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SAFETY BOARD

Oven overheat in aft galley

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N.B: This report is published in the English language, with a separate summary in the Dutch language. If there is a difference in interpretation between the Dutch and English text, the English text will prevail.

CONTENTS

Summary **6**

Abbreviations **9**

General overview **10**

1 Introduction **11**

2 Factual information **12**
- 2.1 History of the flight 12
- 2.2 Injuries to persons 15
- 2.3 Damage to aircraft 15
- 2.4 Personnel information 15
- 2.5 Aircraft information 16
- 2.6 Oven 16
- 2.7 Recorders 18
- 2.8 Tests and research 19
- 2.9 Organisational and management information 20
- 2.10 Additional information 23
- 2.11 Use of Halon 25

3 Analysis **27**
- 3.1 Investigation of the oven 27
- 3.2 Cabin crew action 31
- 3.3 Final remarks 34

4 Conclusions **35**

APPENDIX A **37**
Responses to the draft report 37

APPENDIX B **38**
OM-A Flight Safety and Security Manual (FSSM), procedures cabin crew 38

APPENDIX C **41**
Halon fire extinguishers 41

APPENDIX D **42**
3-Phase Safety Device 42

APPENDIX E **43**
Destructive test of a DF2000 oven 43

APPENDIX F **45**
Smoke, Fire or Fumes checklist 45

APPENDIX G **46**
Service Bulletin 2000-25-0001 46

SUMMARY

On 9 February 2023, a Boeing B777-200 on a flight from Amsterdam Airport Schiphol (hereafter Schiphol) in the Netherlands to Johannesburg - OR Tambo International Airport in South Africa experienced smoke in the cabin after being in flight for about 1 hour and 20 minutes. The smoke originated from an oven located in the aft galley of the aircraft. The purser immediately started fire-fighting activities and was assisted by several cabin attendants. She observed that a thick brown smoke was emitting from the oven and subsequently discharged a Halon fire extinguisher into the oven several times.

The purser informed the captain about smoke in the aft galley. He immediately started the electronic Smoke, Fire or Fumes checklist but did not complete the checklist, as he wanted to make his own assessment about the situation in the aft galley. The captain therefore made his way to the aft galley to assess the situation himself. He asked the purser if the galley area main power had been switched off, which she confirmed, after which the captain encouraged the cabin crew to continue using ample Halon fire extinguishers to fight the oven fire. Upon return to the flight deck, the captain continued the Smoke, Fire or Fumes checklist. The whole event lasted about 20 minutes before the smoke stopped. In total, six fire extinguishers were emptied into the oven.

After consultation with the operator's Operations Control Centre and later with the senior purser, the decision was made, when the aircraft was near Marseille in France, to return to Schiphol. In the captain's opinion, this was warranted by the fact that the oven smoke was under control and an immediate diversion to a nearby airport was not needed. However, as the aircraft still exceeded its maximum landing weight, the flight crew had to jettison fuel. Three crew members as well as twelve passengers suffered from breathing difficulties. Medical assistance was available upon return to the airport.

The investigation into this serious incident revealed that the use of a meal tray carrier with a mostly closed backside extended the heating time of the oven significantly and disturbed the airflow in it. This led to a raised temperature behind the oven, inadvertently influencing the electronic control circuitry in such a way that the heating elements of the oven were commanded on. It caused the temperature behind the oven to increase even further and kept the power control board in a faulty condition. At this point, the 3-phase safety device was already damaged and inoperable and could not disconnect the electrical power to the oven. Consequently, the temperature inside the oven continued to rise to such a degree that it overheated and smoke was emitted from the oven into the galley.

Disconnection of electrical power to the oven by the cabin crew, as dictated by the Oven smoke/fire procedure, did not occur throughout the entire oven overheat event. Furthermore, at no point was the correct position of the main power switch of the galley area verified by checking the power supply of other electrical equipment in the galley,

nor were they required to do so. The circuit breaker of the oven was not pulled by the cabin crew as it was not an item of the Oven smoke/fire procedure. The flight crew did not switch off the utility bus as directed by the Smoke, Fire or Fumes checklist as they considered it unnecessary. As a result, the oven remained powered during the entire overheat event as well as on the return flight to Amsterdam.

As a result of the failure of the heating elements by the prolonged heating at maximum temperature, the temperature behind the oven dropped significantly so that the power control board functioned correctly again. Then, the oven control module transmitted the commanded 'off' signal to the heating elements. The oven overheat event thus stopped. All heat damage remained limited to the inside of the oven and did not cause damage to the surrounding area of the oven.

The operator indicated that Service Information Letter H0212-25-0164 (as incorporated in the Components Maintenance Manual), issued by the oven manufacturer, had not been incorporated in maintenance procedures. This service information letter gives additional instructions for the checking of the 3-phase safety device and its replacement every five years.

Service Bulletin 2000-25-0001, which is also issued by the oven manufacturer, recommends the incorporation of an improved power module, motor, fan, and heating elements among other upgrades, and had not been incorporated either by the operator. The incorporation of this service bulletin has been proven to prevent a potential failure of the power control board from controlling the temperature in the oven. The implementation of this service bulletin was deemed unsuitable by the operator due to certification requirements of the modification and limitations on the use of the oven.

No flames were observed inside the oven. The amount of smoke generated by the overheat event, especially the smoke coming from the cavity between the oven and the galley board, let the cabin crew believe that a fire must have been present. For the cabin crew this justified the use of Halon fire extinguishers. The application of Halon into the oven did not provide any cooling effect and increased the emission of smoke. The Halon gas was exposed to temperatures above its decomposition temperature and became toxic. In the case of a fire, Halon shall be used to extinguish it. It will extinguish the fire quickly. As a result, the temperature will not become as high as in the incident oven and the decomposition temperature of Halon is not reached. The use of a Halon fire extinguisher agent aggravated the circumstances during the oven overheat event and was therefore inappropriate.

The training provided to cabin crew stressed the importance of not manipulating and not resetting tripped circuit breakers. This led to a general understanding among the cabin crew that pulling a circuit breaker was not allowed, even in the presence of fire or smoke emitting from electrical equipment. Company procedures dictated that only after consultation with the flight crew, the pulling of a circuit breaker was allowed.

During the investigation, the operator was already alerted by the Dutch Safety Board on the importance of the implementation into the crew procedures of a check that all power to a failed oven has indeed been switched off. Also, the importance of keeping the oven door shut during an overheat event was pointed out by the Dutch Safety Board during the investigation, as the oven is designed to confine high temperatures to the inside of the oven.

ABBREVIATIONS

Abbreviation	Description
ATL	Aircraft Technical Log
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
C/A	Cabin attendant
CAMO	Continuing Airworthiness Management Organisation
CVR	Cockpit voice recorder
EASA	European Union Aviation Safety Agency
EHAM	Amsterdam Airport Schiphol
FAM	Flight Attendant Manual
FAOR	Johannesburg - OR Tambo International Airport
FDR	Flight data recorder
FSSM	Flight Safety and Security Manual
LVNL	Air Traffic Control the Netherlands
NTSB	National Transportation Safety Board
OCC	Operational Control Centre
OCM	Oven control module
PBE	Protective breathing equipment
PCB	Power control board
QRH	Quick Reference Handbook
SB	Service bulletin
SIL	Service information letter
UTC	Coordinated Universal Time

GENERAL OVERVIEW

Synopsis	Explanation
Identification number:	2023012
Classification:	Serious incident
Date, time of occurrence:	9 February 2023, 12.30-12.45 hours[1]
Location of occurrence:	Mediterranean Sea south of Marseille, France
Operator:	KLM Royal Dutch Airlines
Registration:	PH-BQO
Aircraft type:	Boeing 777-200
Aircraft category:	Fixed wing aircraft – passenger
Type of flight:	Scheduled commercial air transport (passenger)
Phase of operation:	En route
Damage to aircraft:	Galley floor heat damage
Number of flight crew:	3
Number of cabin crew:	10
Passengers:	291
Injuries:	Breathing difficulties by three cabin crew members and twelve passengers
Other damage:	Oven damaged beyond repair
Light conditions:	Daylight

1 All times in this report are local times (UTC + 1 hour), unless otherwise specified.

1 INTRODUCTION

On 9 February 2023, a Boeing B777-200 on a flight from Amsterdam Airport Schiphol (EHAM, hereafter Schiphol) in the Netherlands to Johannesburg - OR Tambo International Airport (FAOR) in South Africa experienced smoke in the cabin after being in flight for about 1 hour and 20 minutes. The smoke originated from an oven in the aft galley of the aircraft.

The Dutch Safety Board classified the occurrence as a serious incident, because the smoke originating from the overheating of the oven as well as the application of the Halon fire agent resulted in breathing difficulties by three cabin crew members as well as twelve passengers.

In accordance with the Dutch Safety Board Act and EU regulation No 996/20102, the Dutch Safety Board, on behalf of the State of Registry and the State of the Operator, conducted the safety investigation into this serious incident. The state of occurrence was France.

The investigation aimed at answering the following questions:

1. Why did the oven overheat event occur?
2. How did the flight and cabin crew's firefighting efforts come about and what were the results of these efforts?
3. What factors may have played a role in both the occurrence of the oven overheating and the subsequent firefighting events?
4. What lessons can be learned from this oven overheat event?

The National Transportation Safety Board (NTSB) of the USA, representing the State of Design and State of Manufacture, participated in the investigation. Collins Aerospace, the manufacturer of the oven, was the NTSB's technical advisor.

The Dutch Safety Board gathered information from the operator. For example, the operator interviewed the crew members and provided the interview reports to the Safety Board. A cabin investigator from the Association of Dutch Cabin Crew[2] assisted with the investigation.

Chapter 2 presents the relevant factual information. In Chapter 3, the analysis is presented. Findings and conclusions are summarised in Chapter 4. Chapter 5 lists a series of recommendations.

2 In Dutch: Vereniging Nederlands Cabinepersoneel.

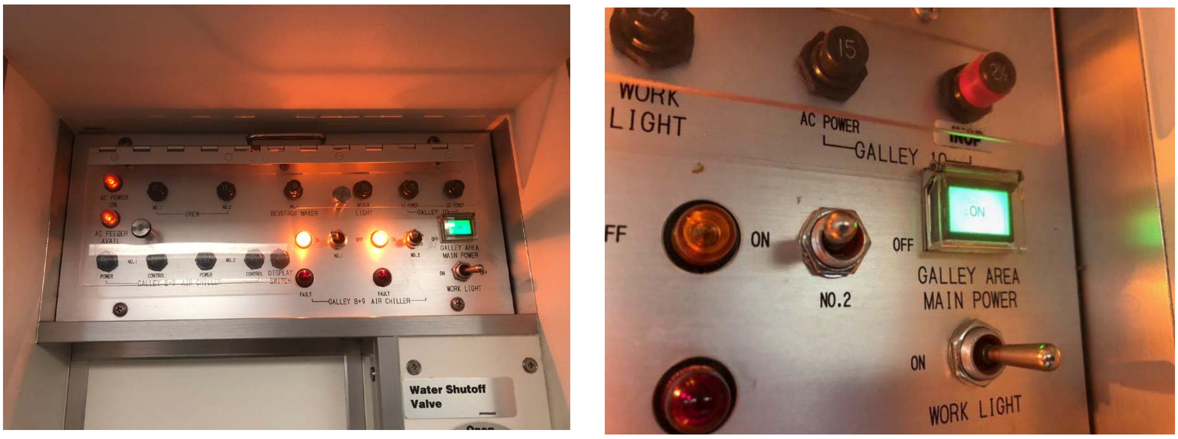
2 FACTUAL INFORMATION

2.1 History of the flight

On 9 February 2023, the Boeing 777-200 with registration PH-BQO was scheduled to operate a passenger flight from Schiphol in the Netherlands to Johannesburg - OR Tambo International Airport in South Africa. The crew consisted of three flight crew members, a captain, a first officer and a second officer as well as ten cabin crew members. A total of 291 passengers were on board.

The following sequence of events is derived from interviews with the involved crew members, flight and cabin crew, and a technical analysis of the oven and data from the flight data recorder. The cockpit voice recorder data did not contain relevant information.

At 10.59 hours, the aircraft departed Schiphol from Runway 18L. Twenty minutes after take-off, the cabin crew turned on the ovens in the galleys. After approximately 1 hour and 20 minutes into the flight, while the aircraft was cruising at FL330, a passenger seated in the aft part of the cabin alerted the purser, who was serving the passengers with meals, that smoke was coming from the aft galley. The purser immediately put aside her meal trolley and made her way to the aft galley, where she discovered smoke originating from oven number 3. She returned to the cabin to warn other cabin crew members about the smoke and to start the standard firefighting procedure, the so-called 'ABC procedure' (see Appendix B). Under this procedure, the purser assumed the role of A (Attack) in charge of firefighting, while a second cabin crew member became B (Buddy) to assist A and a third cabin crew member took on the role of C (Communication), taking care of communications with the flight deck and senior purser. Hereafter, the purser returned to the galley to start the Oven smoke/fire procedure (see Appendix B). The first step of this procedure requires the galley area main power to be switched off. Upon checking the galley area main power button, the purser discovered that the green indicator light (see Figure 1) was not illuminating. She interpreted this as an indication that the galley area main power must have turned off automatically.



▲ *Figure 1: On the right in both pictures, the green lit galley area main power button.*

Hereafter, the purser collected fire resistant gloves and opened the oven door. Inside, she observed a thick brown smoke emitting from the oven and subsequently discharged a Halon fire extinguisher into the oven several times. As the smoke was becoming denser in the galley and aft cabin, she directed other cabin crew members to use protective breathing equipment (PBE) to avoid smoke inhalation. Because of difficulties in communication with other crew members with the use of the PBE and the consternation caused by the emergency situation, the purser was unsure if the flight crew was already informed about the smoke in the aft galley. She therefore removed her PBE to call the flight crew with the cabin interphone system. The captain first started the electronic Smoke, Fire or Fumes checklist, but did not complete the checklist as he needed more information to make his own assessment about the situation in the aft galley. He therefore made his way to the aft galley. He asked the purser if the galley area main power had been switched off, which she confirmed. Subsequently, the captain encouraged the cabin crew to use ample Halon fire extinguishers (see Appendixes B and C) to fight the oven fire. Shortly hereafter, the captain returned to the flight deck to manage the situation from there should a diversion be required and to contact the airline's Operations Control Centre. He also directed the second officer to go to the aft galley to monitor the situation.

In the aft galley, several cabin crew members participated in assisting the purser with her efforts to stop the smoke coming from the oven. When the second officer observed the smoke coming from the oven, he also encouraged the purser to use ample Halon fire extinguishers. After three bottles of the Halon fire extinguishers had been used, the purser, assisted by two cabin crew members, opened the oven door to remove the insert of the oven to be able to have a closer look at the back of the oven. In her opinion, this was the area from where the smoke originated. Both the purser and the second officer observed a glowing object at the bottom of the oven, as well as an orange glow behind the back wall of the oven.

According to the concerned crew members, the whole event lasted about 20 minutes before the smoke stopped. During this period, the smoke appeared to become less thick at some point, after which it became thicker again. In total, six fire extinguishers were emptied into the oven and a seventh fire extinguisher was prepared for use.

As soon as the flight crew was informed about smoke in the aft galley, they started the electronic Smoke, Fire or Fumes checklist. This checklist states that the recirculation fans of the cabin and the utility bus should be switched off in case the fire, smoke or fumes are uncontrollable. The flight crew members did not switch off the utility bus, as they were convinced that the power to the aft galley was already removed by switching off the galley area main power switch. Before the checklist item that requires the flight crew to initiate a diversion, they halted the checklist to await the results of the fire-fighting activities taking place in the aft galley. After the confirmation that no smoke was emitting from the oven anymore, the flight crew executed the remaining steps of the Smoke, Fire or Fumes checklist. The crew concluded that the source of the smoke had been identified, resulting in the possibility to continue the flight towards its intended destination. For the remainder of the flight, the recirculation fans were kept in the off position.

Diversion to Schiphol

The captain had observed the severity of the situation in the aft galley himself and witnessed the fact that the smoke did not decrease quickly. Then, after consulting the first officer, the captain decided that the flight should not continue to Johannesburg. As soon as the senior purser informed the captain that the smoke from the failed oven had disappeared, he made his way to the aft galley to assure himself that the smoke event had stopped. After consultation with the Operations Control Centre and later with the senior purser, the decision was made to return to Schiphol. At that moment, the aircraft was near Marseille. In the captain's opinion, return to Schiphol was warranted by the fact that the oven smoke was under control and an immediate diversion to a nearby airport was not needed. As the aircraft was also still above its maximum landing weight, a return to Schiphol would also give time for the necessary fuel dumping and preparation for an alternative means of travel for the passengers. The senior purser informed the captain that after consulting the entire cabin crew staff, no objections were raised against flying back to Schiphol, which would take about 1,5 hours. The flight crew requested a direct routing to Schiphol from their current position, approaching reporting point BALEN, located over the Mediterranean Sea south of Marseille. While still flying over France, they requested air traffic control to dump 30 tons of fuel. This was approved with the addition that the flight crew needed to squawk the emergency code 7700. Later, when the aircraft flew over the North Sea in Dutch airspace, the flight crew informed air traffic control on the need to dump some more fuel (two tons), as they were still above the maximum landing weight. They also requested the Operations Control Centre to organise medical assistance after landing, as twelve passengers and three cabin crew members indicated breathing difficulties as well as dizziness.

The return was uneventful and the aircraft was parked at the gate at 14.37 hours. The fire brigade entered the aircraft to inspect the oven. They confirmed that no fire or overheat condition existed anymore in and around the oven.

2.2 Injuries to persons

During the flight, three cabin crew members experienced breathing difficulties and dizziness. Supplemental oxygen was administered to them on the flight deck. Additionally, twelve passengers also reported experiencing breathing difficulties. No supplemental oxygen was provided to them during the flight. After the aircraft was parked at the gate, medical personnel entered the aircraft and checked cabin crew members and passengers who indicated having had breathing difficulties.[3] Several persons on board were distressed by the incident.

2.3 Damage to aircraft

The oven suffered overheat damage, consisting of a melted aluminium fan and damage of the entire inner side. During the incident, the insert of the oven together with its trays was removed and placed on the galley floor. The galley floor sustained heat damage from the hot insert through melting of the contact surface.

2.4 Personnel information

The flight crew consisted of a captain, a first officer and second officer. All were qualified to fly the Boeing 777-200. The cabin crew consisted of a senior purser, a purser and eight cabin attendants.

▼ *Table 1: Flight and cabin crew experience.*

Cabin crew	Date of employment	Last recurrent training[4]
Captain	20-04-1995	01-09-2021
First officer	02-03-2011	xx[5]-04-2020
Second officer	10-05-2022	12-05-2022
Senior purser	22-03-1987	05-10-2020
Purser	1-10-2000	16-09-2021
C/A (Buddy)	28-03-2022	07-04-2022
C/A (Communications)	03-10-2022	27-10-2022
C/A (Relief)	01-11-2006	06-07-2021
C/A (Relief)	01-05-2017	29-10-2021

3 One cabin crew member stated that s/he was never checked by medical personnel.
4 Three-yearly joint training for cabin and cockpit crew members where the fire fighting exercise takes place.
5 The exact day has not been provided by the operator.

2.5 Aircraft information

▼ *Table 2: Aircraft information.*

Synopsis	Specification
Manufacturer	Boeing Commercial Airplanes
Model	777-200
Date of manufacture	2007
Serial Number	35295
Registration	PH-BQO

The aircraft had three galleys. In total, there were ten ovens installed of which five in the aft galley. All ovens were of the DF2000 type. The failed oven was installed (on position 914) in the aft galley.

A total of thirteen Halon fire extinguisher bottles were stored throughout the incident aircraft and six of them could be confirmed as being emptied after the incident. One Halon fire bottle was found without it's safety pin installed and therefore ready for use. The aircraft was not equipped with water fire extinguisher bottles.

2.6 Oven

2.6.1 General information

▼ *Table 3: Oven information.*

Synopsis	Specification
Manufacturer	B/E Aerospace, Inc., a part of Collins Aerospace
Model	DF2000 high speed convection oven
Date of manufacture oven	2007
Part number	720740-01-00-00
Serial number	2313
Date of manufacture OCM 2000	2003
Serial number OCM 2000	1035

The DF2000 is a high-speed convection oven. The inside of the oven holds an insert which is capable of holding six trays or shelves. The meals are stored on the trays. The insert can be inserted or removed in the oven with all trays in place. The oven itself is placed inside a galley cavity with some distance between the oven and the adjacent walls (see Figure 2).

Figure 2: The failed oven.

The oven is remotely controlled by a separate oven control module (OCM). The OCM controls, monitors and displays the oven temperature, which is measured by a temperature probe. Although the OCM can provide a variety of cooking programs on the oven, the temperature is fixed at 180 °C regardless of the selected program. The OCM does not power the heating elements of the oven as the oven is powered directly from the galley bus.

Power to the oven is provided via the utility bus, which in turn powers the galley bus. To remove power from the oven and the OCM, a galley area main power switch as well as a designated circuit breaker are installed. They are located on different walls of the galley. Switching off the utility bus will remove power to all galleys and cabin equipment and therefore also to the failed oven.

2.6.2 Overheat protection

The temperature inside the oven is protected by the OCM via the temperature probe and an additional 3-phase safety device which removes power to the oven if the maximum allowed temperature inside the oven is exceeded. It is a passive safety device, meaning that it will not switch off power to the oven if it fails. For a description of the operation of the 3-phase safety device, see Appendix D.
The 3-phase safety device can be easily reset after the maximum temperature has been exceeded by pushing the reset button on the back of the oven. The reset can only be performed when the oven is removed from its designated area in the galley.

2.6.3 The power control board

All electronics controlling the power to the three heating elements and motor (for controlling the fan) as well as the connection with the OCM are incorporated in the power control board (PCB), located at the back of the oven.
The PCB controls the switching of the motor and the three heating elements, as required by the program selected on the OCM. This switching is done via power semiconductors

which will produce some heat themselves. Cooling of the semiconductors is done by a heat sink installed at the back of the oven.
To provide cooling to the heat sensitive PCB, external aluminium cooling ribs are installed. It is known that the PCB may fail if it becomes too hot. If this is the case, it may inadvertently switch on the heating elements when only the motor should be on.

2.6.4 Previous failure

Prior to the event, another oven of the same type and in the same position as that of the overheated oven was removed after a failure had occurred during another flight. The removed oven had a defective heating element resulting in a no heat event. The investigation of the oven control module showed that three error messages were stored in the internal memory, all reading overheat but without a date or time stamp. As the oven on position 914 in the aft galley, the position of the incident oven, was replaced on 5 February 2023, it could not be concluded that the error messages on the oven control module were generated by the incident oven. In the Aircraft Technical Log (ATL) an entry was made two days before the event, containing an overheat condition of the incident oven. The corrective action by the maintenance department consisted of a reset of the 3-phase safety device where after a functional test[6] was performed. This test proved to be satisfactory and the oven was considered serviceable again.

2.7 Recorders

The aeroplane was equipped with a solid-state memory flight data recorder (FDR), manufactured by AlliedSignal and a solid-state cockpit voice recorder (CVR), manufactured by L3 Communications.

The FDR recorded the entire duration of the flight and was available for the analysis of the occurrence. The CVR recording revealed the flight deck conversations just after the occurrence had happened until shortly after the aircraft was parked at the gate. The CVR did not contain any conversations during the firefighting process. On the Boeing 777, it is not possible to preserve the recording as the circuit breaker for the CVR is located in the avionics bay, not accessible for the flight crew during flight.

6 According to the component maintenance manual, a test of the 3-phase safety device should always be done before an oven is returned to service to ensure that it is working.

2.8 Tests and research

2.8.1 First investigation of the incident oven: complete teardown

The oven was shipped to the Lenexa Kansas Collins Aerospace facility for investigation on 30 May 2023, where a complete teardown of the oven took place under laboratory conditions and supervised by an investigator of the Dutch Safety Board. The manufacturer has prepared a report containing the findings of the investigation.[7] These findings are:

Upon teardown of the oven, the 3-phase safety device appeared to have been damaged by one of the three heating elements of the oven rendering it inoperable. Additionally, a meal carrier insert from another manufacturer was discovered in the oven as well as seven trays, although the insert is designed for only six trays. The oven was damaged beyond economical repair. Severe heat damage was observed inside the oven and on the back of the oven. No heat damage was found on the oven's outer shell.

With the 3-phase safety device damaged and the heating elements continuously in the on- position due to the high ambient temperatures near the power control board, the oven temperature increased. This caused the oven to begin emitting smoke and the oven heating elements to glow as seen during the incident.

Molten aluminium parts of the fan were found on the bottom of the oven and on the back wall near the heating elements. The complete inside of the oven was covered with a brownish substance. Also, the outside walls of the oven were covered with a brownish substance. The inside parts of the oven sustained severe heat damage, especially near the heating elements as well as the power control board on the back of the oven.

Despite the fact that the oven faced an overheat situation and smoke was emitted, there were no signs of an oven component related fire. The outer metal covering for the oven showed no signs of heat damage.

2.8.2 Second investigation of the incident oven: the power control board

After analysing the results of the tear down of the oven, the Dutch Safety Board requested the manufacturer to start an additional investigation of the power control board (PCB). This investigation was aimed at establishing an answer to the question whether the incident oven could still power the heating elements, despite the damage to the PCB.[8]

This investigation revealed that the PCB was still functional. Examination of the heating elements revealed that two out of the three heating elements had completely failed. The third heating element was damaged to such a degree that it produced less heat than designed. The manufacturer concluded that the complete and partial failure of the heating elements resulted in the cooling down of the oven. The PCB therefore also cooled down to such a degree that the electronics started working again as designed.

7 B/E AEROSPACE, *Investigation Report, KLM Airlines DF2000 Smoke Event, ENGX-901-31-RPT-01, REV. C*, October 2023.

8 No representative of the Dutch Safety Board was present at this investigation.

With the oven control module switched off and thus commanding the PCB to switch off the oven, the PCB correctly switched off the power to the heating elements after which the overheat event stopped.

2.8.3 Destructive test of a DF2000 oven

The damage on the incident oven was such that no functional test could be performed after replacing damaged parts. As the CVR did not hold any conversations during the incident and no information of electrical loads could be retrieved from the FDR regarding the powering of the oven, a destructive test had to be performed on a different oven of the same model. This in order to establish a timeline of events and to replicate the seriousness of the emitted smoke during the overheat condition. On 12 January 2024, the manufacturer of the DF2000 oven organised a test in Houten in the Netherlands. For this test, they installed additional temperature meters on a test oven, modified the connectors of the fan motor and the temperature probe, and disabled the 3-phase safety device. By doing this, an overheat condition could be duplicated. The test proved to be successful as the average timeline derived from the interviews with the crew about the duration of the overheat event matched the results from the test (see Appendix E). The result of the test is further analysed in Chapter 3.

2.9 Organisational and management information

2.9.1 Safety issue risk analysis

The DF2000 oven had been in use with the operator on several aircraft types from 2003. Because of earlier incidents, a safety issue risk analysis on the risk of use of this type of oven without including all service bulletins was performed by the Engineering & Maintenance's Safety & Quality department and also the operator[9] in 2022. The operator's Continuing Airworthiness Management Organisation (CAMO) decided to reject the implementation of Service Bulletin (SB) 2000-25-0001 (see Section 2.10.2). According to the CAMO, the oven could not be certified after the service bulletin was implemented, due to renewed certification standards for the galley equipment regarding minimum distance between the oven and adjacent galley walls. The operator's CAMO also argued that the additionally required cooling times for the oven would put too much restriction on the use of the oven for in-flight services. Both concerns originated from an investigation on the feasibility of the implementation of SB 2000-25-0001 by the operator's Engineering and Fleet Services department in 2014.

Of the original 900 DF2000 ovens in use with the operator, 550 ovens were still in use as of September 2023.

During the course of the investigation, the Dutch Safety Board was informed by the operator that in the future Service Information Letter (SIL)[10] H0212-25-0164 will be incorporated in maintenance procedures.

9 Integrated Safety Services Organisation (ISSO).
10 Section 2.10.3 explains what a Service Information Letter is.

2.9.2 Cabin crew training

General
Cabin crew training consisted of a yearly recurrent training regarding emergency procedures and general knowledge about the location of emergency equipment as well as the use of, for example, an automated external defibrillator. Every three years, this training incorporated a more extensive hands-on training (together with cockpit crew members) of firefighting techniques and the actual donning of personal safety equipment, like protective breathing equipment (PBE). The features of Halon are covered during the training with an emphasis on the fact that Halon should only be used if flames are visible, as Halon is not effective in case of an overheat event as it has no cooling capability. The training therefore contained events were there is only smoke and the trainees should not use the Halon fire extinguisher.

The captain, senior purser and purser all had received the training multiple times before the incident flight.

Firefighting training
The firefighting training is done in a classroom especially designed to simulate typical fire situations in a passenger cabin, like fires in an oven, in the lavatory area, in the overhead bins and also of a passenger seat. The latter simulating a typical lithium battery fire of a smart phone which overheats during a charging process or which gets damaged between moving parts of a passenger seat.

The fires consist of burning gas which can be controlled remotely by the safety instructor. The fire extinguisher bottles contain water under pressure and when applied on a fire produce a white steam cloud. No use is made of actual fire extinguisher bottles containing Halon.

To simulate an actual event as much as possible, the cabin crew also puts on a PBE. This PBE is a non-working device, where the oxygen generator is removed and the storage box of the PBE is not present. The unpacking of a PBE is therefore not trained but only verbally explained. During the incident flight, it turned out that especially the starting of the oxygen generator presented difficulties for some crew members.

During the fire exercise, the area where the fires are simulated is filled with smoke coming from a smoke generator. The heat, smell and noise levels as experienced in a cabin during flight in case of a fire/overheat condition are not simulated.

ABC-procedure[11]
The training of the ABC-procedure during a fire/smoke event requires two cabin crew members to enter the training area at the same time for the active and supportive roll during firefighting activities. The safety instructor plays the task of the communicator passively outside the training area. As the surrounding noise levels are low and one's

11 A stands for Attack the fire, B for Buddy to offer assistance and C for Communication with the flight deck and passengers.

voice is not distorted by the microphone, the communication between the cabin crew members and the instructor do not present any difficulty. This in contrast to using a working PBE. The use of a PBE during a training is therefore much easier than the use of a working PBE on board an aircraft during flight.

Oven fires

For the training of oven fires, a switch is installed on a wall simulating the galley wall with a galley area main power switch as well as a circuit breaker installed next to it. The galley area main power switch in the training area is a simple toggle switch and has no similarity with the galley area main power switch as installed on the Boeing 777 fleet which contains an internal green light and is a momentary action switch[12] type. In the training area, there is no possibility to check if electrical power is indeed removed from the galley equipment nor is this required by the procedure. A circuit breaker is installed, as the Boeing 737-800 galleys do not have a galley area main power switch. The oven fire procedure on Boeing 737-800 aircraft therefore requires the cabin crew to pull the circuit breaker of the oven.

During the training of an oven smoke/fire event, the cabin crew must switch off the galley area main power and keep the oven door closed. See Appendix B for the procedure in question.
If there is still a fire present, the cabin crew must open the oven door to positively identify the source of the fire or smoke. If flames are present, then a fire extinguisher application needs to be done into the base of the flames. If no flames are present, the fire extinguisher should not be used as the instructor also mentions that the Halon fire agent does not provide any cooling capability and therefore is useless in case of an overheat event. In such cases, the cooling should be done by means of applying water or any other non-flammable liquid as long as no electronic equipment is involved.

The fire-resistant gloves used during training become smooth and supple because of extensive use by the trainees. The fire-resistant gloves used on the aircraft are new and therefore much stiffer, which makes the handling of a fire extinguisher bottle more difficult.

The oven in the training area does not have an insert with trays and is therefore always empty. The removing of the insert from the oven during an oven fire/smoke event is not mentioned in any procedure nor is it discussed.

12 Momentary action switches are spring loaded to the extended position. They activate or deactivate systems or reset system logic. The switch display indicates system status.

2.10 Additional information

2.10.1 Manuals

The following manuals are considered relevant to the present investigation.

Boeing 777-200/-300 Flight Attendant Manual (FAM)
Boeing's FAM contains no procedures specifically for an oven overheat or fire but guidelines for cabin firefighting and smoke removal including for these type of events in the galley area.

OM-A Flight Safety and Security Manual (FSSM), 2.3.2. Halon/Halontron fire extinguisher
The FSSM explains the Halon fire extinguisher and its use on board the incident aircraft. See Appendix B.

OM-A FSSM, 4.9 Smoke, Fires & Fumes
The FSSM describes the standard firefighting procedure, the so-called 'ABC procedure'. Also, a flowchart is presented for an oven smoke/fire (in this report referred to as Oven smoke/fire procedure). Both are presented in Appendix B.

Smoke, Fire or Fumes checklist
After going to the aft galley to attain an overview of the origin and severity of the smoke, the captain, upon returning to the cockpit, consulted the Smoke, Fire or Fumes checklist with the first officer. See Appendix F. This checklist is part of the on-board electronic checklists of the Boeing 777. The same checklist is represented in an on-board paper checklist, the Quick Reference Handbook (QRH).

Trainer Guide for the 3-yearly recurrent training of cabin crew
The Trainer Guide directs trainers to mention that cabin crew should not use a Halon fire extinguisher when only smoke is observed as there are a limited number of Halon fire extinguishers on board the aircraft and because Halon is only effective if flames are observed.

Also, the trainer should mention that if during the exercise of fire-fighting a trainee uses a Halon fire extinguisher on a smoke event, the only result will be that there remains one extinguisher less in case of a real fire as Halon has no effect in case of smoke.

Cooling of an overheated area or equipment containing lithium batteries needs to be done with water or any other non-flammable liquid. No water fire extinguishers were available on the aircraft.

Component maintenance manuals
The component maintenance manuals for the DF2000 and OCM 2000 series provide the procedures to be followed in case of maintenance or a functional test of the oven and OCM. The latest issue date for the oven manual was 2022; for the OCM manual, this was 2015.

2.10.2 Service bulletin

A service bulletin (SB) is the document used by manufacturers of aircraft, their engines or their components to communicate details of modifications which can be embodied in an aircraft.[13] SBs intent to improve the reliability of aircraft systems by changing the design or maintenance requirements. Manufacturers recommend operators to adhere to the requirements as stated in SBs. It is not mandatory to incorporate SBs; it is up to the operator to decide whether or not to do so.

SB 2000-25-0001

To enhance additional safety to the DF2000 oven, Service Bulletin (SB) 2000-25-0001 was issued to counter a known failure mode of overheated optocouplers[14] on the power control board (PCB). Failure of the optocouplers could lead to a thermal runaway of the oven, even after it has been switched off but with the electrical power still connected.

SB 2000-25-0001 was originally issued on 1 January 2008 and revised on 29 April 2015 in the attempt to enhance the reliability of the oven and extend its life expectation by adding additional overheat protection devices. The SB provides better cooling of the PCB through an additional fan on the motor axle and therefore creating more airflow on the backside of the oven and cooling of the PCB. It also recommends the implementation of additional safety features (such as additional circuit breakers) among several other upgrades. See Appendix G.

2.10.3 Service information letters

A service information letter (SIL) is used by manufacturers of aircraft, their engines or their components to communicate details of advisory action or other 'useful information' about their products which may enhance safety, reliability or reduce repetitive costs.[15]

SIL H0212-25-0164

A SIL for the 3-phase safety device, concerning a recommended maintenance program, was issued on 2 December 2013 and amended on 20 April 2022. This SIL with number H0212-25-0164 recommends that the 3-phase safety device is checked every 18-24 months or 6,000-8,000 flight hours whichever comes first and every 36-42 months or 12,000-14,000 flight hours whichever comes first. It also recommends to replace the 3-phase safety device every five years for all units that have not incorporated SB 2000-25-0001.

Upon review of the maintenance records for the oven provided by the operator, it was determined that this oven, manufactured in 2007, had not incorporated SIL H0212-25-0164 as the 3-phase safety device was never replaced and no records existed that the 3-phase safety device was checked for its functionality.

13 https://www.skybrary.aero/articles/service-bulletin-sb (consulted on 15 January 2024).
14 An optocoupler consists of a LED, a light emitting diode which produces a light signal when a current flows, and a light sensitive transistor. When a certain current goes through the LED, light is transmitted from the LED to the transistor which in turn closes an electronic circuit and thus is able to work as a switch. There is no connection between the LED and the transistor.
15 https://skybrary.aero/articles/service-information-letter (consulted on 15 January 2024).

SIL H0212-25-0328
Field experience and research show that many failures are caused by lack of maintenance and unincorporated product improvements. With SIL H0212-25-0328[16], the manufacturer therefore emphasizes the importance of periodic maintenance, regular inspection/replacement of life limited components and incorporation of product improvements per SB.

2.10.4 Similar occurrences of oven overheat events

On 18 August 2019, an oven fire occurred on board a Boeing 777-200ER of the operator. The operator investigated the occurrence and prepared a report.[17] The report mentions that review of engineering databases and occurrences showed 22 oven incidents related to an electrical failure over the last 2 years. These failures were often caused by a burned power module assembly print board.

The report contains two conclusions. First, it was concluded that the DF2000 oven type operates at temperatures that cause degradation of the oven components. Although most reliability issues have no direct impact on safety, failure of some components can result in uncontrolled heating. The second conclusion was that the DF2000 oven type is a 'fade out' product, which does not meet the latest certification requirements. Although previously approved configurations are still certified, it is very difficult to certify new changes and product improvements.

In response to the occurrence of the 2019 oven fire, the manufacturer recommended to apply SB 2000-25-0001 to the DF2000 ovens in order to assure the unit electronics are being operated within its specifications.

2.11 Use of Halon

Decommissioning of fire extinguishers containing halons
Halon 1211, Halon 1301 and Halon 2402 are ozone-depleting substances listed as controlled substances in the Ozone Regulation[18] (see Appendix C). Their production in EU Member States has been banned since 1994, as required under the Montreal Protocol[19], but they may be placed on the EU market and used for 'critical uses', including some uses on aircraft.

Halons are fire-extinguishing agents that have been used in aircraft fire-protection systems. Historically, it has been difficult to replace them with alternative agents with a lower ozone-depleting potential[20], so 'critical uses' (applications) of halons have been accepted, subject to:

16 Initially issued on 20 April 2022.
17 Reactive SIRA Report Oven fire.
18 Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer.
19 The Montreal Protocol and its subsequent amendments are designed to reduce emissions of some 90 ozone-depleting substances by phasing out their production and consumption.
20 A measure of how much damage a chemical can cause to the ozone layer compared with a similar mass of trichlorofluoromethane.

- 'cut-off dates', after which halons cannot be used for fire extinguishers or fire-protection systems for new equipment and new facilities for the application; and
- 'end dates', after which halons cannot be used for the application and by which fire extinguishers and fire-protection systems containing halons must be decommissioned.

Portable extinguishers, using halon 1211 and 2402, with the purpose of protection of cabins and crew compartments have a cut-off date of 31 December 2014 and an end date of 31 December 2025.[21] The main reason that halon may no longer be used for these purposes in the future is that it is a chemical that damages the ozone layer when released to the atmosphere. The operator in question aims at using the fire extinguishing agent halon until the by EASA determined end date of 31 December 2025. The operator will use the fire extinguishing agent halotron as a replacement for halon in its new aircraft. Although the use of fire-extinguishing agents has the potential to have an adverse effect on the health of the occupants of a commercial aircraft, it must be recognized that there is a need to combat fire and smoke on board.

21 EASA, *Halon replacement in the aviation industry*, November 2019.

3 ANALYSIS

3.1 Investigation of the oven

To answer the investigation question "Why did the oven overheat event occur?", it was necessary to have a complete understanding of the functioning of the oven to determine what factors contributed to the overheat of the oven to occur. Therefore, a teardown of the oven was necessary (Sections 3.1.1 and 3.1.2) as well as a test to duplicate the sequence of events (Section 3.1.3) besides an investigation into the maintenance history of the oven (Section 3.1.4).

3.1.1 Cause of the overheat condition of the oven

Based on the inspection of the oven, it had been operated with an aftermarket meal tray carrier from another manufacturer. Based on previous oven overheat incidents, the manufacturer concluded that it is plausible that the oven had been operated for several sequential, or very long cooking cycles (possibly heating up deeply frozen meals), without any cool-down time between cycles.

The meal tray carrier mostly had a closed perforated backside (see Figure 3, left). As a result, the heating time of the oven was significantly extended because of the disturbed airflow of the fan and heating elements. Confirmed by previous investigations of the manufacturer, this increased the temperature of the area behind the baffle plate as the closed backside reduced the heat distribution to the meals inside the carrier.

▲ *Figure 3: Left, carrier with meal trays and mostly closed perforated backside in oven.*

▲ *Right, meal tray carrier with an open back. (Source: B/E Aerospace)*

The operator reported that it is not unusual for airlines to purchase an insert from another manufacturer and that the oven manufacturer does not prescribe mandatory use of their brand inserts. The manufacturer of the oven confirmed that while it is not forbidden to use aftermarket inserts, they strongly recommend the use of an insert with an open back plate for the best operating performance of the oven. The reason why the insert type with the perforated back plate was chosen is that in the past liquids and packaging materials from meals ended up in the opening of the fan, because it remained relatively unprotected due to the open back of the other insert. This led to damaged and stuck fans inside the oven. There was a need for an extra barrier between the meals and the fan opening. The operator decided to solve this with a perforated backside for the insert.

The use of an aftermarket meal tray carrier with a mostly closed perforated backside had a negative effect on the reliability of the oven, as well as placing the oven at a higher risk for an overheat condition.

The result of these combined factors was that the ambient temperature of the oven power control electronics reached approximately 75 °C or higher. Once this occurred, the too high ambient temperatures near the power electronics influenced the control circuitry in such a way that the heating elements were inadvertently commanded on. This allowed the continuous powering of the heating elements, causing the temperature behind the oven to increase even further and keeping the power control board in a faulty condition.

3-phase safety device

Some time prior to this event, the 3-phase safety device's capillary tube was damaged by the heating element. This is evident from the fact that the ends of the line are fused, the damage to the surface of the heating elements, and the observation that the 3-phase safety device activation indicator did not show the device had been triggered by the overheat event.

The capillary tube could have potentially been damaged during maintenance or cleaning activities prior to the overheat event. As the capillary tube was installed from the date of manufacture of the oven (2007), the service information letters[22] concerning the change of the 3-phase device every five years (as reflected in the Component Maintenance Manual), had not been followed by the operator. As the 3-phase safety device was not checked during maintenance visits, the failure of it could go undetected. Not following the manufacturers recommendations regarding the 3-phase safety device did put the oven at a higher risk for overheating.

The combined effect of the power control board generating an 'on' signal to the heating elements and the 3-phase safety device incapable of cutting power to the oven, was that the oven overheated.

22 H0212-25-0164 and H0212-25-0328.

Smoke during the overheat event was mainly caused by melting parts installed on the back of the oven. The smoke therefore came through the upper cavity between the oven and the surrounding wall. Smoke from the inside of the oven was mainly caused by the use of Halon fire extinguisher agent on the heating elements and the melting aluminium fan. The oil in the capillary tube of the 3-phase safety device only produced minimal smoke. No other parts were identified as being capable of emitting large amounts of smoke.
As aluminium[23] melts at temperatures between 575 °C and 638 °C and the tubes[24] of the heating elements reached an estimated maximum temperature of 900 °C, the release of Halon on heated parts inside the oven resulted in the decomposition of Halon into toxic products which does not remain colorless.
As Halon has a higher specific weight than air, the smoke from the Halon fire extinguisher agent had a downward motion consistent with the observation from a flight attendant.

The investigation of the oven also revealed that the outer metal cover of the oven showed no signs of heat damage consistent with the report from the operator's maintenance department that only cleaning of the area around the incident oven was required. Although the electronics on the backside of the oven also sustained heat damage, the covers around the electronics only sustained minor heat deformation. The heat generated by the oven during the overheating therefore remained confined to the inside of the oven.

The oven overheat event did not cause damage to the surrounding area of the oven. All heat damage remained limited to the inside of the oven.

3.1.2 Electrical power to the oven

As soon as the purser was informed about smoke coming from the aft galley, she immediately went to the galley to identify the cause and observed that oven number 3 was the source of the smoke. By memory, she addressed the first step of the Oven smoke/fire procedure. This is to switch off the galley area main power, which removes electrical power to all galley equipment. As the light in the galley area main power button did not illuminate green at that moment, she assumed that the power must have been switched off automatically. During the investigation, the Board concluded that no automatic switching of the galley area main power switch is possible.

Without the green light on in the galley area main power button, it is not visible whether the switch (in the button) is on or off. The only other indication about the status of the switch must come from other electrical equipment or lights on the control panel indicating that power is established on the respective bus. As the Oven smoke/fire procedure does not incorporate a step that checks the actual state of the galley bus (being on or off), the crew relied on the green internal light of the galley area main power switch indicating the correct state. As the green light was not illuminated during the whole oven overheat event, the crew was convinced that all power to the oven had

23 The fan material is AL5083.
24 The tube material of the heating elements has a maximum sheath temperature of 871 °C.

been switched off. The circuit breaker of the incident oven was never pulled, as the Oven smoke/fire procedure does not mention this step.

The Dutch Safety Board deemed it necessary to investigate the electrical power control board (PCB) of the oven more in-depth to establish what caused the removal of electrical power to the incident oven. This was done in Lenexa (USA), as the incident oven was still in storage at the investigation department of the manufacturer. This investigation revealed that two out of three heating elements were damaged, causing them to no longer function, and the third heating element sustained enough damage to restrict the emitted heat. This allowed the temperature on the PCB to drop enough, resulting in the electronics to follow the 'off' signal from the oven control module and switching off all power to the heating elements. The investigation of the PCB confirmed that the electronics remained fully functional throughout the incident and therefore also their sensitivity for failure when the critical temperature is reached.

Electrical power to the failed oven was not removed by actions from the cabin or flight crew. The smoke event of the oven stopped because of the failure and damage of the heating elements. This enabled the temperature on the power control board to drop enough to allow the electronics to follow the commanded 'off' signal from the oven control module. This resulted in switching off all electrical power to the heating elements and the oven cooled down completely.

3.1.3 Duration of electrical power to the oven

As soon as smoke was detected by a passenger coming from the aft galley, the purser returned to the aft galley and investigated the situation. She immediately identified that the smoke was originating from the number 3 oven on the starboard side of the airplane.
During the firefighting procedures by the cabin crew, multiple protective breathing equipment (PBE) were used. At a certain point one cabin crew member noticed that her PBE stopped working, meaning that the oxygen generator reached it's designed operating time of 20 minutes. The duration of the smoke event could therefore be estimated to be between 20 and 30 minutes. This is in accordance with the estimates given by the cabin and flight crew members during their interviews.

In Houten, during the testing of the oven in an overheat condition, the same damage to the oven as the incident oven could be reproduced. During this test, the failure of the heating elements happened approximately 20 minutes after continued electrical powering.

The duration of the smoke event is estimated at between 20 and 30 minutes.

3.1.4 Non-incorporation of SIL and SB

The oven in question was manufactured in 2007 and the oven control module in 2003. The first registered maintenance visit took place on 23 October 2013 where the heating elements were replaced. As the capillary tube for the 3-phase safety device runs in close proximity to the heating elements, an opportunity existed for misplacing or damaging the tube. The operator did not demonstrate records, indicating that Service Information Letter H0212-25-0164 (released on 2 December 2013 and revised on 20 April 2022) regarding additional instructions for the checking of the 3-phase safety device and the replacement of it every five years, had been incorporated in maintenance procedures. It was also not demonstrated that the 3-phase safety device had been checked for correct operation before the incident took place.

Upon review of the maintenance records for the oven provided by the operator, it was determined that this oven had also not incorporated the recommended Service Bulletin (SB) 2000-25-0001 (issued on 1 January 2008 and revised on 29 April 2015). The implementation of this SB was deemed unsuitable by the operator due to certification requirements of the modification and limitations on the use of the oven.
The SB recommends implementation of an improved power module, motor, fan, and heating elements among other upgrades. The incorporation of this SB has been proven to prevent a potential failure of the power control board from controlling the temperature in the oven. If the ambient temperature of the oven power control electronics is over approximately 75 °C, the fan "on" signal can be interpreted as the oven heating elements "on" signal. This means that during an overheat error where the fan signal is commanded on, the oven heating elements will also remain on and will continue heating the oven.[25]

The non-incorporation of Service Information Letter H0212-25-0164 into the operator's maintenance procedures, resulted in not noticing the damage to and the incorrect operation of the 3-phase safety device and resulted in not replacing the device. The non-incorporation of Service Bulletin 2000-25-0001 resulted in certain overheat protection devices and safety features not being installed in the oven. As a result, the overheat condition of the oven could arise.

3.2 Cabin crew action

For the investigation of the crew action, it was necessary to investigate both the factors that played a role in the flight and cabin crew's firefighting efforts and the result of each effort.

3.2.1 The galley area main power button

The first action by a flight attendant when performing the Oven smoke/fire procedure should be to switch off electrical power to the galley by pushing the galley area main power button. This button has a green internal light which illuminates when electrical power to all galley equipment is available. The button itself is a so-called momentary action switch, meaning that the position of the switch after it is pushed on or off does not change as opposed to a toggle switch. Without the green internal light of the main power button operable, a flight attendant cannot determine whether the switch is on or

25 The manufacturer is aware of two other thermal overheat incidents of the same operator (in 2019 and 2021), observed on a DF2000 oven which had not implemented the recommended service bulletin.

off. The preflight check of the galley therefore incorporates a check if the green internal light of the galley area main power button is working when switched on. As the cabin crew did not mention any malfunctioning of the green light during their preflight procedure, the galley area main power button indication light most likely illuminated correctly.

During inspection of the galley area main power button after the incident by an investigator of the Dutch Safety Board, the switch including the green light was confirmed to be operating normally.

The Safety Board did not investigate the reason for the intermittent illumination of the green internal light of the galley area main power button, as a cause would be difficult to trace. Also, the benefit of knowing the exact cause, if at all possible to determine, would be limited, as this light might fail at any time during the flight. The Oven smoke/fire procedure does not incorporate a step to verify that electrical power to all galley equipment is indeed removed. As several crew members only asked the purser if the galley area main power button had been switched off without independent verification, the switching of the button was solely dependent on the purser.
The test of the sequence of events in Houten confirmed that switching off all power to the oven would have stopped the overheat condition within minutes.

> The procedure for an oven smoke/fire incident did not include a verification step that all electrical power has been switched off to a failed oven or other galley equipment.

3.2.2 Firefighting activities of the cabin crew

During the overheat event, ample Halon fire extinguishers were used despite the fact that no flames were present in the oven. The orange glow behind the back wall of the oven as well as the glow of the metal piece on the bottom of the oven, along with the dense smoke, may have contributed to the confusion about the presence of flames.

Although Halon has little to no effect when flames are not present, it produces a lot of smoke on heated surfaces. The application of a large amount of Halon fire extinguisher worsened the oven incident, as the increased smoke caused increased breathing difficulties.

In the case of a fire, Halon shall be used to extinguish it. It will extinguish the fire quickly. As a result, the temperature will not become as high as in the incident oven and the decomposition temperature of Halon is not reached.

> Halon fire extinguisher gas was exposed to temperatures well above its decomposition temperature and it therefore became toxic. It also caused the smoke to increase and did not provide any cooling to the overheated parts of the oven. The use of Halon fire extinguisher agent was therefore inappropriate during the oven overheat event.

3.2.3 Differences between training and actual conditions

As the smoke during the oven overheat event was dense, the crew used protective breathing equipment (PBE) as well as heat protective gloves. The operator identified several areas of improvement in the training of crew members during the investigation. First of all on the importance for the checking of flames during smoke events, but also emphasizing the difference between training equipment and the equipment on board an aircraft. For example, the gloves used during training are more flexible and better to use than new gloves as used on the aircraft. Also, the non-working and not sealed PBEs during training and the ones used on the aircraft differed significantly. Since the operator has indicated to include these lessons in future crew training, the Dutch Safety Board has not investigated this further.

> The operator has identified several areas for improvement in training crew members in the importance for the checking for flames during smoke events, as well as the difference between training equipment and the equipment on board an aircraft.

3.2.4 Opening of the oven door in case of a fire/smoke event

The procedure for the oven smoke/fire events directs the cabin crew members to verify if a fire is present inside the oven. The only way to make the assessment between a fire or an overheat condition is to open the oven door and look for flames. Opening of an oven door immediately releases a large amount of smoke, as the heated air will escape from the oven cavity. It will also allow oxygen to enter the oven and thereby possibly increase an existing fire.

As the oven is designed to withstand high temperatures without the risk of heat transfer to the surrounding area, the benefit of opening the oven door should be weighed against the negative effects. A fire inside the oven will most likely self-extinguish if the oven door is kept shut. This is also mentioned in the Oven smoke/fire procedure, but a timeline for the cabin crew is not given. With dense smoke emitting from the oven, the actions by the cabin crew will in most cases result in opening of the oven door, as the urge to start firefighting activities is often felt.

During training, an oven fire/smoke situation always leads to the opening of the oven door as the crew has to check for flames. This allows the trainer to see if the cabin crew member will use the fire extinguisher under the correct condition. Hence, not opening the oven door is not trained nor assessed.

> The smoke/fire procedure as well as the training for an oven smoke/fire condition did not clearly reflect when the opening of the oven door is necessary, given the condition that a fire may self-extinguish and an overheat condition will not persist if all electrical power is removed to the oven.

3.3 Final remarks

Controlling the incident situation
After the overheating of the oven began, certain events exacerbated the consequences of the incident. Although no flames were visible, the orange glow and amount of smoke from the back of the oven led the crew to believe that a fire was present, prompting them to use Halon fire extinguishers. Opening the oven door while applying Halon increased the amount of smoke coming from the oven.

Crucially, during and after the incident, the oven's electrical power remained connected. The cabin crew, following the Oven smoke/fire procedure, believed power had been disconnected since the galley area main power button's green light was off. This, in turn, led the flight crew to believe it was no longer necessary to switch off the utility bus from the cockpit.

All crew members were confident they had performed their respective smoke/fire procedures correctly. The crew's existing procedures did not mandate further verification to confirm the status of electrical power. Maintaining in control of an incident during high-stress, emergency situations is important. Enhancing crew training with specific emphasis on evaluation of an incident situation and verifying electrical disconnections could help mitigate a similar incident and its consequences in the future. During the investigation, the airline was already alerted by the Dutch Safety Board on the importance of pulling a circuit breaker in case of an electrical fire/smoke event to ensure that the oven in question is no longer powered. Also, the importance of keeping the oven door shut during an overheat event was pointed out by the Dutch Safety Board during the investigation, as the oven is designed to confine high temperatures to the inside of the oven.

4 CONCLUSIONS

Cause of the smoke originating from the oven

The use of a meal tray carrier with a mostly closed backside extended the heating time of the oven significantly and it disturbed the airflow in it. The result was a raised temperature behind the oven. This influenced the control circuitry in such a way that the heating elements were inadvertently commanded on. It caused the temperature behind the oven to increase even further, keeping the power control board in a faulty condition. At this point, the 3-phase safety device was already damaged and inoperable and could not turn off electrical power to the oven. The temperature inside the oven also continued to rise to such a degree that it experienced an overheat condition and smoke was coming from the oven into the galley.

The removal of electrical power to the oven, as dictated by the Oven smoke/fire procedure, did not happen during the entire oven overheat event as the galley area main power was not switched off. Also, at no point was the correct position of the galley area main power button verified by checking the powering of other galley electrical equipment. The circuit breaker of the oven was not pulled by the cabin crew nor were they directed to do so by the Oven smoke/fire procedure.
The flight crew did not switch off the utility bus as directed by the Smoke, Fire or Fumes checklist as they considered it as unnecessary. The reason for this was that they were convinced that the power to the aft galley was already removed by means of switching off the galley area main power switch. As a result, electrical power to the failed oven remained connected even after the flight and cabin crew assessed the oven overheat event as stopped.

As a result of the failure of the heating elements, the temperatures behind the oven dropped significantly so that the power control board functioned correctly again and transmitted the commanded 'off' signal by the oven control module to the heating elements. The oven overheat event thus stopped. The oven overheat event did not cause damage to the direct surrounding area of the oven. All heat damage remained limited to the inside of the oven.

The operator indicated that at the time of the occurrence, Service Information Letter H0212-25-0164 had not been incorporated in maintenance procedures. This service information letter gives additional instructions for the checking of the 3-phase safety device and the replacement of it every five years and is incorporated in the Component Maintenance Manual.

Service Bulletin 2000-25-0001, which recommends the incorporation of an improved power module, motor, fan and heating elements among other upgrades, had also not been incorporated by the operator. The incorporation of this service bulletin has been proven to prevent a potential failure of the oven control module and temperature probe from controlling the temperature in the oven. The implementation of this service bulletin was deemed unsuitable by the operator due to certification requirements of the modification and limitations on the use of the oven.

Operator's firefighting procedures and firefighting efforts by the flight and cabin crew
No flames were observed inside the oven, but the orange glow in the back of the oven together with the amount of smoke caused by the overheat event led the crew to believe that a fire must have been present. In the eyes of the crew, the use of Halon fire extinguishers was therefore warranted. The application of Halon into the oven did not provide any cooling capability but increased the amount of emitted smoke coming from the oven. The Halon gas was exposed to temperatures well above its decomposition temperature and became toxic. The use of Halon fire extinguisher agent was therefore inappropriate during the oven overheat event.

The training of the cabin crew stressed the importance of not manipulating and not resetting tripped circuit breakers. This led to the general impression by the cabin crew that pulling of a circuit breaker was also not allowed even in the presence of fire or smoke emitting from electrical equipment. Only after consultation with the flight crew, the pulling of a circuit breaker was allowed.

During the investigation, the airline was already alerted by the Dutch Safety Board on the importance of pulling a circuit breaker in case of an electrical fire/smoke event to ensure that the oven in question is no longer powered. Also, the importance of keeping the oven door shut during an overheat event was pointed out by the Dutch Safety Board during the investigation, as the oven is designed to confine high temperatures to the inside of the oven.

APPENDIX A

Responses to the draft report

In accordance with the Dutch Safety Board Act, a draft version of this report was submitted to the parties involved for review. The following parties have been requested to check the report for any factual inaccuracies and ambiguities:

- Air Traffic Control the Netherlands (LVNL)
- B/E Aerospace, Inc. a part of Collins Aerospace
- Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA)
- Cabin crew members
- Dutch Ministry of Infrastructure and Water management
- European Union Aviation Safety Agency (EASA)
- Flight crew members
- KLM Royal Dutch Airlines
- National Transportation Safety Board (NTSB)
- The Boeing Company

The responses received, as well as the way in which they were processed, are set out in a table that can be found on the Dutch Safety Board's website (https://onderzoeksraad.nl/en/).

The responses received were processed in the following way:

- Corrections and factual inaccuracies, additional details and editorial comments thatwere taken over by the Dutch Safety Board (insofar as correct and relevant). The relevant passages were amended in the final report.
- Responses that were not adopted by the Dutch Safety Board. The reason for this decision is explained in the table.

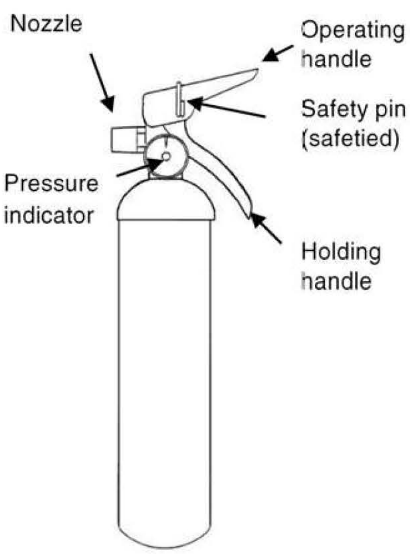
APPENDIX B

OM-A Flight Safety and Security Manual (FSSM), procedures cabin crew

2.3.2 Halon/halotron fire extinguisher (red)

Pre-flight check: check pressure (yellow needle must be in the green area).

The halon/halotron fire extinguisher can be used safely for all kinds of fires but is less effective on burning solid materials (no deep cooling).



To operate:

- Check pressure (yellow needle in green area).
- Remove safety pin.

Caution: *Do not squeeze the holding handle and operating handle too tightly together during extraction of the safety pin because this makes it difficult to remove the pin.*

- Keep extinguisher upright, hand under holding handle.
- Control discharge by squeezing operating and holding handles.

Discharge time ± 10 seconds.

Halon/halotron:

- is heavier than air;
- is slightly toxic in high concentrations.

Warning: *Do not discharge directly on exposed skin and eyes.*

Note: *All flight crew members must wear oxygen masks and use (100%) oxygen with emergency selected when using a fire extinguisher on the flight deck.*

Note:

- *The halotron extinguishing agent is more environmentally friendly than halon.*
- *The halotron extinguishing agent is 50% heavier than halon.*
- *The bottles differ in weight: 1.7 kg for halon and 2.7 kg for halotron.*
- *The bottles differ in size: the halotron bottle is slightly bigger than halon.*
- *The general appearance, effectiveness and how to*

4.9.5 Standard firefighting procedure ('ABC procedure')

The CA who first notices smoke or fire (CAa) shall get the nearest appropriate extinguisher.Meanwhile signals another CA (CAb) for assistance. A third cabin crew member (CAc) is necessary to communicate with flight crew and passengers. The following actions must always be taken, irrespective of the kind of fire:

CAa (Attack)	CAb (Buddy)	CAc (Communication) *
Alarm CAb (or instruct a passenger to do so)	Alarm CAc ((sr.) purser) about the nature of the problem (interphone)	Inform flight crew about the nature of the problem (interphone)
Obtain extinguisher, gloves and PBE unit	Obtain additional fire fighting equipment	PA announcement to inform the passengers that the necessary steps are in progress
Identify source	Remove oxygen bottles, PBE units, and baggage from the vicinity of the fire	Relocate passengers away from the fire area
Use PBE in case of smoke or fumes	Use PBE in case of smoke or fumes	Use PBE in case of smoke or fumes
Extinguish fire	Support CAa during fire fighting	Keep flight crew informed
Identify the cause of the problem		
Monitor for possible re-ignition		

* CAc and communication

The flight crew has to rely on the cabin crew member's senses. The flight crew will need to anticipate and make their judgments as to whether to continue the flight or not. Cabin crew shall not mention the word 'fire', unless flames are actually visible.

It is crucial that flight crew can rely on the information provided by cabin crew. Essential information from cabin crew to flight crew includes:

- Which cabin crew member is speaking and from what location;
- The location of the smoke/fire/fumes;
- The amount and colour of the smoke that is being produced;
- The associated smell;
- The cabin crew actions being undertaken;
- Passenger reaction and cabin crew actions to control the situation.

When there is a fire detected:

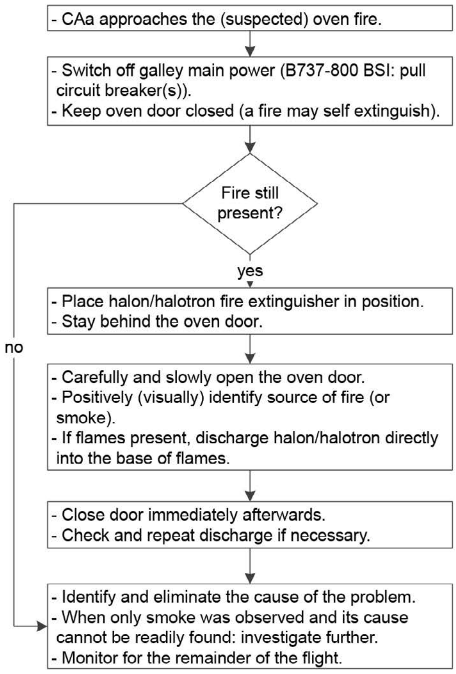
- The size of the fire;
- The source of the fire.

As soon as the fire is extinguished:

- The development of the situation;
- The conduct of post-fire procedures;
- The number of portable fire extinguishers used.
- Uncontrolled

4.9.9 Oven smoke/fire

When smoke is generated by an oven:



Note: The steps in this flowchart serve as guideline. Where necessary, adapt your actions to the actual situation at hand.

Note:

Regardless of the type of affected electrical galley equipment you should always turn off the main galley power (B737-800 BSI: pull circuit breaker(s)).

When the situation is declared safe and only after consultation with flight crew:
- pull circuit breaker of affected oven;
- switch on galley main power.

APPENDIX C

Halon fire extinguishers

Halons are fire extinguishing agents which are gaseous when discharged in the aircraft environment. Halons have, until recently, been in almost universal use in aircraft fire extinguishers, both portable and fixed. They exist in two forms, as Halon 1211, also known as 'BCF', and as Halon 1301.

- Halon 1211 is used only in portable extinguishers and is a streaming agent.
- Halon 1301 is used only in fixed extinguisher installations typically cargo holds or engines and is a total flooding agent.

Halons are electrically non-conducting and have been acknowledged as the most effective universal extinguishing agent for aircraft use. They work mainly by chemically interrupting the reaction described as the 'Fire Triangle' (Fuel-Oxygen-Heat), which must be sustained for a fire to continue. They do not produce residues and therefore do not cause secondary damage. However, the fumes are toxic if inhaled and all practicable precautions should be taken when they are used.

The chemical constituents in Halon gases, and the products of the reactions they induce when discharged on fires, have been identified as causing damage to the Ozone layer. As a result, their manufacture and use have been banned for many years in most countries and non-essential uses have been eliminated. However, the search for alternatives of comparable effectiveness has proved difficult and success limited, so they remain in wide use on board aircraft for most applications.[26]

Toxicity of Halon

Halon is chemical stable up to a temperature of 482 °C. Above this temperature, Halon will decompose in hydrogen bromide, hydrogen chloride, hydrogen fluoride, free halogens, and small amounts of carbonyl halides. These by-products have a sharp irritating odour as they mainly consist of toxic acids. From the carbonyl halides the Tetrachloride gas gives a brown-orange residue.

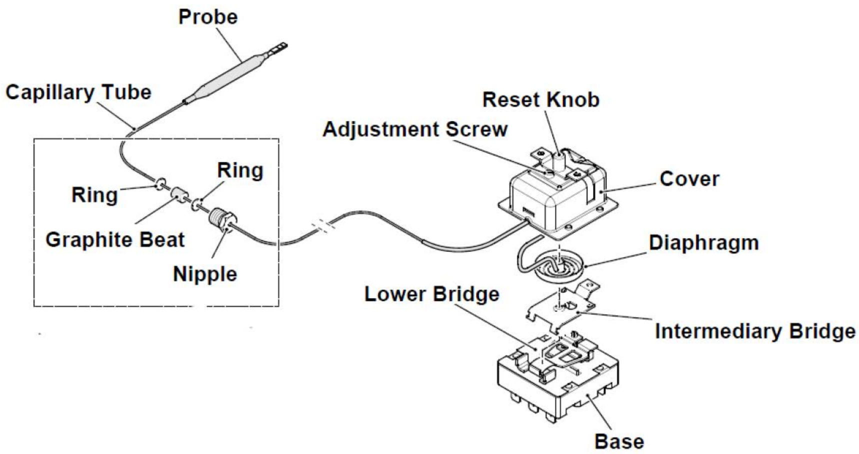
The other toxic aspect of Halon consists of the removal of oxygen and the inhalation of high concentrations of this gas may lead to heart arrhythmias. It also can cause an oxygen-deficient environment. Individuals breathing such an atmosphere may experience symptoms which include headaches, ringing in ears, dizziness, drowsiness, unconsciousness, nausea, vomiting, and depression of all the senses.[27]

26 https://skybrary.aero/articles/halon-fire-extinguishers (consulted on 1 September 2023).
27 https://ehs.umich.edu/wp-content/uploads/2017/01/SHFES_App_A.pdf (consulted on 1 December 2023).

APPENDIX D

3-Phase Safety Device

The operation of the 3-phase safety device



▲ *Figure 4: 3-Phase Safety Device Exploded View. (Source: B/E Aerospace)*

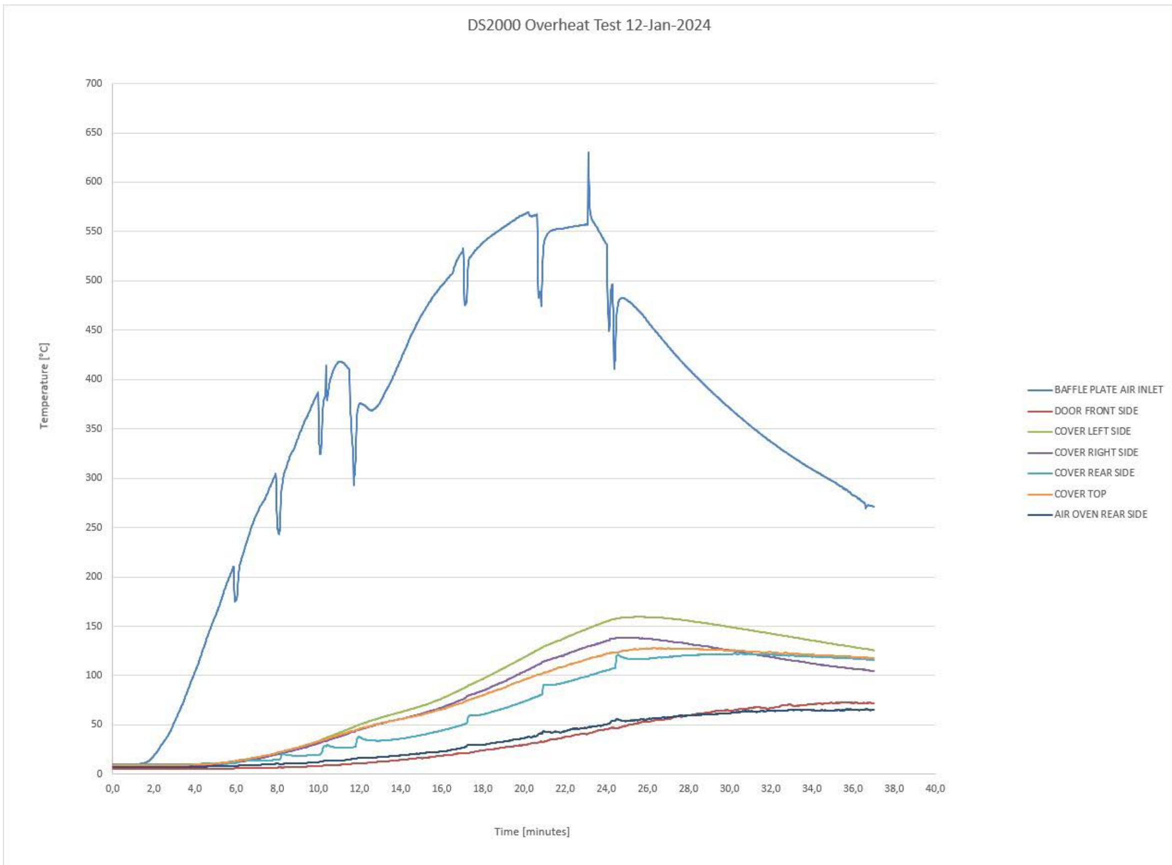
If the temperature inside the oven is increasing, a probe installed inside the oven will heat up and will react to the expansion medium inside the probe and capillary tube. The pressure inside the closed-circuit system will therefore increase. When the maximum temperature is exceeded, the pressure inside the tube will be high enough to exert sufficient displacement of the diaphragm so that a snap-action switch will open the electric circuit rendering the oven powerless. The probe inside the oven is located close to the heating elements and before the fan. The capillary tube runs from the probe through the back wall of the oven to the safety switch installed at the back of the oven and is very sensitive for bending.

When the temperature inside the oven decreases below the maximum allowed temperature, the pressure inside the capillary tube decreases allowing the reset switch to be pushed and thus restoring power to the oven.

The 3-phase safety device also comprises of an adjustment screw which allows the maximum allowed temperature to be set. It is factory set and sealed. Adjustments of the screw is not allowed as well as disassemble of the 3-phase safety device in order to prevent dangerous thermal failures of the oven.

APPENDIX E

Destructive test of a DF2000 oven



▲ *Figure 5: The values measured by the various temperature meters on the test oven while duplicating an overheat condition. (Source: B/E Aerospace)*

◀ *Figure 6: The inside of the test oven at maximum temperature. (Source: B/E Aerospace)*

◀ *Figure 7: Smoke coming from the oven in the test setup. (Source: B/E Aerospace)*

APPENDIX F

Smoke, Fire or Fumes checklist

8.6
KLM
777 Flight Crew Operations Manual

Smoke, Fire or Fumes

Condition: Smoke, fire or fumes occurs.

Objective: To remove power from the ignition source. To land the airplane as soon as possible, if needed.

1 Diversion may be needed.

2 Don oxygen masks and smoke goggles, if needed.

3 Establish crew and cabin communications.

4 IFE/PASS SEATS switch . . . . OFF

5 RECIRC FANS switches (both) . . . . Off

6 APU BLEED AIR switch . . . . Off

7 **Any time** the smoke or fumes becomes the greatest threat:

►►**Go to the Smoke or Fumes Removal checklist on page 8.23**

▼ Continued on next page ▼

8.7
KLM
777 Flight Crew Operations Manual

▼Smoke, Fire or Fumes continued▼

8 Choose one:

◆Source of the smoke, fire or fumes **is** obvious **and can** be extinguished quickly:

Isolate and extinguish the source of the smoke, fire, or fumes.

If practical, remove power from the affected equipment by switch or circuit breaker in the flight deck or cabin.

►►**Go to step 9**

◆Source of the smoke, fire or fumes is **not** obvious **or cannot** be extinguished quickly:

►►**Go to step 10**

9 Choose one:

◆Source **is** visually confirmed to be extinguished **and** smoke or fumes are **decreasing**:

Continue the flight at the captain's discretion.

Restore unpowered items at the captain's discretion.

►►**Go to the Smoke or Fumes Removal checklist on page 8.23, if needed.**

■ ■ ■ ■

◆Source **is not** visually confirmed extinguished **or** smoke or fumes **continue**:

►►**Go to step 10**

▼ Continued on next page ▼

March 24, 2022 8.7

8.8
KLM
777 Flight Crew Operations Manual

▼Smoke, Fire or Fumes continued▼

10 Advise the cabin that the main cabin lighting will be turned off.

11 CABIN/UTILITY switch. . . . . OFF

12 Initiate a diversion to the nearest suitable airport while continuing the checklist.

13 Consider an immediate landing if the smoke, fire or fumes situation becomes uncontrollable.

14 Do not delay landing in an attempt to complete the following steps.

15 C BLEED AIR ISLN switch . . . . Off

16 L PACK switch . . . . Off

17 L TRIM AIR switch . . . . Off

18 Do **not** accomplish the following checklists:

PACK L

TRIM AIR L

19 **Wait** 2 minutes unless the smoke or fumes are increasing.

▼ Continued on next page ▼

APPENDIX G

Service Bulletin 2000-25-0001

SB 2000-25-0001 was issued in 2008 and revised in 2015 and improves the reliability of the oven by adding additional overheat protection devices. It contains of;

1. A thermostat on the power control board with a trip point of 95 °C. It safeguards the temperature of critical components on the power control board.
2. A thermostat on the power control board heat sink (cooling ribs) with a trip point of 110 °C. It safeguards the temperature of critical components on the heatsink.
3. A 3-phase circuit breaker in the supply of the motor and the OCM. It safeguards against the current to the motor or the OCM becoming too high.

Both thermostats are connected in series with the thermostat and the thermal fuse of the motor. When the trip point of one of the thermostats is exceeded, it opens and interrupts the power supply of the OCM, causing to switch off the oven completely. The thermostats will reset after the oven has cooled down sufficiently. The circuit breaker in the motor does not reset automatically where after maintenance on the oven is needed.

The additional thermostat on the PCB may cause the oven to shut down after approximately 3-4 cycles continuously at unusual high galley temperatures. After the temperatures have decreased within normal limits, the thermostat will reset and the oven can be used again

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