# *Challenges in Emergency and Abnormal Checklist Design*

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at the NASA Ames Research Center


Human Factors
research and technology

The Emergency and Abnormal Situations project is funded through the NASA Aviation Safety and Security Program.

# *Emergency and Abnormal Situations Project*
# *Industry Contacts and Consultants*

| | |
|---|---|
| Manufacturers: | Boeing, Bombardier, Airbus Industries, BAe Systems, |
| Regulatory and Governmental Agencies: | FAA, CAA (UK), JAA, ICAO, Eurocontrol, NavCanada |
| Unions and Trade Groups: | ALPA, APA, SWAPA, ATA, IATA, AFA, ADF |
| Accident Investigation Bodies: | NTSB, TSB of Canada, ISASI |
| Airlines: | Airborne Express, Air Canada, Alaska, Aloha, American, Atlantic Southeast, Cathay Pacific, Continental, Delta, Fed Ex, Frontier, Hawaiian, Horizon, JetBlue, Southwest, United, UPS, US Airways, TWA (prior to merger) |


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# *Emergency and Abnormal Situations Project*

15 Different Categories of Issues – some are related to:

- Training
- Human Performance under Stress
- Automation and Automated Aircraft Systems
- Emergency Equipment and Evacuation Issues
- Checklists and Procedures


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# Smoke, Fire, and Fumes

# Checklists and Procedures

# *Smoke, Fire, and Fumes Checklists and Procedures*

## What Drives (or Should Drive*) the Design and Content?

- Differences in aircraft and equipment design
- Understanding of how different types of fires are ignited, fed, and spread
- Type of operations – extended range, passenger vs. cargo
- Assumptions about efficacy of crew response and expectations about amount of time available
- Human factors considerations, Understanding of human performance while under stress *
- History of the air carrier, History within the industry
- Philosophies, company policies, and economic considerations
- Regulations, Advisory Circulars, etc.


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# *Smoke, Fire, and Fumes Checklists and Procedures*

## *A Few of the Many Issues*

Ambiguity of cues / level of certainty about situation

Conflicting warnings / cues

Smoke / Fumes of an unknown origin

Determining / Accessing the proper checklist

Length of time to complete procedures

Initiate descent / diversion and when

What type of descent profile

Checklist wording – how compulsory

Reduced visibility – font size, layout

What memory items

Timing of source identification vs. smoke removal vs. descent initiation vs. fighting fire

High false smoke alarm rate

EROPS – nearest airport is far away

Ditching while on fire

How much troubleshooting

Fire in inaccessible places

Powering down electrical buses

Circuit breaker resetting

If / when to declare an emergency with ATC

Communicating / coordinating with Cabin crew


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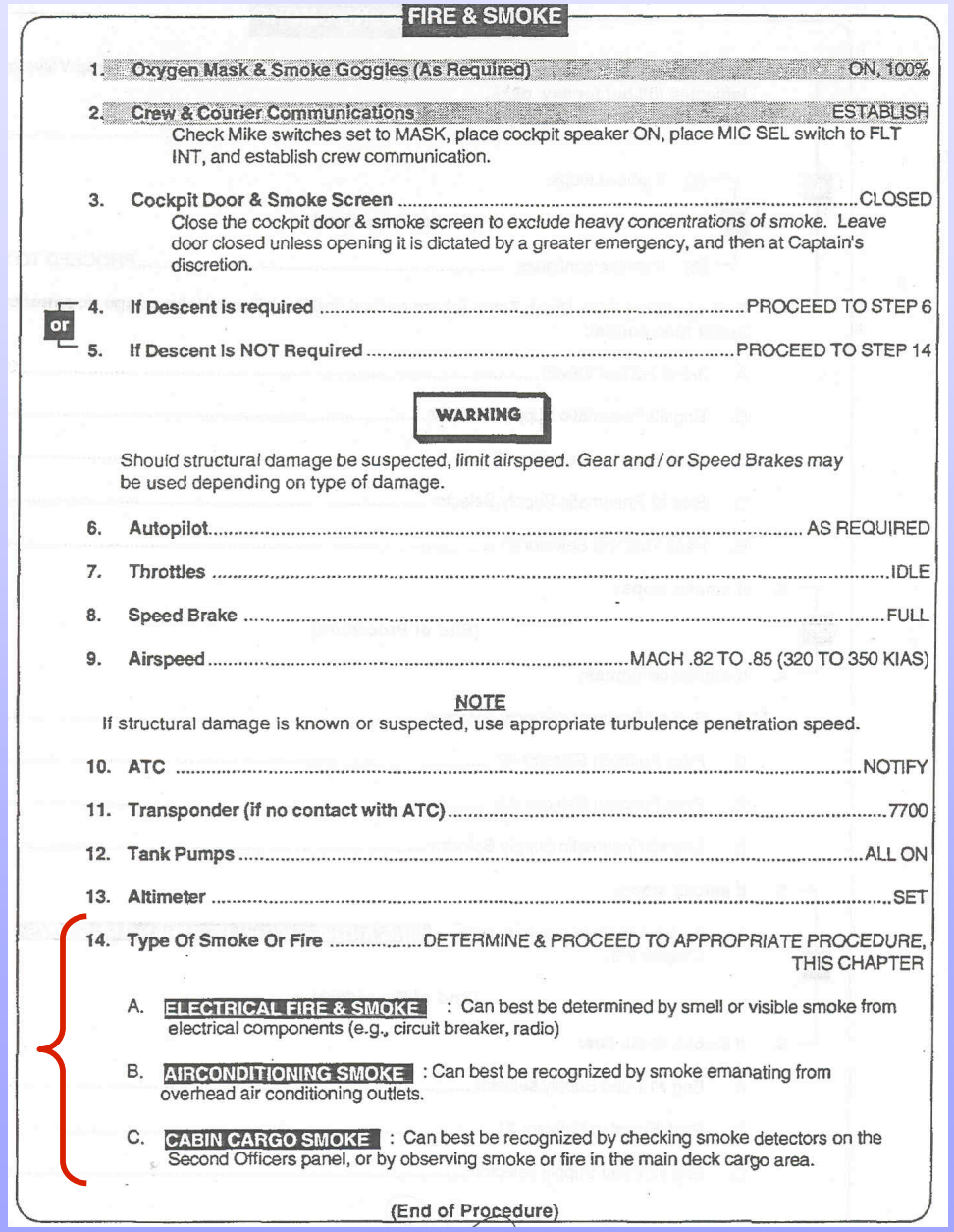
## Methods for Accessing the Correct Checklist:

- Gateway Checklist
- Several Separate Checklists
- One Integrated Checklist

# Accessing the Correct Checklist: Gateway Checklist



**FIRE & SMOKE**

1. **Oxygen Mask & Smoke Goggles (As Required)** ..... ON, 100%

2. **Crew & Courier Communications** ..... ESTABLISH
   Check Mike switches set to MASK, place cockpit speaker ON, place MIC SEL switch to FLT INT, and establish crew communication.

3. **Cockpit Door & Smoke Screen** ..... CLOSED
   Close the cockpit door & smoke screen to exclude heavy concentrations of smoke. Leave door closed unless opening it is dictated by a greater emergency, and then at Captain's discretion.

or

4. **If Descent is required** ..... PROCEED TO STEP 6

5. **If Descent Is NOT Required** ..... PROCEED TO STEP 14

**WARNING**

Should structural damage be suspected, limit airspeed. Gear and / or Speed Brakes may be used depending on type of damage.

6. **Autopilot** ..... AS REQUIRED

7. **Throttles** ..... IDLE

8. **Speed Brake** ..... FULL

9. **Airspeed** ..... MACH .82 TO .85 (320 TO 350 KIAS)

**NOTE**

If structural damage is known or suspected, use appropriate turbulence penetration speed.

10. **ATC** ..... NOTIFY

11. **Transponder (if no contact with ATC)** ..... 7700

12. **Tank Pumps** ..... ALL ON

13. **Altimeter** ..... SET

14. **Type Of Smoke Or Fire** ..... DETERMINE & PROCEED TO APPROPRIATE PROCEDURE, THIS CHAPTER

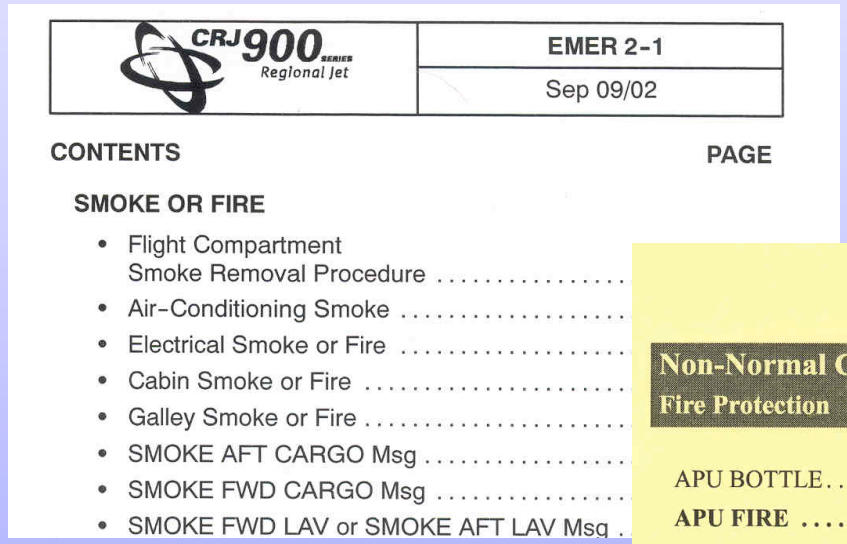
   A. **ELECTRICAL FIRE & SMOKE** : Can best be determined by smell or visible smoke from electrical components (e.g., circuit breaker, radio)

   B. **AIRCONDITIONING SMOKE** : Can best be recognized by smoke emanating from overhead air conditioning outlets.

   C. **CABIN CARGO SMOKE** : Can best be recognized by checking smoke detectors on the Second Officers panel, or by observing smoke or fire in the main deck cargo area.

**(End of Procedure)**

# Accessing the Correct Checklist: Several Separate Checklists



CRJ900 Series Regional Jet

EMER 2-1

Sep 09/02

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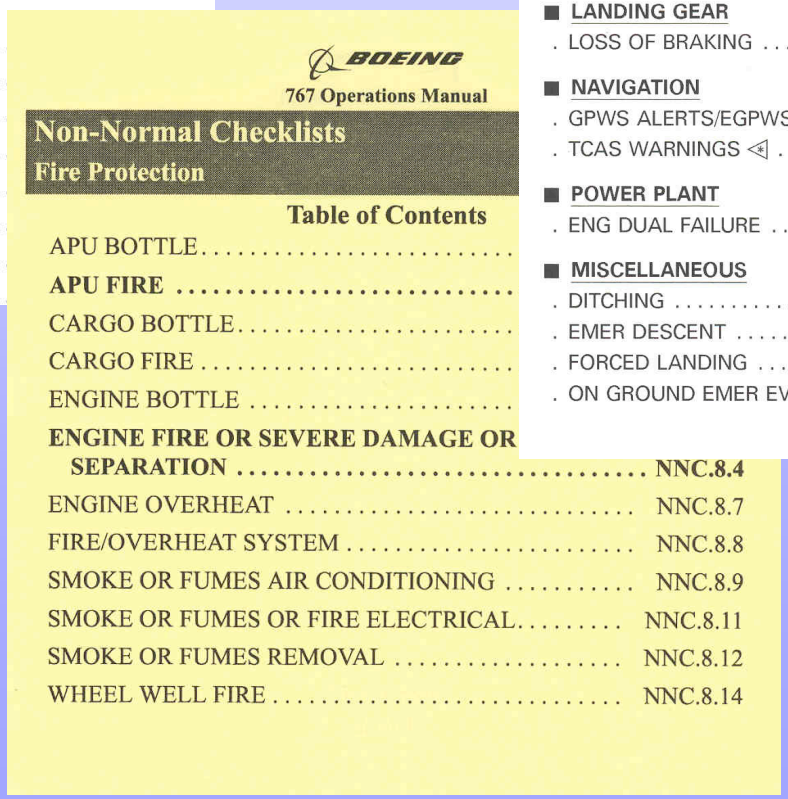
- Air-Conditioning Smoke .....
- Electrical Smoke or Fire .....
- Cabin Smoke or Fire .....
- Galley Smoke or Fire .....
- SMOKE AFT CARGO Msg .....
- SMOKE FWD CARGO Msg .....
- SMOKE FWD LAV or SMOKE AFT LAV Msg .



BOEING

767 Operations Manual

Non-Normal Checklists

Fire Protection

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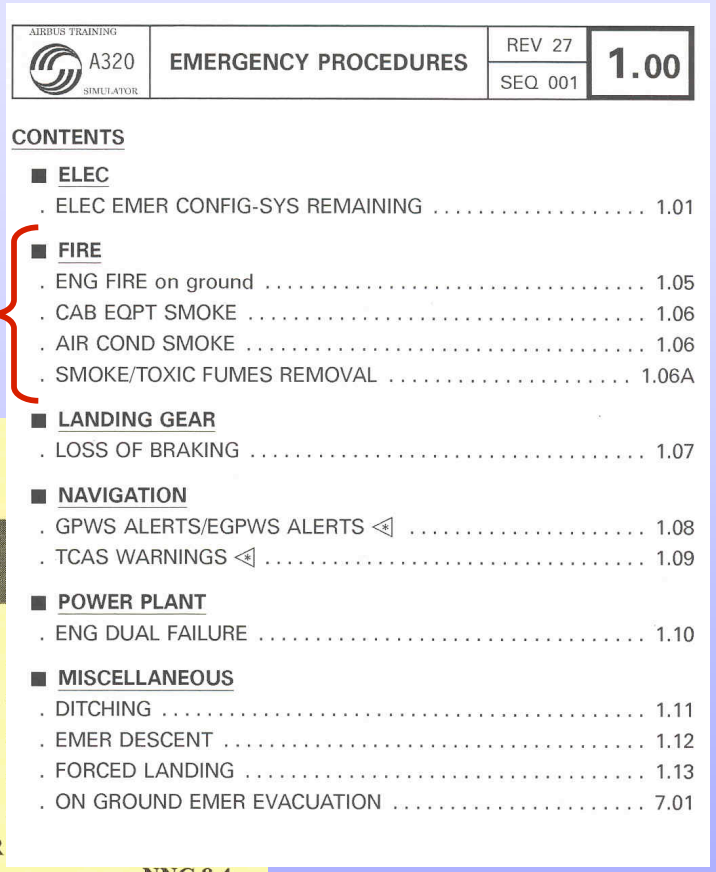

AIRBUS TRAINING A320 SIMULATOR | EMERGENCY PROCEDURES | REV 27 SEQ 001 | 1.00

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# Accessing the Correct Checklist: One Integrated Checklist

**SMOKE, CABIN/COCKPIT**

- Oxygen masks and regulators . . . . . On, 100%
- Crew and flight attendant communications . . . . . Establish
- Cabin fans switch . . . . . Off
- Blower switch . . . . . Override
- Extract switch . . . . . Override
- Galley/galley and cabin switch . . . . . Off
- Descent . . . . . Initiate

***WARNING:*** *Do not delay descent or diversion to find the smoke source.*

- Cabin signs . . . . . On

**CONTINUED FROM QRC**

If dense smoke at any time, accomplish reverse side.

*REFERENCE ACTION:*

If electrical, cabin, or galley equipment smoke/fire is suspected:

- Emergency exit light switch . . . . . On

If commercial switch installed:

- Commercial switch . . . . . Off

If commercial switch is not installed:

- Bus tie switch . . . . . Off
- Generator 2 switch . . . . . Off

If smoke persists or just before landing gear extension:

- Generator 2 switch . . . . . On
- Bus tie switch . . . . . Auto

**END**

If air conditioning smoke is suspected:

- APU bleed switch . . . . . Off
- Blower switch . . . . . Auto
- Extract switch . . . . . Auto
- Pack 1 switch . . . . . Off

If smoke does not decrease:

- Pack 1 switch . . . . . On
- Pack 2 switch . . . . . Off
- Cargo heat aft isolation valve switch . . . . . Off

If smoke persists:

- Pack 2 switch . . . . . On
- Blower switch . . . . . Override
- Extract switch . . . . . Override

**END**

If avionics smoke is suspected:

Accomplish AVIONICS SMOKE ECAM or Flight Manual procedure 14.20.39.

**END**

**DENSE SMOKE**

EMERGENCY DESCENT

- FCU altitude (safe altitude/10,000 feet) . . . . . Set
- FCU expedite switch . . . . . Push
- Target speed . . . . . Confirm, .80M/340KIAS
- Thrust . . . . . Confirm, idle
- Speed brakes . . . . . Extend
- ATC . . . . . Advise

SMOKE REMOVAL

- Pack flow selector . . . . . High
- Landing elevation selector . . . . . Safe altitude/10,000 feet

When at safe altitude/10,000 feet:

- Pack switches 1 + 2 . . . . . Off
- Cabin pressure mode selector . . . . . Manual
- Manual vertical speed control switch . . . . . Full up

When differential pressure is less than 1 PSI:

- Ram air switch . . . . . On

If cockpit smoke requires a cockpit window to be opened:

- Maximum speed . . . . . 200 KIAS
- Headsets . . . . . On
- Cockpit window . . . . . Open

EMERGENCY ELECTRICAL CONFIGURATION (If Required)

- Emergency electrical generator 1 line switch . . . . . Off
- Emergency electrical power switch . . . . . Manual on

When emergency generator available:

- APU generator switch . . . . . Off
- Generator 2 switch . . . . . Off

Before landing gear extension:

- Generator 2 switch . . . . . On
- Emergency electrical generator 1 line switch . . . . . On

Courtesy of Captain Richard Gilbert, UAL

# *What Drives (or Should Drive) the Design and Content?*

## Determining / Accessing the Proper Checklist

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# Emergency Descent and Diversion Guidance:

## Where in the Checklist

## and

## How Stated?


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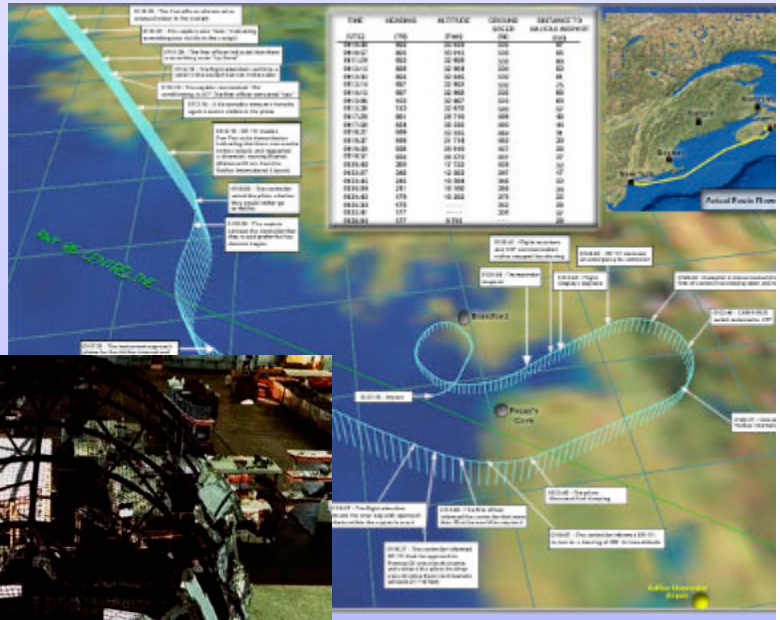
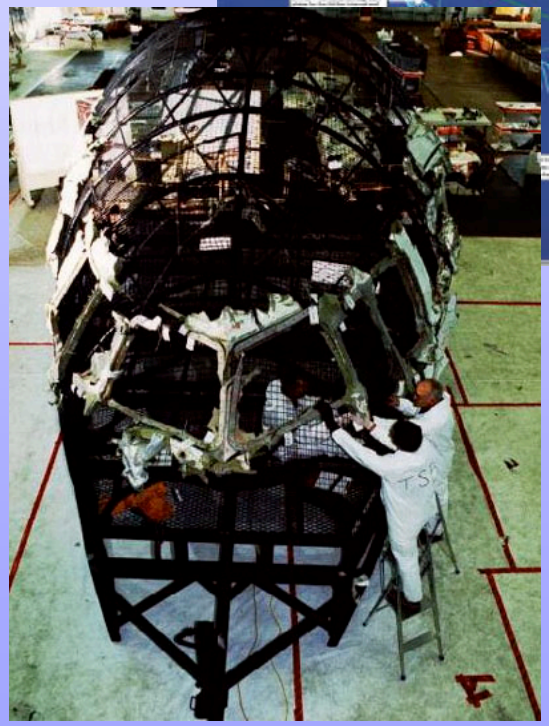
# *Swissair 111 - In-flight Fire*
# *Nova Scotia, Canada*
# *September 2, 1998*





OCT/25.JAN.96 | EMERGENCY CHECKLIST ALERT AND NON-ALERT | MD-11 | 41.1 Page 9

## AIR CONDITIONING SMOKE

ECON P/B ---------- OFF

SMOKE DECREASES

NO

No further action required.

END

AIR SYSTEM P/B ---------- MANUAL
ECON P/B ---------- ON
PACK 1 ---------- OFF

SMOKE DECREASES

NO

BLEED AIR 1 ---------- OFF
1 - 3 ISOL ---------- ON

DO NOT activate BLEED AIR 1 or PACK 1 for remainder of flight.

END

PACK 1 ---------- ON
PACK 3 ---------- OFF

SMOKE DECREASES

NO

BLEED AIR 3 ---------- OFF
1 - 3 ISOL ---------- ON

DO NOT activate BLEED AIR 3 or PACK 3 for remainder of flight.

END

PACK 3 ---------- ON
PACK 2 ---------- OFF

SMOKE DECREASES

NO

BLEED AIR 2 ---------- OFF
1 - 2 ISOL ---------- ON

DO NOT activate BLEED AIR 2 or PACK 2 for remainder of flight.

END

PACK 2 ---------- ON

Smoke is not of air conditioning origin.

Refer to EMERGENCY Procedure - SMOKE / FUMES OF UNKNOWN ORIGIN.

END

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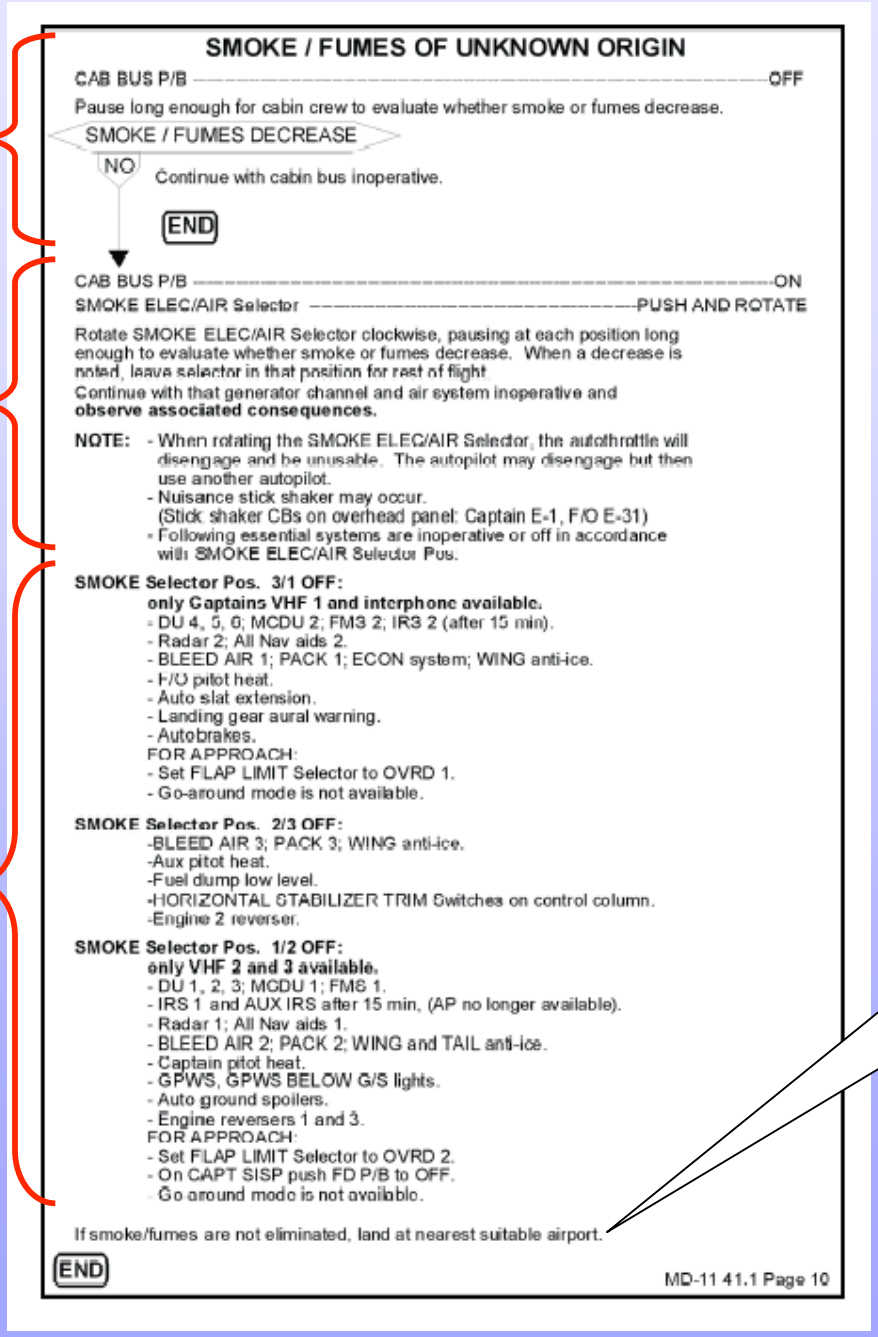

## SMOKE / FUMES OF UNKNOWN ORIGIN

CAB BUS P/B ---------- OFF

Pause long enough for cabin crew to evaluate whether smoke or fumes decrease.

SMOKE / FUMES DECREASE

NO — Continue with cabin bus inoperative.

END

CAB BUS P/B ---------- ON

SMOKE ELEC/AIR Selector ---------- PUSH AND ROTATE

Rotate SMOKE ELEC/AIR Selector clockwise, pausing at each position long enough to evaluate whether smoke or fumes decrease. When a decrease is noted, leave selector in that position for rest of flight.

Continue with that generator channel and air system inoperative and **observe associated consequences.**

**NOTE:**
- When rotating the SMOKE ELEC/AIR Selector, the autothrottle will disengage and be unusable. The autopilot may disengage but then use another autopilot.
- Nuisance stick shaker may occur. (Stick shaker CBs on overhead panel: Captain E-1, F/O E-31)
- Following essential systems are inoperative or off in accordance with SMOKE ELEC/AIR Selector Pos.

**SMOKE Selector Pos. 3/1 OFF:**
**only Captains VHF 1 and interphone available.**
- DU 4, 5, 6; MCDU 2; FM3 2; IRS 2 (after 15 min).
- Radar 2; All Nav aids 2.
- BLEED AIR 1; PACK 1; ECON system; WING anti-ice.
- F/O pitot heat.
- Auto slat extension.
- Landing gear aural warning.
- Autobrakes.

FOR APPROACH:
- Set FLAP LIMIT Selector to OVRD 1.
- Go-around mode is not available.

**SMOKE Selector Pos. 2/3 OFF:**
- BLEED AIR 3; PACK 3; WING anti-ice.
- Aux pitot heat.
- Fuel dump low level.
- HORIZONTAL STABILIZER TRIM Switches on control column.
- Engine 2 reverser.

**SMOKE Selector Pos. 1/2 OFF:**
**only VHF 2 and 3 available.**
- DU 1, 2, 3; MCDU 1; FM6 1.
- IRS 1 and AUX IRS after 15 min, (AP no longer available).
- Radar 1; All Nav aids 1.
- BLEED AIR 2; PACK 2; WING and TAIL anti-ice.
- Captain pitot heat.
- GPWS, GPWS BELOW G/S lights.
- Auto ground spoilers.
- Engine reversers 1 and 3.

FOR APPROACH:
- Set FLAP LIMIT Selector to OVRD 2.
- On CAPT SISP push FD P/B to OFF.
- Go around mode is not available.

If smoke/fumes are not eliminated, land at nearest suitable airport.

END

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# *Swissair 111 - In-flight Fire*
# *Nova Scotia, Canada*
# *September 2, 1998*

If smoke/fumes are not eliminated, land at nearest suitable airport

CRJ900 SERIES Regional Jet

EMER 2-4

Sep 09/02

## Air-Conditioning Smoke

**CAUTION**

The 'Flight Compartment Smoke Removal Procedure' should be used as necessary during smoke or fire conditions.

| | | |
|---|---|---|
| (1) | Oxygen masks/ smoke goggles | DON, SET TO 100% |
| (2) | Crew communication | ESTABLISH |

| | | |
|---|---|---|
| (3) | Flight compartment door | CLOSED |
| (4) | NO SMKG and SEAT BLTS | ON |
| (5) | AIR CONDITIONING, AFT CARGO | OFF |
| (6) | RECIRC FAN | OFF |
| (7) | Prepare to land immediately at nearest suitable airport. | |

**Immediate smoke removal required:**

**Yes**

| | | |
|---|---|---|
| (8) | Descent | INITIATE to 10,000 feet or lowest safe altitude |
| (9) | PRESS CONTROL | MAN |
| (10) | MAN ALT | UP |
| (11) | MAN RATE | Maximum INCR |

**When smoke has cleared:**

| | | |
|---|---|---|
| (12) | MAN ALT | HOLD |

**- END -**

**No**

▼

(7) Prepare to land immediately at nearest suitable airport

CRJ 900

# A320

## AIR COND SMOKE

*If electrical smoke from the avionic compartment is suspected, refer to the AVIONICS SMOKE abnormal procedure.*

– CREW OXY MASK ..... ON/100 %
*Use the emergency knob when necessary*
– CAB FANS ..... OFF
– APU BLEED ..... OFF
– PACK 1 ..... OFF

● **if smoke persists :**
– PACK 1 ..... ON
– PACK 2 ..... OFF
– SMOKE/TOXIC FUMES REMOVAL PROC
(see 1.06A, if necessary) ..... APPLY

R

NOTE : *If cargo ventilation system is installed, it is recommended that the cargo ventilation be closed to prevent a cargo smoke warning from being triggered by smoke coming from the cabin.*



## SMOKE/TOXIC FUMES REMOVAL

*Use the smoke removal procedure in case of dense smoke or toxic fumes (smell) or if smoke generation cannot be stopped.*
*If a scent similar to orange peel is smelt in the cockpit, suspect a toxic leak of rain repellent fluid (if installed).*

– CREW OXY MASKS ..... ON/100 %
*Check that the oxygen diluter is at 100 %.*
*Use the emergency knob when necessary.*
– SEAT BELTS/NO SMOKING ..... ON
– CAB FANS ..... OFF
– PACK 1 + 2 (if fuel vapors) ..... OFF
– PACK FLOW (if no fuel vapors) ..... HI
*Do not shut down air cond. packs and do not reduce ventilation in an attempt to smother the fire. Do not deploy pax oxygen masks if fire is suspected in the cabin.*
– LDG ELEV ..... 10 000 FT/MEA
– DESCENT (FL 100 OR MEA) ..... INITIATE
*PAX oxygen as required by regulation.*
– ATC ..... NOTIFY

● **When △P 1PSI or below :**
– RAM AIR ..... ON

● **if cockpit window opening required :**
– MAX SPD ..... 200 KT
– HEADSETS ..... ON
– COCKPIT WINDOW ..... OPEN

CAUTION
Due to increased noise level pay particular attention to visual warnings

**LDG ELV……10,000 FT/MEA**

**DESCENT (FL 100 OR MEA)….INITIATE**

## SMOKE OR FUMES AIR CONDITIONING

Condition: **A concentration of air conditioning smoke or fumes is identified.**

**OXYGEN MASKS AND SMOKE GOGGLES**
**(If required) . . . . . ON**

**CREW COMMUNICATIONS**
**(If required) . . . . . ESTABLISH**

**RECIRCULATION FAN SWITCHES (Both) . . . . . OFF**

[Removes fans as a possible source of smoke or fumes. Stops recirculation of smoke or fumes and increases fresh air flow.]

**GASPER FAN SWITCH . . . . . OFF**

**APU BLEED AIR SWITCH . . . . . OFF**

[Removes APU, if running, as a possible source of smoke or fumes.]

**If smoke or fumes continues:**

**LEFT AND RIGHT ISOLATION SWITCHES . . . . . OFF**

[Isolates left and right sides of the bleed air system.]

**RIGHT PACK CONTROL SELECTOR . . . . . OFF**

[Removes right side of the air conditioning system as a possible source of smoke or fumes.]

**If smoke or fumes continue:**

**RIGHT PACK CONTROL SELECTOR . . . . . AUTO**

[Restores right side of the air conditioning system.]

**LEFT PACK CONTROL SELECTOR . . . . . OFF**

[Removes left side of the air conditioning system as a possible source of smoke or fumes.]

**If smoke or fumes are persistent:**

**Plan to land at the nearest suitable airport.**

**Do not accomplish the following checklists:**
**PACK OFF**
**RECIRCULATION FAN**

B767-400

If smoke or fumes are persistent:

Plan to land at the nearest suitable airport.

# Emergency Descent and Diversion Guidance Summary: Air Conditioning Smoke

## (A Somewhat Unfair Comparison)

| Aircraft Type | Number of Checklists* | Location | Wording |
|---|---|---|---|
| MD-11 | 2 | Last item, 2nd checklist | If smoke/fumes not eliminated, land at nearest suitable airport |
| CRJ-900 | 1 | Middle of checklist (step 7) | Prepare to land immediately at nearest suitable airport. |
| A320 | 2 | Nowhere | N/A |
| B767-400 | 1 | Next to the last item | If smoke or fumes are persistent: Plan to land at the nearest suitable airport. |


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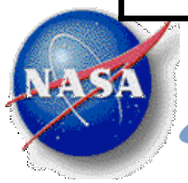
* to get to descent / diversion guidance

## Emergency Descent and Diversion Guidance Summary: Electrical Smoke / Fire

| Aircraft Type | Number of Checklists* | Location | Wording |
|---|---|---|---|
| CRJ-900 | 1 | First third of checklist (step 6) | Prepare to land immediately at nearest suitable airport. |
| A320 | - | There is no electrical smoke or fire checklist | N/A |
| | 1 | Avionics Smoke has items for electrical smoke – 1st item | LAND ASAP |
| B767-400 | 1 | Last item on the checklist | If smoke or fumes or fire persists or source is unknown: Plan to land at the nearest suitable airport. |

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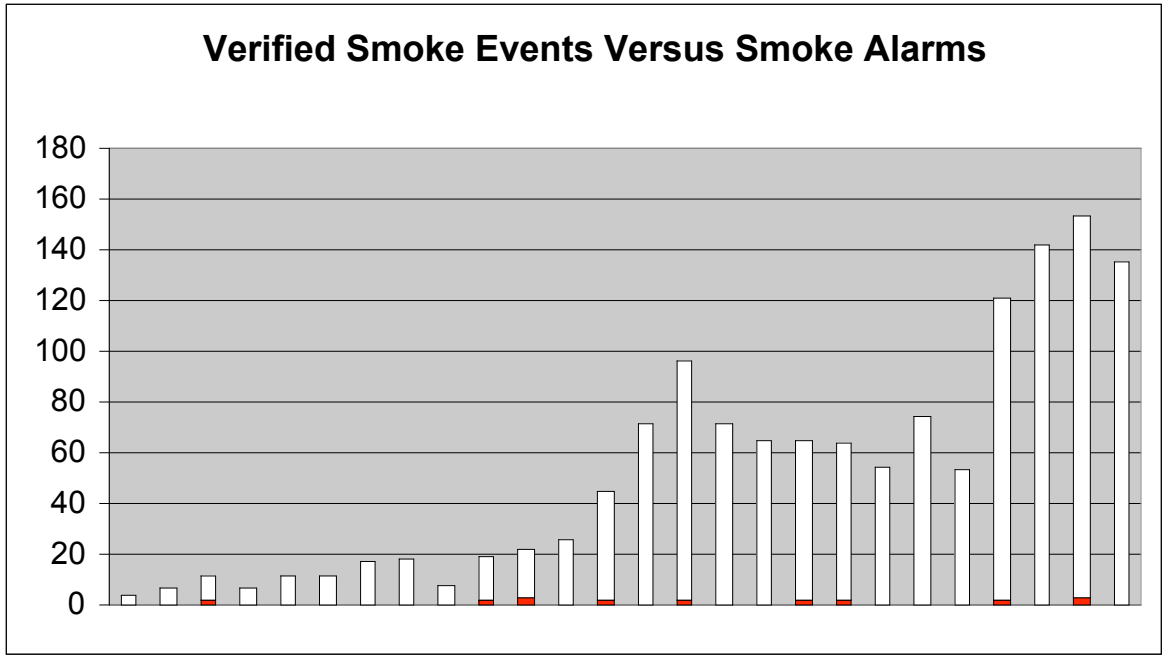
* to get to descent / diversion guidance

## Emergency Descent and Diversion

In a study of 15 in-flight fires that occurred between January 1967 and September 1998, the TSB of Canada determined that the average amount of time between the detection of an on-board fire and when the aircraft ditched, conducted a forced landing, or crashed was 17 minutes.

# *Smoke, Fire, and Fumes Checklists and Procedures*

False Cargo Smoke Alarms, 1974 -1999




D. Blake, 2000

Cost of Diversions: fuel, passenger ill-will, operational considerations, aircraft and crew scheduling, possible evacuation injuries, etc.

# *What Drives (or Should Drive) the Design and Content?*

## Descent and Diversion Guidance – Location and Wording

- Differences in aircraft and equipment design
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- Type of operations – extended range, passenger vs. cargo
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- Regulations, Advisory Circulars, etc. (AC 120-80: "…flight crew members should begin planning for an emergency landing as soon as possible after the first indication of fire" pg 6.)

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