Statens haverikommission
Swedish Accident Investigation Board

# Report RL 2004:26e

## Incident involving aircraft SE-LGZ in the air space over Mariehamn, Sweden on 31 January 2003

Case L-03/03

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SHK investigates accidents and incidents with regard to safety. The sole objective of the investigations is the prevention of similar occurrences in the future. It is not the purpose of this activity to apportion blame or liability.



The report is also available on our web site: www.havkom.se

Translated by Tim Crosfield from the original Swedish at the request of the Swedish Accident Investigation Board.

In case of discrepancies between the English and the Swedish texts, the Swedish text is to be considered the authoritative version.

The report is also available on our web site: www.havkom.se

Statens haverikommission (SHK) Swedish Accident Investigation Board

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2004-09-03 L-03/03

Swedish Civil Aviation Administration

601 79 NORRKÖPING

Sweden

**Report RL 2004:26e**

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an incident that occurred on 31 January 2003 in the air space over Mariehamn involving an aircraft with registration SE-LGZ.

In accordance with section 14 of the Ordinance on the Investigation of Accidents (1990:717), the Accident investigation Board herewith submits a final report on the investigation.

Carin Hellner

Mats Öfverstedt

Henrik Elinder

# Contents

# Report RL 2004:26e

L-03/03
Report finalised 2004-09-03

| | |
|---|---|
| *Aircraft; registration and type* | **SE-LGZ**, British Aerospace ATP |
| *Class/ airworthiness* | Normal, valid Certificate of Airworthiness |
| *Owner/operator* | European Turboprop Management AB/ West Air Sweden |
| *Time of occurrence* | 2003-01-31, 07.15 hours, in dawn light<br>*Note:* All times are given in Swedish standard time (UTC + 1 hr) |
| *Place* | In the air space over Mariehamn, (approx. posn. 6008N 01954E; 5 800 m above sea level |
| *Type of flight* | Freight |
| *Weather* | According to SMHI's[1] analysis:<br>Wind 310° kts/10 kts. visibility > 10 km, 0-2/8 stratus with base 500 ft. and 2-4/8 stratocumulus 3000-5000ft, temp./dp -15/-17°C, QNH 1010 hPa. |
| *Persons on board: crew* | 2 |
| *passengers* | - |
| *Injuries to persons* | None |
| *Damage to aircraft* | None |
| *Other damage* | None |
| *Pilot in command:* | |
| *Sex, age, licence* | Man, 48 years, D licence |
| *Total flying time* | 6 696 hours, of which 88 hours on type |
| *Flying hours past 90 days* | 87, all on type |
| *Number of landings past 90 days* | 43 |
| *Co-pilot* | |
| *Sex, age, licence* | Man, 32 years, B licence |
| *Total flying time* | 1 300 hours, of which 725 hours on type |
| *Flying hours past 90 days* | 80 hours, all on type |
| *Number of landings past 90 days* | 61 |

The Swedish Accident Investigation Board (SHK) was notified on 31 January 2003 that an aircraft with registration SE-LGZ had been involved in an incident at 07.15 hrs on that day in the air space over Mariehamn.

The incident has been investigated by SHK represented by Carin Hellner, Chair; Monica J Wismar, Chief investigator flight operations until and including 30 September, Mats Öfverstedt subsequently and Henrik Elinder, Chief technical investigator aviation.

The investigation was followed by Max Danielsson, Swedish Civil Aviation Administration.

[1] SMHI = Swedish Meteorological and Hydrological Institute

## Summary

Approximately 15 minutes after takeoff from Stockholm/Arlanda airport, a total loss of electricity occurred in the aircraft's right electrical system, whereupon all flight and navigation instruments (EFIS[2]) on the right hand side went U/S. In connection with the loss of electrical power, the main warning lamp started to blink, the blue mimic line in the R/H GEN switch went out, the R/H INVERTER and EXIT lit up on the emergency panel. By re-starting (switching off and on) some of the systems, normal electrical function was regained but after a minute or so it was lost again.

The pilots contacted air traffic control and requested clearance to return to Stockholm/Arlanda. They were radar-vectored for an approach and landing on runway 01L. The pilots did not recognize the problem and did not think that any point in the emergency checklist matched the fault. They therefore elected not to take any further fault-finding steps because of the risk of making the situation worse. The landing was performed without problems and without using flaps.

The electrical failure was caused by two independent faults, of which one arose in an early-version component with known weaknesses. The problem in the aircraft's electrical system is known to the manufacturer and steps have been taken both by the manufacturer and the aircraft company to rectify it. It would probably have been possible for the pilots to recover full electrical function by cross-connecting from the left electrical system, as becomes partly clear from the emergency checklist.

In SHK's view the checklist in use is not user-friendly and does not constitute the natural aid to the pilot in identifying a possible fault and taking the most suitable steps from the point of view of flight safety. It is complicated, the logic is not self-evident, the typeface is small, warning panel text is not reproduced as headings for steps to be taken, etc. SHK has noted that there is no international standard for the design of emergency checklists.

The incident was caused by two independent faults in the aircraft's electrical system occurring simultaneously.

## Recommendations

Reference is made to SHK recommendation RL 2004:13 R1 and R2 with the text:

*"The Swedish Civil Aviation Administration is recommended:*

- *in connection with the issuing of an AOC[3] to consider specially the design of emergency checklists from the point of view of understandability and user-friendliness (RL 2004:13R1) and*
- *in international flight safety work to promote the production of an international standard for the disposition, logic and layout of emergency checklists used in professional aviation (RL 2004:13R2)".*

[2] EFIS – Electronic Flight Instrument Systems

[3] AOC – Air Operator Certificate

# 1 FACTUAL INFORMATION

## 1.1 History of the flight

Aircraft SE-LGZ, line number SWN-808, was on a freight flight from Stockholm/Arlanda airport to Helsinki. About 15 minutes after takeoff, when the aircraft had reached FL 190 (approx. 5 800 metres) a total loss of power in the right electrical system occurred, whereupon all flight and navigation instruments (EFIS[2]) on the right side became U/S.

In connection with the power loss the main warning lamp started to blink, the blue mimic line in the R/H GEN switch went out, and the warning R/H INVERTER and EXIT lit up on the emergency panel. On the instruments the pilots saw that the right 28 V DC[4]-system was without voltage and the right battery was no longer connected. The instruments for the right engine did not work.

By restarting (switching off and on) some of systems, it was possible to regain normal function in the electrical system, but after a minute or so they went down again in the same way as previously.

The pilots then contacted air traffic control and requested clearance to return to Stockholm/Arlanda. They were radar vectored for an approach and landing on runway 01L. During the flight they switched off all current consumers from the right 28V DC-system. By transferring the right side AC[5] load to the left side AC-system, the function of the right EFIS was regained.

The pilots did not recognize the problem. They consulted the emergency check list (Card 34 and Card 36) but did not think that any of the cards in the check list matched the fault. They therefore decided not to make any further troubles hooting because of the risk of making the situation worse.

The landing took place without problems and without using flaps.

The incident occurred in position approximately 6008N 01954E, 5800 metres above sea level.

## 1.2 Injuries to persons

| | *Crew* | *Passengers* | *Others* | *Total* |
|---|---|---|---|---|
| Fatal | – | – | – | – |
| Serious | – | – | – | – |
| Minor | – | – | – | – |
| None | 2 | – | – | 2 |
| Total | 2 | – | – | 2 |

## 1.3 Damage to aircraft

None.

## 1.4 Other damage

None.

[4] DC – Direct Current

[5] AC – Alternating Current

## 1.5 The crew

### 1.5.1 Pilot

The pilot in command, a man, was aged 48 at the time of the incident and had a valid D Licence.

| *Flying hours* | | | |
|---|---|---|---|
| *latest* | *24 hours* | *90 days* | *Total* |
| All types | 0 | 87 | 6 696 |
| This type | 0 | 87 | 88 |

Number of landings this type previous 90 days: 43.
Latest PC (proficiency check) carried out on 2002-11-07.

### 1.5.2 Co-pilot

The co-pilot, male, was 32 years old at the time and had a valid B Licence.

| *Flying hours* | | | |
|---|---|---|---|
| *previous* | *24 hours* | *90 days* | *Total* |
| All types | 0 | 80 | 1 300 |
| This type | 0 | 80 | 725 |

Number of landings this type previous 90 days: 61.
Latest PC carried out on 2002-11-07.

## 1.6 Aircraft information

### 1.6.1 General


| AIRCRAFT | |
|---|---|
| *Manufacturer* | British Aerospace |
| *Type* | ATP |
| *Serial number* | 2021 |
| *Year of manufacture* | 1990 |
| *Gross weight* | Max TOW 23 680 kg, actual weight 16 130 |
| *Centre of gravity* | Within CG limits |
| *TT* | 16977 hrs |
| *TC* | 24 169 |
| *Flying time since latest inspection* | 81 hrs (A-Check) |
| *Fuel filled before event* | Jet A1 |

| ENGINE | | |
|---|---|---|
| *Manufacture* | Pratt and Whitney | |
| *Model* | PW 126A | |
| *Number of engines* | 2 | |
| *Engine* | No 1 | No 2 |
| *Total operating time, hrs* | 10 752 | 13 977 |
| TSO | 267 | 4 717 |
| *CSO* | 296 | 6 178 |

| PROPELLER | | |
|---|---|---|
| *Manufacture* | Hamilton standard | |
| | No 1 | No 2 |
| *TSO* | 3 093 | 5 985 |
| *CSO* | N/A | N/A |

The aircraft had a valid Certificate of Airworthiness.

### *1.6.2 The aircraft's electrical system*

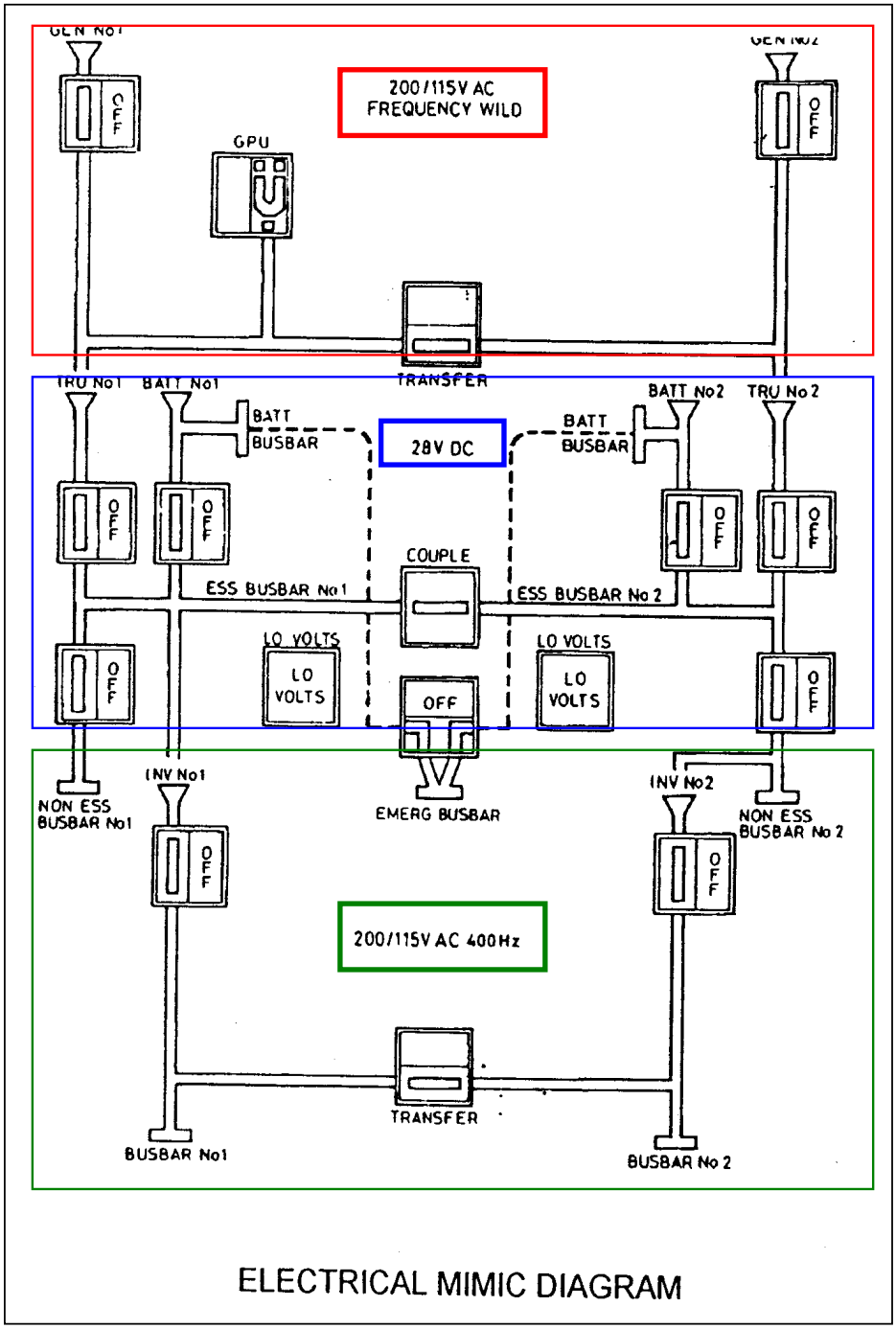
This aircraft type has two separate electrical systems, left and right. Each system has a direct current part, 28V DC and an alternating current part, 115V AC, 400Hz.

The electrical system is normally powered from a generator for each system mounted on the left and right engines, respectively. Each generator has the capacity to supply both electrical systems. The load can be transferred from one generator to the other by first deselecting the relevant generator and then selecting the other via the TRANSFER-button. (See diagram below.)

The generators deliver a variable alternating voltage of 115/200V AC which is transformed via two Transformer Rectifier Units (TRU) to 28V DC. The direct current system is also powered from two 37 AH NiCa batteries. The DC-system can be paralleled by use of the COUPLE-button.

From the 28V DC-system the voltage is transformed to 115V AC via two inverters. The load from one inverter system can be transferred from one system to the other by first deselecting the relevant inverter and then select the other one via the TRANSFER-button.

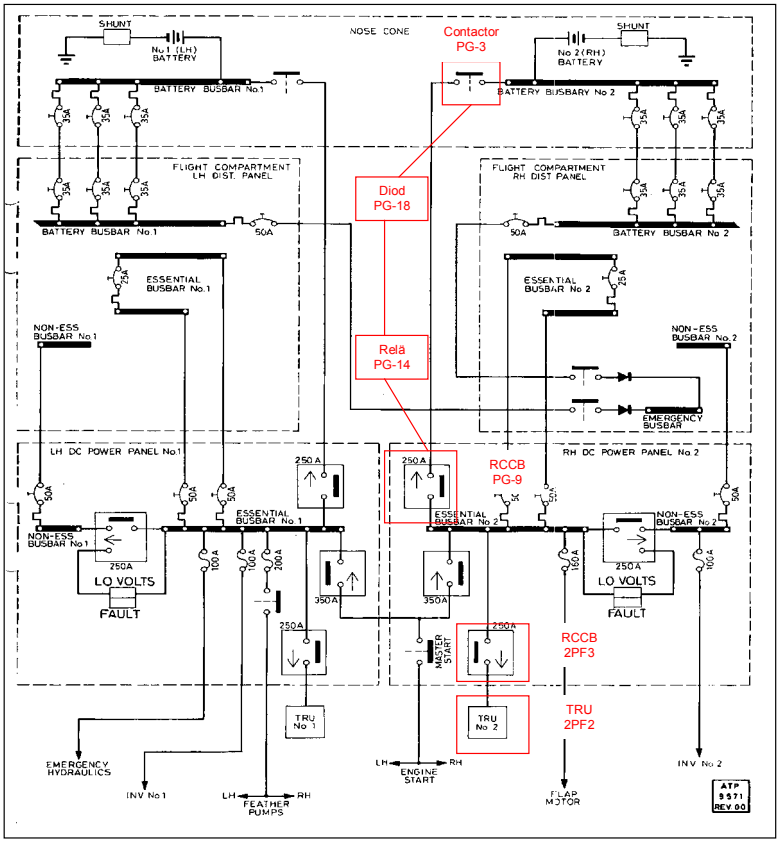
The systems are electrically connected and influence each other through different types of checking, regulating and warning system.




Electrical systems

### 1.6.3 *The 28V DC-system*

Current is supplied to the 28V DC- system, both from the TRUs and from the batteries, via a special type of relay, the Reverse Current Circuit Breaker (RCCB) which, apart from breaking and making the connection, also acts as a diode. The RCCBs are controlled in their turn by switches, contactors, relays and diodes included in the aircraft's electrical system. One of these contactors is the battery main switch.




Portion of wiring diagram

### 1.6.4 *Control panel*

In the ceiling above the left pilot's seat there is a control panel for controlling and checking the status of the aircraft's electrical system. Switching on and off is effected on the panel with press-buttons that light up with a blue line if they are 'on' and show a lighted OFF symbol if they are 'off', see photograph below.


Control panel

### 1.6.5 *Emergency panel*

At the top of the instrument panel there is an emergency panel with warning texts that light up in the event of failures or abnormal situations. In connection with such warnings a blinking main emergency lamp and an acoustic warning signal (Master Caution) are activated. An interruption in the power supply from a battery does not trigger a warning.


Emergency panel

### 1.6.6 *Instrumentation*

The majority of the aircraft's instrumentation is supplied with power from the 28V DC- and the 115V AC-systems. Primary flight and navigation information is powered from the AC-system and presented on two EFIS monitors at each pilot position.

## 1.7 Meterological information

According to SMHI´s analysis : wind 310°/10 kts, visibility > 10 km, cloud 0-2/8 stratus with base at 500 ft and 2-4/8 stratocumulus with base at 3000-5000 ft, temp./dp –15/-17 °C, QNH 1010 hPa.

## 1.8 Aids to navigation

The aircraft was equipped for instrument flying.

## 1.9 Radio communications

Until the point when the pilots declared an emergency, radio communication between the aircraft and air traffic control was normal. The electrical fault did not effect the function of the no 1 VHF radio, that was in use.

## 1.10 Aerodrome information

Stockholm/Arlanda airport had status according to AIP[6]

## 1.11 Flight and sound recorders

### 1.11.1 *Flight Data Recorder (FDR, QAR, GPS)*

FDR data not analysed.

### 1.11.2 *Cockpit Voice Recorder (CVR)*

CVR data not analysed.

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[6] AIP – Aeronautical Information Publication

## 1.12 Site of occurrence

### *1.12.1 Site of occurrence*

The incident occurred when the aircraft had reached FL 190 and was in the vicinity of Mariehamn.

## 1.13 Medical information

No medical examination of the pilots was carried out.

## 1.14 Fire

There was no fire.

## 1.15 Survival aspects

Not relevant

## 1.16 Tests and investigtions

### *1.16.1 Technical investigation*

SHK was informed by the aircraft company of the incident on the same day that it occurred, since the SHK was already investigating a similar incident with the same aircraft type that had afflicted the company just under three months previously. Further investigation of the aircraft was conducted by technicians from the aircraft company in consultation with SHK. During the fault-finding and putting in order of the aircraft selected components were replaced and checked separately. At functional tests of these components the RCCB (2PF3) was found to be unserviceable.

## 1.17 The company's organisation and management

The company has its head office in Göteborg, and is authorized to operate heavy air traffic. At the time of the incident 9 Hawker Siddeley 748's and ATP's were being operated. Operations consist largely of freight traffic within Europe.

## 1.18 Additional information

### *1.18.1 Similar incidents*

On 13 November 2002, just under three months before the present event, the company was afflicted by a similar incident with the same aircraft type, with the difference that power was lost from the left system. Both the course of events and the disturbances and faults in the aircraft's electrical system exhibit great similarities. The same applies to the pilots' view that they had difficulties in finding any support in the aircraft's emergency checklist for the situation that arose.

### 1.18.2 BAe SIL Ref. 24-010

In a Service Information Leaflet dated 11 October 1999 (SIL Ref. 24.010) the manufacturer, BAe gave information about the risk of failure of the electrical system owing to faulty function of the RCCB. Operators using the aircraft type were recommended to replace RCCBs of an early version ("Mod A") with RCCBs of a later version ("Mod B"), which was stated to be more reliable.

The RCCB:s "Mod A" were not replaced to "Mod B" in the actual aircraft. The reason for this is suggested to be that the aircraft was in long term storage at the time when SIL Ref. 24.010 was issued. Neither the actual operator, nor the previous operator was aware of it.

### 1.18.3 Information from BAe

In consequence of these two incidents the aircraft manufacturer BAe, in consultation with the aircraft company carried out a detailed analysis of the incidents. The analysis concludes that the loss of DC power was the result of two independent faults, one of which was the RCCB (2PF3). The loss of No 2 battery power however, can not be fully explained although several possible scenarios have been discussed, of which one a temporary faulty in another RCCB.

In the manufacturer's view the main cause of the faulty function was low reliability of RCCB "Mod A", a component used at many points in the electrical system and still installed in many of the company's aircraft. Among other things, replacement with RCCB "Mod B" and shorter operating time intervals between batteries is recommended.

In addition BAe have stated that SIL Ref. 24-010 will be re-issued and an All Operator Message will be distributed to inform operators about these events. An Engineering Process Folow Up (EPFU) has been published on BAe System internet website, which provides the same information.

The aircraft company has subsequently, in consultation with the manufacturer, initiated a programme for tackling this problem. The programme includes:

- replacing all RCCB "Mod A" with RCCB "Mod B",
- introducing operating time limitations for RCCBs
- shortening the operating time interval for batteries.

### 1.18.4 Emergency checklist

In the emergency checklist for the aircraft, the following instructions may be relevant for the type of failure that is the subject of the present report:

CARD 34 CARD 34

# DOUBLE GEN/TRU FAILURE OR DC BUSBAR LOW VOLTAGE

Ensure DC busbars are not coupled.

**ARE BOTH LO VOLTS WARNINGS ON THE DC POWER PANEL LIT?**

YES — NO

**ARE BOTH GENERATORS INDICATING OFF?**

YES — NO

Both generators ..... OFF
Check voltage, if correct select on line.

Select both TRU OFF and back on line.

**ARE BOTH LO VOLTS WARNINGS STILL LIT?**

YES — NO

**IS ONE LO VOLTS WARNING STILL LIT?**

YES — NO

Go to Card 36, TRU Failure or Single DC Busbar Low Voltage - **END**

If GEN warning indicated, Go to Card 35, Generator Failure or Overload - **END**

Land as soon as possible.

EMERGENCY BUSBAR ..... On (switch depressed)
Intercom ..... EMERGENCY
Power levers ..... Retard by 1 inch
Engine control ..... MANUAL
Restore power as required
Both batteries ..... OFF (See NOTES 1 and 2)

PITOT HEATERS, STANDBY ..... EMERG ON, if required.
No 1 NAV controller ..... select RAD
Cabin emergency lights ..... OFF

Only DC emergency busbar loads are being supplied (See NOTE 3).

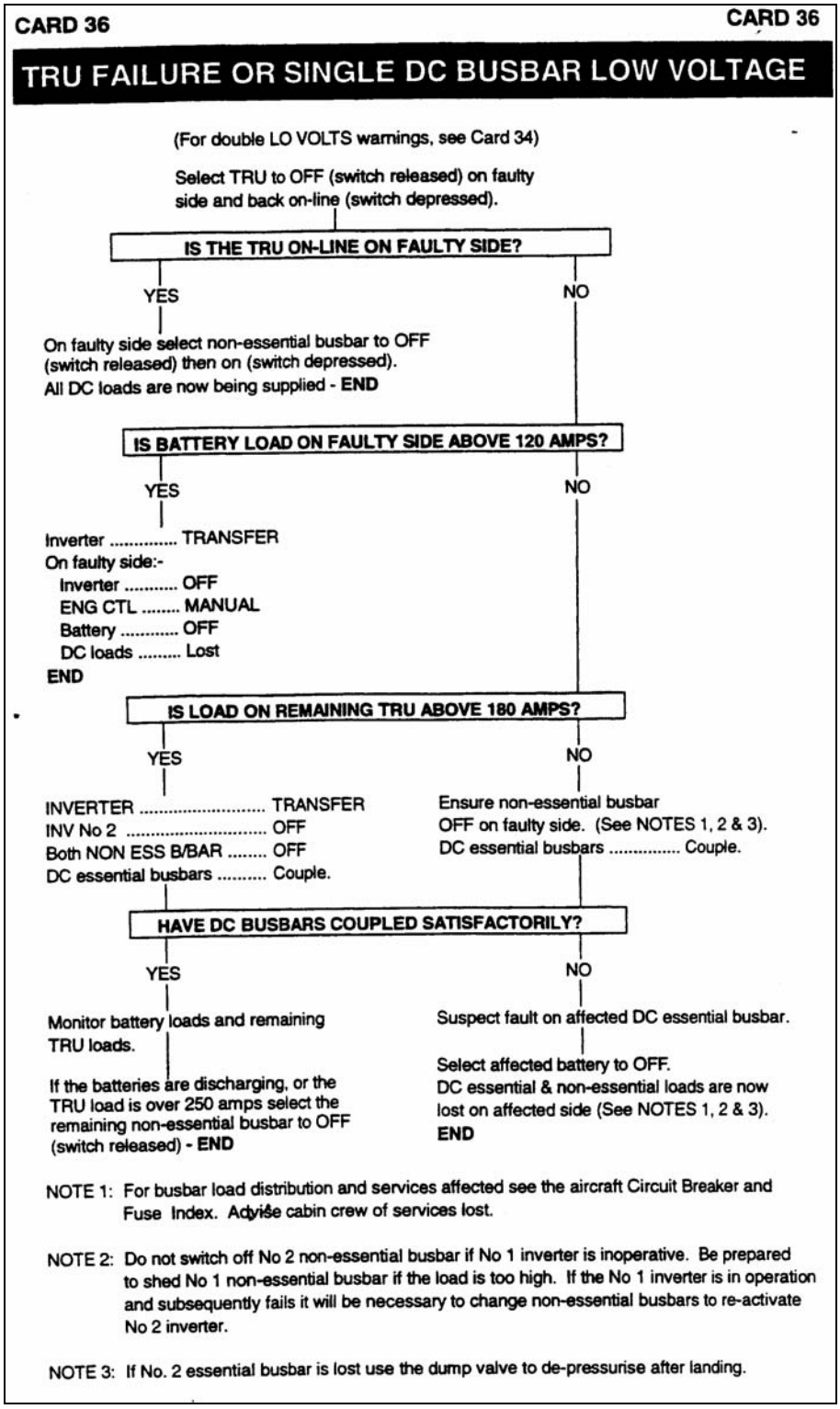
Cabin crew ..... Advise - reduced cabin services
Flaps ..... Will not operate normally (See Flap Motor - Failure to Run - Card 32)
Before landing ..... Cabin emergency light - ARM
Before landing (at night) ..... Dim flight deck lighting
During landing roll ..... Nosewheel steering will not be available
After landing ..... Use dump valve to depressurise the aircraft
**END**

NOTE 1: If the batteries are not below 70% charge and are switched off within 5 minutes of the DC LO VOLTS WARNING, the emergency busbar loads will be supported for a minimum of 60 minutes from the DC LO VOLTS warning. This period may be extended if emergency busbar loads, which are not essential, are switched off. Significant loads greater than 1 amp are listed below:-

| | |
|---|---|
| Cabin emergency light system ..... 1.0A | Cabin roof lights ..... 6.4A |
| VHF No 1 Com/Nav ..... transmit 5.0A | PA (normal) ..... transmit 2.0A |
| ECS pack control ..... 3.0A | ECS temp control ..... 1.3A |
| Left pilots roof panel lights ..... 3.3A | Standby pitot heater ..... 4.3A |

NOTE 2: The hydraulic and fuel gauges will not operate when the batteries are OFF.

NOTE 3: With no electrical power available the flight idle baulk will remain engaged. A steady pull of 50lbs on each power lever will be required to select ground idle. Use extreme caution when manoeuvring using the wheelbrakes, do not manoeuvre in confined areas. It is recommended that taxying be confined to that necessary to safely clear an active runway. There will be no indication of brake pressure and the propellers will be operating in the non-permitted band.




### *1.18.5 Arrangement of checklists, generally*

The emergency checklist is one of the Master Checklists included in the operative manuals of all aircraft and normally produced by the manufacturer. Within certain limits the emergency checklist can be modified and amended by operators and aircraft owners. There is no international standard for how emergency checklists shall be organised. Arrangement, logic and layout may differ essentially between aircraft types and between different operators.

Special requirements apply to emergency checklists. Such a checklist should be the natural aid for pilots to identify, in an abnormal or critical

situation, a possible fault and take the most suitable measures from the flight safety viewpoint. It should be easy to understand and user-friendly.

Aircraft manufacturers have had varying success in this respect. The problem of less-well-designed emergency checklists and the need to produce standard patterns for the design of these lists was dealt with in the FAA[7] publication "Human performance considerations in the use and design of aircraft checklists" dated January 1995 and in the FSF[8] publication "Studies Suggested Methods for Optimising Checklist Design and Crew Performance" dated May 1995.

# 2 ANALYSIS

## 2.1 The incident

The electrical fault occurred without warning shortly after takeoff from Stockholm/Arlanda airport. All flight and navigational instruments at the left pilot's position functioned normally and the flight situation should have given the pilots the opportunity, using the emergency checklist, to identify the fault and find relevant measures for tackling the problem. It proved nevertheless difficult to find any point that matched the error information available. Instead, the pilots chose to attempt to solve the problem by restarting the systems that were not functioning normally. When the fault disappeared but recurred shortly afterwards, the pilots became even more uncertain about how serious it was.

Since the aircraft was fairly near an airport it is understandable that the pilots, instead of venturing upon an uncertain trouble-shooting for a possible serious fault, elected to attempt to land as soon as possible. They feared the risk that the functioning systems were being powered only from the batteries and that the time these systems would be available was thus limited.

As mentioned above, the emergency checklist should be the natural aid to pilots to identify a possible fault and take the most suitable action from the point of view of flight safety. It should be easy to understand and very user-friendly. In SHK's opinion the present emergency checklist does not meet these demands. It is complicated, the logic is not self-evident, the typeface is small, the text on the emergency panel is not given as headlines for steps to be taken, etc.

Apart from the present incident and that mentioned in 1.18.1, SHK has noted in earlier investigations that pilots have refrained from using emergency checklists for the same reasons as in these cases. The checklist is felt to be too complicated and there is no time to attempt to follow it. This is understandable but unfortunate since the checklist frequently contains measures that are essential for flight safety but are perhaps not self-evident to pilots attempting to solve a serious problem in what may be a stressful situation.

The Board's report C 1999:8, for example, deals with an accident involving a Douglas DC-9-81 in which the pilots suspected an electrical fire on board and the emergency checklist was not used. On that occasion the aircraft landed with the automatic braking system (ABS) and the Anti-Skid System disconnected, whereupon the four main wheels locked and the tyres of three of them punctured.

As shown in 1.18.4 the problem of unsuitably arranged emergency checklists is well known and many initiatives have been taken to resolve the issue. SHK finds it unfortunate that there has so far been no agreement on an in-

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[7] FAA – Federal Aviation Administration

[8] FSF – Flight Safety Foundation

ternationally accepted standard for the arrangement, logic and layout of emergency checklists in professional aviation. There are therefore reasons for the Civil Aviation Administration, as a part of international air safety work, to initiate action for the purpose of achieving this objective.

### 2.2 The electrical fault

For the 28 V DC-system to become 'dead', it is necessary that the current supply from both generators/TRUs and batteries is interrupted. The technical fault detected in the RCCB explains the power cut from the TRU side. Regarding the power cut from the battery circuit, several explanations are possible It has however been impossible to produce any definite conclusion.

Interruption of the power supply from the battery does not normally trigger any warning but is shown only by the blue line on the switch for battery contactors to extinguish. Thus the power supply from the battery may have been interrupted for some time before the incident without the pilots noticing it.

Since the left electrical system was functioning without remark, there are strong indications that it would have been possible to supply the right DC system from the left via "COUPLE", thus regaining full function in all systems connected to the right side DC- and AC-systems. In fact, this emerges to some extent from the emergency checklist (Card 36) under the heading "TRU FAILURE OR SINGLE DC BUSBAR LOW VOLTAGE".

However, by transferring the right side AC load to the left AC-system via "TRANSFER" the pilots regained function in the right side EFIS and engine instrumentation.

Disturbance in the electrical system in consequence of faulty RCCB is evidently a problem known to the manufacturer of the aircraft. Various steps have been taken, both by the manufacturer and the operator, to deal with the problem. SHK has therefore no reason to make any recommendation in this respect.

## 3 CONCLUSIONS

### 3.1 Findings

*a)* The pilot was qualified to perform the flight.
*b)* The aircraft had a valid Certificate of Airworthiness.
*c)* The power loss was caused by two independent faults.
*d)* One of these faults occurred in a component of an earlier version and with known deficiencies.
*e)* Even before the incident, the manufacturer had taken steps to deal with this weakness in the system.
*f)* There was a possibility to regain full electrical function by transferring the right side AC load to the left AC- system .
*g)* The emergency checklist is not user-friendly.
*h)* There is no international standard for the arrangement of emergency checklists.

### 3.2 Causes

The incident was caused by the simultaneous occurrence of two independent faults in the aircraft's electrical system.

# 4 RECOMMENDATIONS

Reference is made to SHK recommendation RL 2004:13R1 and R2, which runs:

*"The Swedish Civil Aviation Administration is recommended:*

- *in connection with the issuance of AOC[9] to take special note of emergency checklists with regard to comprehensibility and user-friendliness (RL 2004:13R1), and*
- *in international flight safety work to encourage the creation of an international standard for the arrangement, logic and layout of emergency checklists used in professional aviation (RL 2004:13R2)".*

[9] AOC – Air Operator Certificate.