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British Aerospace Regional Aircraft Limited, Manchester

Chloride Industrial Batteries Limited, Manchester

Dowty Aerospace Propellers, Gloucester

Dunlop Aviation Division, Coventry

Lucas Aerospace Engine Control Systems, Birmingham

Lucas Aerospace Power Systems, Hemel Hempstead

Lucas Aerospace Switchgear and Ignition Division, Coventry

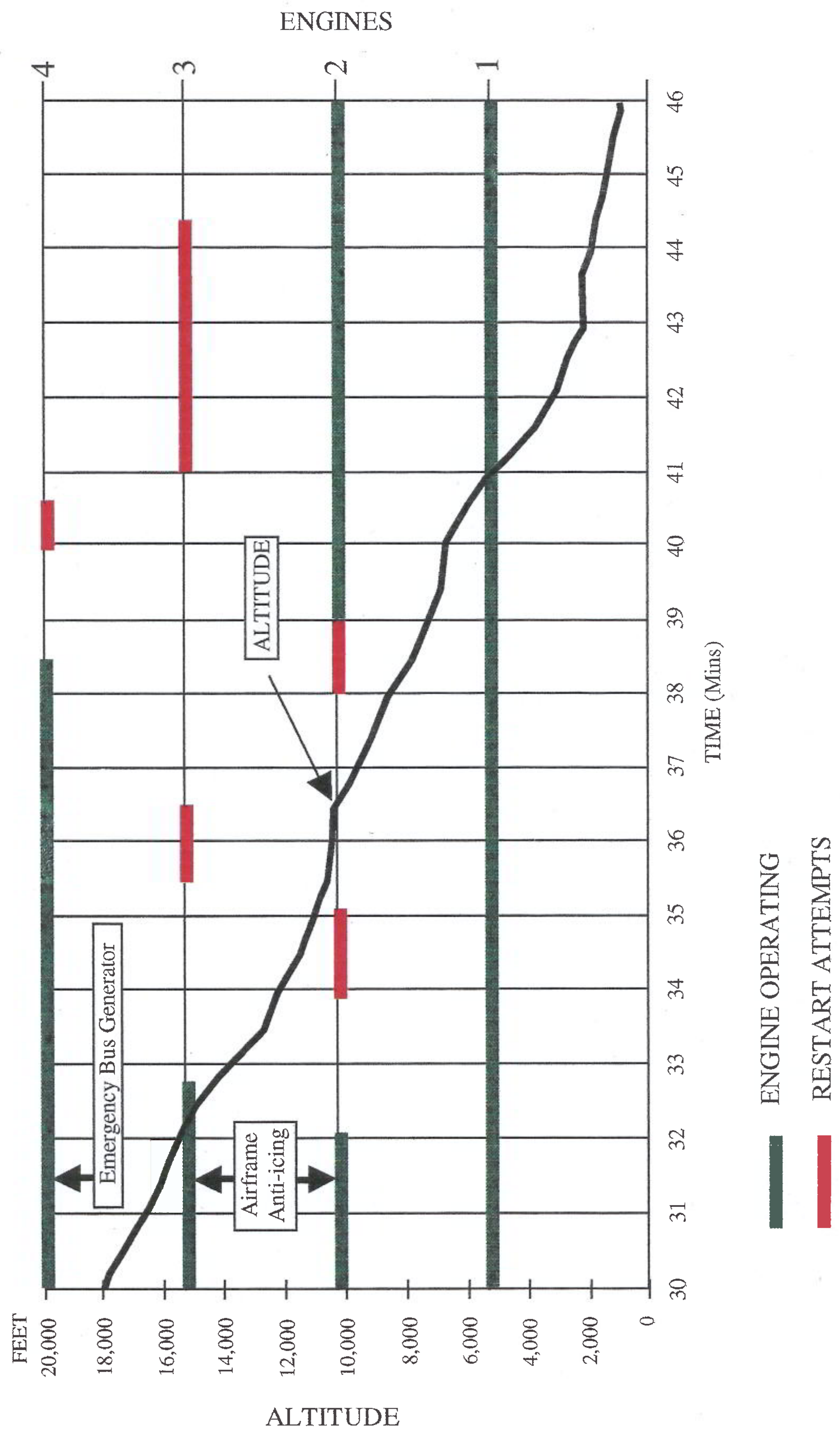
Rolls-Royce Commercial Aero Engines Limited, East Kilbride

Simon Aviation, Edinburgh

World Aviation Support Limited, Southend

RADAR DERIVED TRACK PLOT OF G-OHOT

ENGINE FAILURE SEQUENCE



VISCOUNT 813 ELECTRICAL SUPPLY (Simplified)

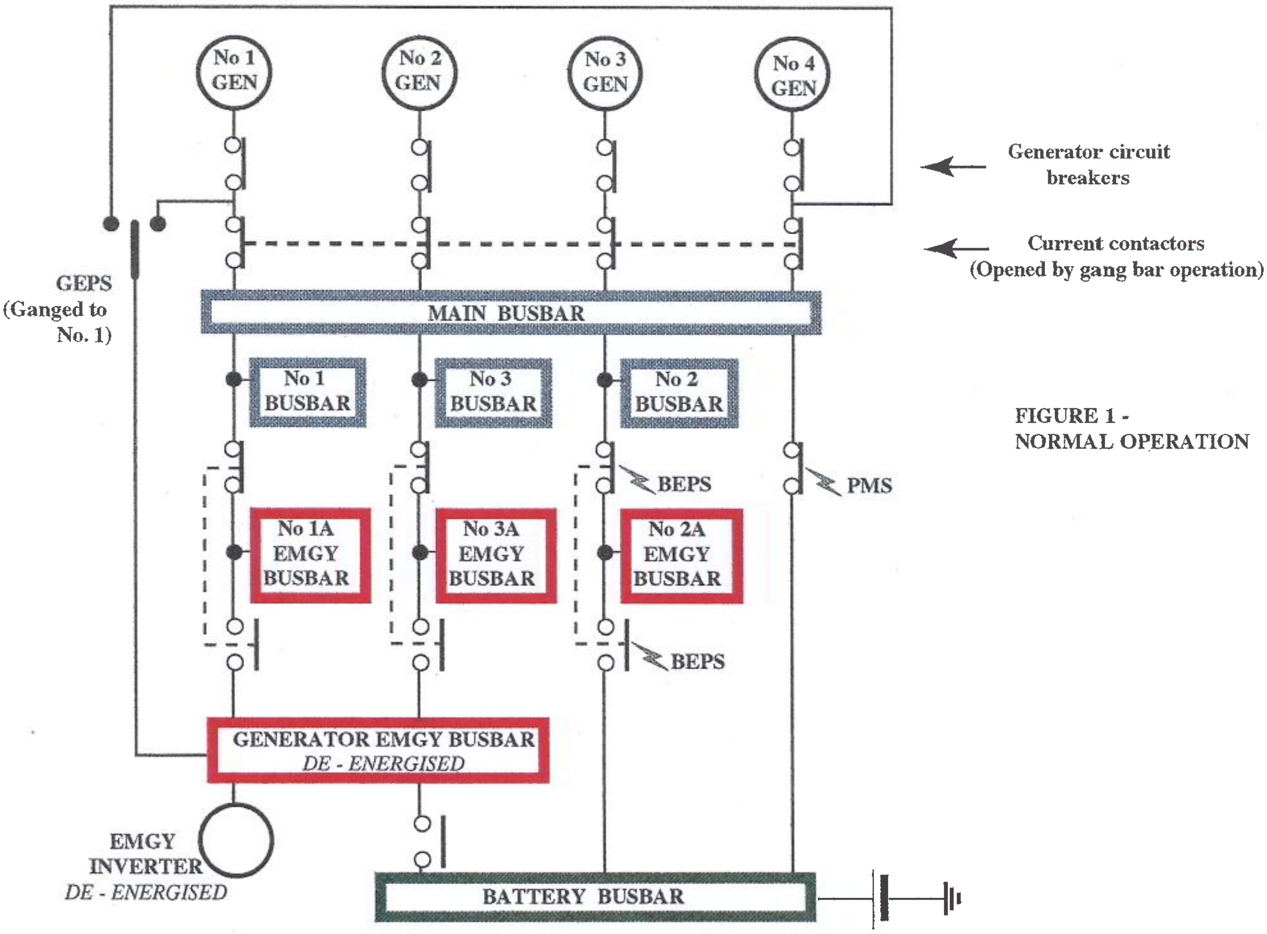


FIGURE 1 -
NORMAL OPERATION

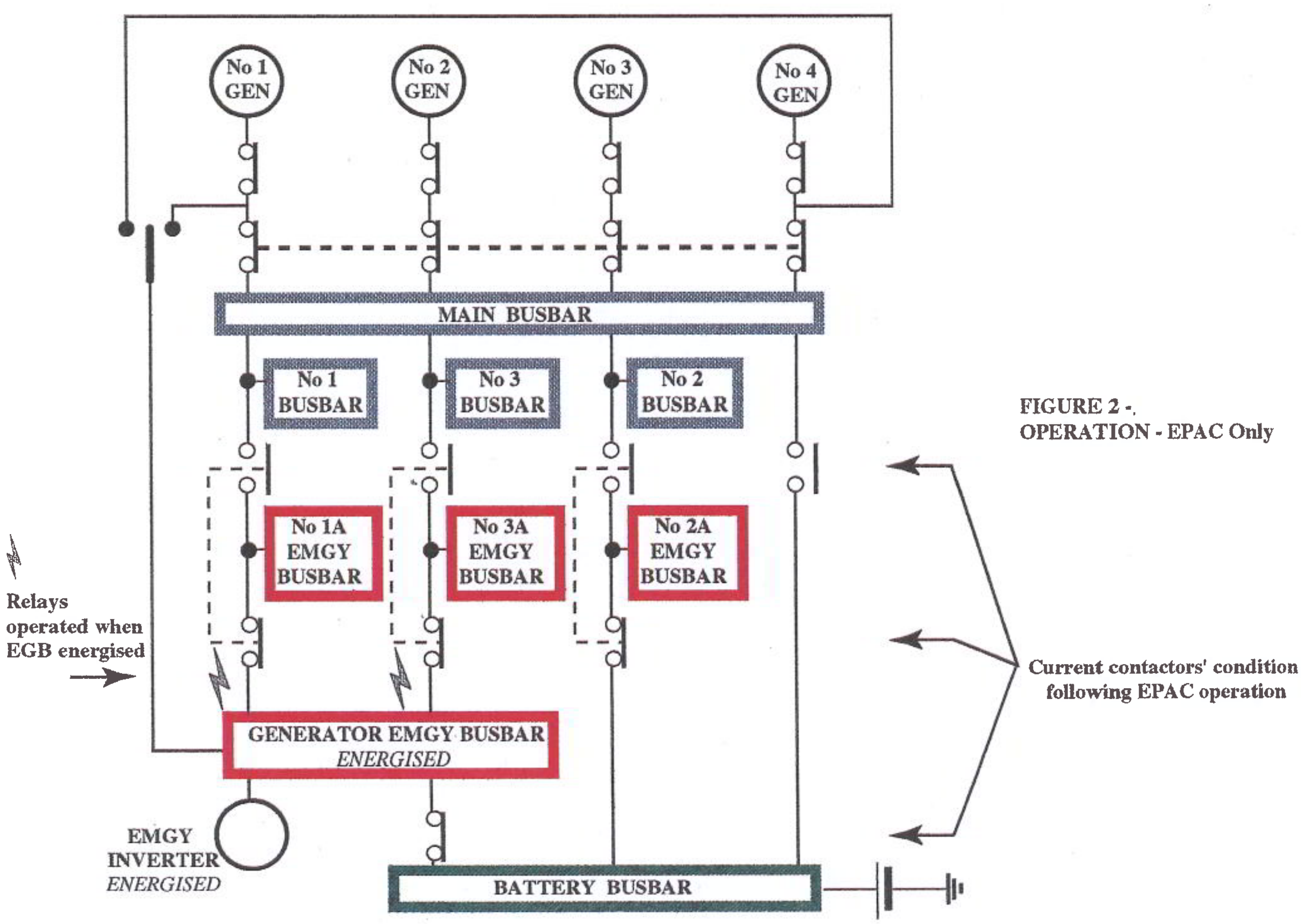


FIGURE 2 -
OPERATION - EPAC Only

BRITISH CIVIL AIRWORTHINESS REQUIREMENTS

ICING CONDITIONS

'Airframe

The standard atmospheric conditions against which an assessment can be made as to an aircraft's suitability to fly in "light", "moderate" or "all" icing conditions are as follows:

TABLE 1

Air temp (°C)	Liquid water content (grammes/cubic metre)	Droplet size (microns)	Altitude (feet)
0	0.8	20	SL --- 20,000
-10	0.6	20	3,000-27,500
-20	0.3	20	3,000-30,000
-30	0.2	20	3,000-30,000

NOTE: It is recognised that it may not be possible to protect aeroplanes against the prescribed atmospheric conditions at sea level before a certain flying speed has been reached. For practical purposes the icing conditions at 0°C may be assumed to apply to altitude range 3,000-20,000 feet.

Power-plant

General. The complete power unit, including the propeller shall be capable of functioning satisfactorily without unacceptable loss of power in the icing conditions shown here, and in any precipitation conditions (rain, snow or hail) and ice crystal cloud conditions, or any likely combinations of these conditions:

TABLE 2 ATMOSPHERIC CONDITIONS - INTERMITTENT MAXIMUM

Air temp (°C)	Liquid water content (grammes/cubic metre)	Droplet size (microns)	Altitude (feet)
0	2.5	20	10,000-20,000
-10	2.2	20	10,000-27,500
-20	1.7	20	15,000-30,000
-30	1.0	20	15,000-35,000
-40	0.2	20	15,000-40,000

NOTE: The above conditions are assumed to apply as follows:-

(a) Up to 30,000 feet. Intercepts 3 miles long of "Intermittent Maximum" conditions with gaps of 3 miles between intercepts, these gaps consisting of the corresponding "Continuous Maximum" conditions.

(b) Between 30,000 and 40,000 feet. As (a) except that the gaps between intercepts are each of 20 miles of clear air.

TABLE 3 ATMOSPHERIC CONDITIONS - CONTINUOUS MAXIMUM

Air temp (°C)	Liquid water content (grammes/cubic metre)	Droplet size (microns)	Altitude (feet)
0	0.8	20	SL --- 20,000
-10	0.6	20	3,000-27,500
-20	0.3	20	3,000-30,000
-30	0.2	20	3,000-30,000

NOTES:

(1) It is recognised that it may not be possible to protect aeroplanes against the prescribed atmospheric conditions at sea level before a certain flying speed has been reached. For practical purposes the icing conditions at 0°C may be assumed to apply to altitude range 3,000-20,000 feet.

(2) The thickness of the icing layer, for these conditions, will not normally exceed 6,500 feet.

Turbine engines. Acceptable methods of providing satisfactory evidence that the requirements of the above are met will be by demonstrations that, either in the air or on the ground:-

(a) The power unit continues to function satisfactorily without unacceptable loss of power when operating for a period of 30 minutes in the combination of "Intermittent" and "Continuous Maximum" icing conditions given in the note to TABLE 2.

(b) The behaviour of the power unit is satisfactory when operating in conditions equivalent to the aeroplane encountering, for a distance of half-a-mile, the conditions of TABLE 2, but with the water content values double those stated.'

ANALYSIS OF METEOROLOGICAL DATA FOR THE CENTRAL BRITISH ISLES ON 25 FEBRUARY 1994

An active double frontal zone, aligned WNW to ESE and oscillating south then north over the British Isles, lay between markedly contrasting (warm and cold) airmasses and was associated with:

a) An intense anticyclone of over 1032 mb, near eastern Greenland, which was feeding cold Arctic air southwards over Scotland; and

b) A deep 968 mb low pressure complex, in the mid Atlantic, pushing tropical maritime air north or north eastwards over SW Ireland and Cornwall.

This provided copious and exceptional amounts of precipitation in the areas where the 'thermal contrast' was greatest.

The presence of some supercooled cloud droplets larger than the 20μ diameter size mentioned in BCARs, possibly as large as 50μ diameter, is frequently observed in air of maritime origin. In this case, the aircraft had been descending in 'tropical maritime' air which had been over the sea for three hours or more and contained thick cloud with large micron diameter water droplets. It remained in this mixture of ice crystals and liquid water for over eleven minutes, until breaking through the cloudbase at 1941 hrs.

Because of the 'saturated' air near the active warm frontal surface; the liquid water content provided by orographic uplift from the melting-snow covered Pennines; and, the high liquid water content provided by heavy precipitation from clouds with temperatures from minus 67°C at 36,000 feet to 0°C at the low levels; the water content is likely to have been as high as one gram per cubic metre. This exceeded the BCAR design criterion for 'continuous (exposure) maximum'.

Concerning the lower altitudes, interpolation between several meteorological balloon ascents at Aughton shows that the temperature below the general freezing level of 5,500 feet rose in the lowest layers of nimbostratus, but then fell again to below 0°C at about 3,500 feet. Between 3,500 feet and 2,200 feet the temperature dropped to a minimum of about minus 1.5°C in cloud and, between 2,000 feet and 1,000 feet to minus 1°C.

The observer closest to the final flight path of G-OHOT, reported:

> "Earlier snow turned to sleet at around 1700 hrs and, at 1810 hrs, there was continuous light-to-moderate freezing rain, with the air temperature at minus 0.3°C. At this time the ground was covered with 14 cm of snow, from a 20 cm fall on 23 February. The freezing level was about 880 feet and, above this, the ground was covered with 6 mm of clear ice. Small, 1-2 mm diameter, ice pellets were occasionally observed in the freezing rain between 1800 and 2000 hrs. At about 2030 hrs the temperature rose above 0°C and the glaze began to thaw."

Records show that, considering every February since 1965 (30 years), an almost identical situation occurred last in 1978, and there have been three other years, 1966, 1979 and 1985, in which a similar active and complex double frontal system with similarly intense thermal contrast occurred.

Given these five occasions in 30 years, there is a one-in-six chance of meeting an equally severe (very heavy precipitation etc) weather frontal zone over the UK, and a one-in-fifteen chance of experiencing extreme thermal-contrast fronts such as those which occurred in 1978 and 1994.

PROPOSED FLIGHT OPERATIONS INTERNAL QUALITY ASSURANCE PROCEDURES

The CFOI wrote in his letter [reference 10A/270/10 and 10A/380/15 dated 28 June 1994] covering the draft paper on Quality Systems:" The paper represents current thinking within the Flight Operations Department and could be subject to change in the light of more specific proposals from JAA."

1. AIM

The aim of this paper is to provide initial guidance and information for UK CAA Air Operators' Certificate (AOC) holders on the proposed Flight Operations Internal Quality Assurance procedures.

2. BACKGROUND

There have been substantial changes within the Aviation Industry and in particular to the regulatory requirements in recent years. These factors, allied to the increased complexity of modern aircraft, their operation, and the companies engaged in their operation means that what have become the traditional methods of inspecting are now no longer appropriate.

To continue with such methods would require resources which both industry and society would probably consider to be an unacceptable burden.

It is now therefore generally accepted that the responsibility for monitoring and reviewing the procedures and practices of operators should largely be devolved to the operators themselves, and that they should set in place structured internal Quality Assurance procedures acceptable to the Authority.

The emphasis in regulation is therefore likely to change from a process of regular inspections by the regulatory authority to a system whereby operators 'self-audit' their own operation against a clearly defined quality system. The Authority's role will shift to the verification of operators' compliance with their quality system and the legislation.

16. CONCLUSIONS

The development of internal audit and evaluation programmes relies heavily upon AOC Holders continuously monitoring and auditing their operations to ensure that they are safe and conform to the requirements and the legislation.

The Authority will continue surveillance and some of its current inspecting practices. It is envisaged that flight inspections and liaison visits will continue, to ensure that current levels of productive dialogue between operators and the Authority are maintained. The travelling public however will be best served by operators who utilise internal evaluation procedures to recognise shortcomings speedily and then take prompt action to prevent their recurrence.

ICE RELATED INCIDENTS (not the subject of AAIB reports)

April 1976	Viscount 806	Very heavy icing encountered on climb FL 90. Severe vibration. Power loss on No 4 engine. Manually feathered. Re-light not reported.
October 1976	Viscount 813	Very heavy icing encountered on climb FL 160 to 180. Vibration from iced propellers, No 3 engine autofeathered. Re-light not reported.
October 1976	Viscount 815	Heavy icing conditions. No 2 engine autofeathered. Height not reported. Re-light not reported.
October 1976	Viscount (815?)	Vibration on climb in icing conditions. No 1 engine autofeathered. Height not reported. Re-light not reported.
January 1977	F 27 (?)	De-ice cyclic timer intermittent. FL 80. No 1 engine autofeathered and was re-lit.
January 1978	Viscount 813	No 2 engine autofeathered in cruise, following climb in icing conditions. Re-light successful. No height recorded.
February 1978	Herald 202	In the cruise, left engine cut with no abnormal indications. Igniters selected for 3 minutes and then de-selected. Port engine failed, excess TGT, manual shut down. No height or re-light reported.
February 1982	Herald (?)	Icing conditions, left LP fuel warning, engine flame-out. Suspected cavitation in left tank. Engine re-lit.
October 1989	F 27 200	Right power unit de-icing failed. Ice build-up, speed loss, precautionary descent. Attempt to reset power resulted in flame-out below icing cloud. Re-light successful.
January 1991	F 27 500	Right engine flamed out due ice ingestion at IOAT minus 20°C. Report continues "de-ice cycling had been moved to slow at minus 6 °C(?)". Rapid re-light. Five minutes later left engine coughed but did not flame-out.
February 1994	Herald 200	During descent in icing conditions, at 6,500 feet, right engine autofeathered. Re-light successful. Right antice timer found to be intermittent.

In February 1978 a Viscount reported heavy ice accretion on the engine nacelles and leading edges. The de-icing duct temperatures were reported as being: Left wing 140°C, right wing 135°C, tail 85°C. The CAA considered that the conditions were in excess of the design standards.

ICE RELATED SAFETY RECOMMENDATIONS

Incident to an F27 in January 1991

Both engines flamed out, one in the cruise and the other in the descent. The second failed engine was re-started whilst the pilot was setting up a glide approach. The AAIB made the following Safety Recommendation:

> The occasions when engine igniters (continuous ignition) on Dart engines are already required to be selected ON are extended to include flight in moderate or severe icing irrespective of the number of engines operating. (AAIB Reference Number EW/C1197/025/R1).

CAA Response

> The Authority accepts this recommendation. Discussions with Rolls-Royce have been held to agree changes to the Operating Instruction Manuals for all Dart engines to respond fully to the recommendation.

Following these discussions the Manual amendments were issued in December 1991, and a Rolls-Royce 'Notice to Operators' (number 1118) addressing this subject was issued in November 1991.

Notice to Operators (NTO) No 1118:

'SELECTION OF POWER UNIT ICE PROTECTION

<u>This NTO is issued for the Attention of Flight Crews</u> and highlights the importance of applying the Flight Manual requirements for selection of the Power Unit Ice Protection system.

Review of world wide experience by Rolls-Royce has confirmed that engine flame out due to ice ingestion is a comparatively isolated event. Nevertheless such isolated events do continue to occur and investigation has indicated that a significant proportion are associated either with incorrect procedures being applied or correct procedures being implemented too late to prevent flame out.

The procedures for selection of the power unit ice protection system are clearly defined in all the Flight Manuals and in Rolls-Royce Dart Operating Instruction Manuals. These include:-

normal protection requirements relative to OAT;

late selection drills requiring the selection of HE ignition switches ON for both engines (twin); all four engines (four engine aircraft);

encountering 'abnormal' icing conditions (selection of HE ignition as above);

rapid engine re-light drills.

Rolls-Royce's review indicated that incorrect procedures most often occur during encounters with unexpected and/or 'abnormal' icing conditions and are often associated with failure to select HE ignition switches ON.

Taking into account the generally satisfactory experience over many years Rolls-Royce and the aircraft manufacturers do not intend to make any changes to the existing specific procedural requirements associated with the selection of power unit ice protection. However to highlight the need to ensure that HE ignition switches are selected ON in all cases where moderate or severe icing conditions may occur Rolls-Royce are making the following text change to the Dart Operating Instructions Manuals. These changes are also intended to ensure that under such icing conditions the use of igniters should not be restricted in relation to any concern regarding HE Ignition Unit life. It is essential that igniters be selected ON for as long as moderate or severe icing conditions persist.

In detail the changes are:-

(1) redefine 'abnormal icing conditions'.

"If moderate or severe icing is encountered immediately switch ON the igniter switches for both engines (all engines in the case of a four engined aircraft) whilst such conditions continue to exist. Only return the switches to OFF when it has been positively confirmed that the flight is clear of icing conditions. Record the length of time igniters used".

(2) The current "WARNING" on the use of HE ignition is now replaced with -

"CAUTION: Igniter Unit life is a function of usage. Do not operate igniters longer than is necessary to ensure safe operation".

These changes will be issued with the next Dart Operating Instruction Manual Transmittal letters.'

Incident involving a BAe ATP in August 1991

Whilst climbing out of East Midlands Airport, the aircraft stalled because of severe icing and lost 3,500 feet before recovery to normal flight, the AAIB made several Safety Recommendations. The relevant ones, together with the CAA responses were:

'Recommendation 4.4

> For UK registered aircraft certificated with approval for flight into known icing conditions, the CAA require a reliable means of actively alerting the flight crew to all conditions where operation of the airframe de-icing system is necessary to maintain safe flight (Recommendation No 92-61).

CAA Response

> The Authority accepts that there is a need to investigate the effectiveness of ice detection methods. A research project was outlined early in 1992 by the JAA Research

Committee and funds are being sought from the European Commission under their forthcoming EURET II programme. It is expected that this project will commence in FY 1993/94 and will review the capability, reliability, controllability and overall effectiveness of current turboprop aircraft systems, including ice detection facilities and determine if new certification and/or operational standards are required.

Recommendation 4.6

The CAA use this and other incidents during the summer of 1991 to re-educate the pilot profession of the unexpected onset of glaze ice which can quickly lead to an insidious stall which may be difficult to recognise because it can occur at abnormally high airspeed and before the stall warning system is activated (Recommendation No 92-63).

CAA Response

The Authority accepts this Recommendation. This advice has already been incorporated in the update of Aeronautical Information Circular entitled "Frost, Ice and Snow on Aircraft", which was issued on 20th August 1992.

Recommendation 4.12

The CAA, in conjunction with the FAA and NASA conduct a reappraisal of the icing envelopes specified in the JARs, particularly in the area of large droplet sizes and temperatures just below freezing (Recommendation No 92-69).

CAA Response

The Authority accepts this Recommendation. The Authority is already collaborating with FAA on a review of the JAR 25/FAR Part 25 Appendix C icing envelope. The FAA is completing worldwide atmospheric data collection, which includes conditions outside the existing Appendix C. The Authority has contributed significant data to this programme, particularly with respect to freezing rain. The FAA will shortly begin consideration of revisions to the airworthiness requirements based on this data. However, the complexities of this subject are such that revised requirements, including means of compliance, are not expected to be available for several years. In addition to this work, a European research project has been outlined by the JAA Research Committee with the objective of expanding and, if necessary, improving the scope, validity and presentation of Appendix C. Funds are being sought from the European Commission under their EURET II programme, and it is expected that this project will commence in FY 1993/94 and be completed within approximately 3 years.'

EMERGENCY CHECKLIST - HUMAN FACTORS ASSESSMENT

'NB. In what follows no attempt has been made to comment on the accuracy of the information contained in the checklist. Any comments are directed specifically at the human factors considerations raised by the format of the checklist as at 30:6:89.

1 Size

The checklist is rather a large document. This may be unavoidable in view of the amount of information contained on each page. However, the size of the document may well present problems for storage on the flight deck and/or use.

2 Binding

Whilst it is appreciated that the checklist examined is some 5 years old, the binding seems rather fragile.

3 Colour

The cover of the checklist is not particularly attention getting, but this needs to be reviewed in relation to other documents on the flight deck. It is important that the checklist stand out and be immediately visible to the user, especially since it is likely to be needed urgently and in a situation which could well involve stress.

The pages of the checklist are in a rather unfortunate shade of pink. This does not give particularly good contrast with the type face. It also raises the question of legibility of the information when viewed under less than optimal lighting conditions. Experienced pilots would be able to answer questions concerning the legibility or otherwise of this combination of colours in operational use.

4 Font

Throughout the checklist there appears to be inconsistency in the selection of font and upper and lower case. Lower case is generally considered to be easier to read, but upper case predominates in this document. It would appear that little or no consideration has been given to utilising fonts and types faces as a positive aid to information presentation. It seems that the size of font used has been more the result of expediency and space constraints rather than an attempt to present the information in the most usable format.

On some of the pages, eg. page 18, the type face is extremely small and could well prove specially difficult to read in a poor light. This would increase the likelihood of information being missed when the checklist is used.

5 Quality of reproduction

The whole document has been extremely poorly reproduced. Words are frequently illegible, pages are crooked, information has been missed from the bottom of some pages because the original document has been incompetently photo-copied. A number of dark "smudges" would again suggest poor photo-copying.

6 Indexing

There is an index at the front of the document with appropriate page numbers. However, the numbers on the pages themselves are not readily apparent because of the extraneous information contained in the top right hand corner of all the pages. In addition, it would be useful to the user to have a thumb-page access with the relevant section clearly marked.

7 Irrelevant information

There is a good deal of irrelevant information on the checklist eg. the repetition of the word "checklist", "reverse side blank" or the volume numbers etc at the top of each page. If they have to be reproduced, for example to ensure that the correct edition is being used or the correct updates have been included, they could be thus rendering the page number more obvious in an emergency. These headings take up valuable and limited space which could have been utilised to improve the overall presentation. It would appear that some information is only included because it was present on the pages of the original manual from which this checklist has been reproduced.

8 Prioritisation of information

With the exception of the memory items enclosed in solid lines, there appears to have been no attempt to prioritise or emphasise any piece of information relative to any other. No attempt has been made to draw attention to restrictions, warnings etc, which may have operational significance and/or could affect safety.

There is also apparent inconsistency in the use of underlining, eg. some items are boxed and underlined eg. page 4/4 and some boxed and not underlined eg. page 4/5.

9 Page numbering

The page numbering is strange eg. it starts on page 4, while the rest of the pages are prefixed with a "4" 4/2, 4/3, etc.

10 Checklist list presentation

Some of the checklist items are presented laterally rather than vertically eg page 6. Vertical listing would probably be easiest in a checklist format and could reduce the likelihood of items being omitted.

11 Density of information

Overall the presentation is very dense, ie. there is a great deal of information, frequently contained in a very cramped space. However, if more thought were given to the layout, it should be possible to maximise the usage of available space while, at the same time, rendering the information in a more "user friendly" format.'

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