing to each to verify compliance. The flight crew depressurised the aircraft descending through 6,000 ft and landed at Ravensthorpe.

There was extensive heat damage to the insulation blanket and in the general area of the escape rope panel on the copilot's side of the flight deck. No injuries to the crew or passengers were reported.

## **Maintenance inspection of the aircraft**

### **Autopilot malfunction**

Prior to this incident, there had been a number of uncommanded disengagements of the aircraft's autopilot over a number of months. Maintenance troubleshooting by the operator indicated that the synchronising switch on the captain's control wheel was the probable cause.

The operator advised that the disengagement of the autopilot immediately prior to the smoke event appeared to be a recurrence of the ongoing autopilot malfunction. There was no evidence to link the disengagement of the autopilot to the smoke event.

### **Electrostatic filter**

An inspection of the flight deck by the operator showed that the right windshield's electrostatic filter, known as the 'A' windscreen filter, had failed and that the associated circuit breaker had tripped. That filter was one of six in the aircraft's windshield heating system. The failure caused the filter to arc or short-circuit internally, which provided a path to ground for the 115V alternating current (AC) powering the system and generated significant localised heat (Figure 1). Smoke and

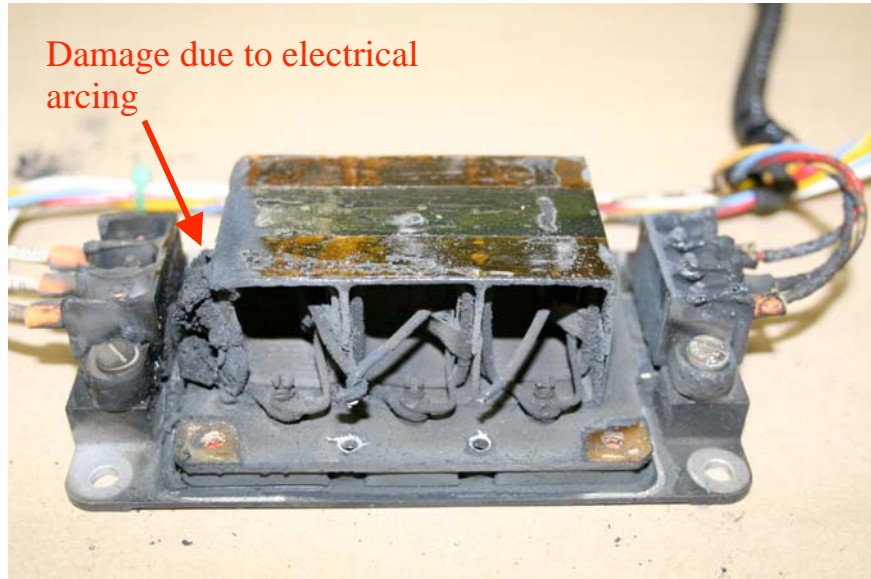
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5 A radio call to indicate uncertainty or alert.

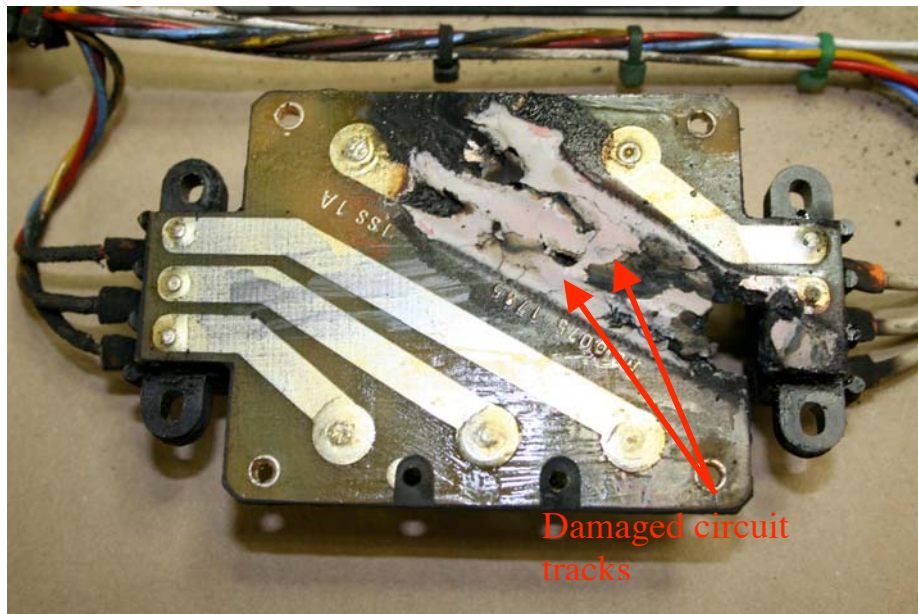
6 An examination of the ATSB occurrence database identified four prior instances over a period of 13 years where a flight crew had reported experiencing communication difficulties once they had donned their emergency oxygen equipment.



**Figure 2. Disassembled electrostatic filter exhibiting damage consistent with severe electrical arcing**



**Figure 3. Filter base, showing damaged circuit tracks**



The screw heads were subjected to microscopic examination in order to characterise the white substance. That examination identified the substance as a corrosion product of the surface cadmium plating. The corrosion was evident over all of the screw heads' external surfaces, and its structure and distribution was consistent with its formation in the presence of condensed moisture.

## **Aircraft manufacturer**

### ***Examination of in-service electrostatic filters***

The aircraft manufacturer requested a number of Australian and European operators to examine their aircrafts' electrostatic filters based on the insulation tests that were

contained in the Component Maintenance Manual, and to report their findings. Work packages were devised in the form of Technical Operational Responses (TORs) and distributed to the operators to explain the scope of those checks.

In addition, a sample of serviceable electrostatic filters was requested by the aircraft manufacturer to be removed from three different operators' aircraft for inspection by the component manufacturer.

### ***Design review of the electrostatic filter***

The aircraft manufacturer also conducted a series of equipment design reviews in order to assess alternative strategies to address the failures of the aircraft's electrostatic filter. Those reviews prompted the aircraft manufacturer to determine that:

- The melting and charring of the insulation blanket in the area of the filters only continued while a heat source acted on that blanket, and ceased once that source was removed. That was consistent with the design of the blanket.
- The only electrical wiring in the vicinity of the filters was of a design type that would not propagate a fire.
- In all of the reported instances of filter failure, the relevant circuit breaker automatically tripped, removing the electrical power and therefore heat source.
- There was no apparent trend in relation to the age of the failed filters.
- They considered that the failure condition was not predictable, and therefore placing a life on the filters was not practicable.
- The existing abnormal and emergency procedures were sufficient to manage the effects of a filter failure.

### **Component manufacturer**

During its inspection of the serviceable filters that were received from the Australian and European operators, the component manufacturer observed a very small amount of movement on one of the electrical terminal blocks that connected power to the filter units.

The component manufacturer initially indicated that the failure mechanism would appear to be the long-term fatigue of the solder joints. The manufacturer was unable to say exactly what had caused the fatigue of the solder joints but thought that it was most probably due to a combination of effects, including vibration, age (time in service), wear and tear, moisture and heat. The component manufacturer described that the fatigue of the solder joints would have lead to increased contact resistance, eventual overheating and arcing and, finally, a destructive thermal runaway.

The thermal runaway was felt by the component manufacturer to not be related to a breakdown between the electrical phases. On that basis, and because continuity resistance measurements on the unit prior to its failure showed no signs of an imminent failure, the manufacturer believed that measuring the insulation resistance would not detect a potential failure.

The component and aircraft manufacturers believed that the actions described in the TOR documents were unlikely to have been able to detect the identified failure

mode, and the aircraft manufacturer requested the operators to cease their checks of the electrostatic filter.

## **Electrostatic filter failure history**

Prior to this occurrence, six similar failures of the electrostatic filters were reported to the aircraft manufacturer since 2002. In all cases, the associated circuit breaker was reported to have correctly tripped, which removed the power supply to the failed filter.

In the period since this occurrence, there have been two similar electrostatic filter failures, one in Belgium and one in the United Kingdom. In each case, the symptoms and damage as a result of the failures were generally consistent with those in this occurrence.

The results of an examination by the component manufacturer of the failed electrostatic filter from the Belgian aircraft were consistent with the condensation-related damage that was identified in the ATSB examination of the occurrence aircraft's filter.

As a result of its examination of this and the Belgian occurrences, the component manufacturer advised the ATSB that all of the failed electrostatic filters that it had examined had achieved a minimum of 12 years time in service, and had been located in the 'A' windscreen filter location. None of the affected aircrafts' other five electrostatic filter locations sustained filter failures, including in the 'B' filter location. The filter in that location was identical to that on the 'A' filter location and carried an almost identical electrical load.

Contrary to the advice that was received from the aircraft manufacturer, the component manufacturer believed that the 'A' windscreen filters became susceptible to failure after extended periods in service in the moisture-laden environment associated with that filter's location. The manufacturer attributed the lack of any failures of the 'B' filter to the more benign environment in that location. The manufacturer concluded that it was unlikely that there was an inherent problem with the design of the filter, and that 'the unit's location in the aircraft may generate a combination of environmental factors detrimental to the unit's service life.'

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## ANALYSIS

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The failure of the 'A' windscreen electrostatic filter was consistent with an electrical arcing event. The correct operation of high voltage equipment, such as the electrostatic filter, requires effective electrical insulation. Any ingress of water, as was apparent in this case, can compromise the required insulation, with the result that electrical arcing can occur. The presence of corrosion on the filter's screw heads confirmed the presence and effect of condensation on that filter. The location of the filter in the aircraft increased the risk for that to occur.

The disparity in the aircraft and component manufacturer's conclusions in regard to the influence of 'A' windscreen filter time in service on the failure mechanism was noteworthy. However, the finding by the component manufacturer that all of the failed 'A' filters had at least 12 years in service appeared significant. That, and the observation by the component manufacturer that there had been no filter failures in the more benign 'B' filter location appeared to suggest that extended time in service in the 'A' filter location increased the risk of an electrical arcing event in that filter.

The action by the flight crew to don their emergency oxygen equipment mitigated the risk associated with the production of smoke and potentially other toxic substances as a result of the electrical arcing and damage to the insulation blanket. The manual confirmation by the crew of compliance with the aircraft's emergency checklist overcame the communication difficulties experienced once they donned that equipment.

Crews should be prepared for the possible degradation of their normal communication should the requirement to don their emergency oxygen equipment eventuate during flight.



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# FINDINGS

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## Context

From the evidence available, the following findings are made with respect to the smoke event involving BAE SYSTEMS BAe 146-100 aircraft, registration VH-NJE that occurred 80 km west-north-west of Ravensthorpe, WA on 19 August 2006. They should not be read as apportioning blame or liability to any particular organisation or individual.

## Contributing safety factors

- The 'A' windscreen electrostatic filter failed as a result of an electrical arcing event.
- The electrical arcing and damage to the insulation blanket resulted in smoke with potentially toxic substances being produced on the flight deck.

## Other safety factors

- An extended time in service in the 'A' windscreen filter location appeared to increase the risk of an electrical arcing event in that filter. (*Safety issue*)
- The flight crew's emergency oxygen equipment hindered their communication during the occurrence.



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## **SAFETY ACTIONS**

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The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report. A safety risk analysis was carried out by the ATSB as part of its consideration of appropriate safety action in response to the responsible organisations' submissions on the content of the draft report. The aircraft and component manufacturers were then provided with a copy of that draft safety action and invited to provide additional comment on that action.

### **Aircraft manufacturer**

In September 2006, the aircraft manufacturer alerted BAe 146 operators of this event. In addition, it was also discussed at the September 2007 Operators' Conference.

Following the Operators' Conference, the aircraft manufacturer issued Service Information Letter (eSIL) No. 25-146-RJ-512-1. That eSIL advised operators to check the correct positioning of the insulation blankets in the vicinity of their aircraft's overhead electrostatic windscreen filters. The intent was that removing the surrounding insulation bag from direct contact with the filters would reduce the potential consequence of the event – that is, smoke on the flight deck.

The aircraft manufacturer intends re-issuing the eSIL to include recent operator feedback and to provide more detailed guidance on the rearrangement of the insulation blankets. The revised eSIL will include supporting photographs.

## **Australian Transport Safety Bureau**

### **Risk of an electrical arcing event in the aircraft's 'A' windscreen filter**

#### ***Safety Issue***

An extended time in service in the 'A' windscreen filter location appeared to increase the risk of an electrical arcing event in that filter.

#### ***Aircraft manufacturer comment***

In its consideration of alternate strategies to address the failure of the aircraft's 'A' windscreen electrostatic filter, the aircraft manufacturer determined that there was no apparent trend in relation to the age of the failed filters. Similarly, the manufacturer considered that the failure condition was not predictable, and therefore placing a life on the filters was not practicable.

#### ***Additional aircraft manufacturer comment***

In its response to the draft safety action that was proposed by the ATSB, the aircraft manufacturer advised that, in accordance with its procedures, the classification of the event was 'MAJOR' but that, given the total flight hours of the BAE 146/RJ of over 10 million hours, the electrostatic filter failure rates were 'within acceptable levels for this failure classification.' In regard to the possibly age-related nature of the 'A' windscreen electrostatic filter failures, the manufacturer noted that, although the first aircraft was delivered in 1986, the failures were confined to units that were manufactured in or after 1987.

#### ***Component manufacturer***

The manufacturer of the electrostatic filter believed that the 'A' windscreen electrostatic filters became susceptible to failure after extended periods in service in the moisture-laden environment associated with that filter's location. Advice was provided by the manufacturer that 'the unit's location in the aircraft may generate a combination of environmental factors detrimental to the unit's service life.'

#### ***Additional component manufacturer comment***

In its response to the draft safety action that was proposed by the ATSB, the component manufacturer advised that, in its opinion, placing a time in service limit on 'A' windscreen filters 'would be the most prudent action to avoid repeat incidences similar to that contained in the report'.

In addition, the component manufacturer carried out an examination of its internal design and drawing modifications records for the electrostatic windscreen filter, including since the inception of the BAE 146 aircraft. That examination found no correlation between any design or production changes to the electrostatic filter and the late 1980s period.

***ATSB comment***

Despite the disparity in the aircraft and component manufacturers' conclusions with regard to the influence of 'A' windscreen electrostatic filter time in service on the risk of an electrical arcing event in that filter, an extended time in service in the 'A' filter location appeared to increase that risk.

Whereas, to date, the existing engineering and other defences had minimised the consequences of electrical arcing events in the 'A' windscreen electrostatic filter, it appears that there may be an opportunity to reduce the likelihood of future electrical arcing events in those filters as a result of the consideration of an appropriate time in service for filters in that location.

**ATSB safety recommendation R20080003**

The Australian Transport Safety Bureau recommends that BAE SYSTEMS, in conjunction with GKN Aerospace, address this safety issue.

**ATSB safety recommendation R20080004**

The Australian Transport Safety Bureau recommends that GKN Aerospace, in conjunction with BAE SYSTEMS, address this safety issue.