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Summary of the results of special wind tunnel tests

A series of special tests in a low speed wind tunnel using a 1/14.5 scale complete model of the BAe 748 aircraft were carried out by the manufacturer shortly after the accident. These tests investigated the effects of a baggage door lodged either in the door aperture or on the tailplane leading edge in positions substantially normal to the airstream. Later, further tests were performed using a 1/8 scale half model to assess the effects on pitch behaviour and elevator hinge moment of a baggage door on the tailplane leading edge. The results of these tests are summarised below.

In the first series of tests there was no significant change in lift with the door jammed in the doorway but there was an increase in drag and a small loss of stability and of elevator power was noted. More significant results in the context of the accident were obtained when the door was placed on the tailplane leading edge. Various attitudes for the door were used in the tests and a generally similar pattern of behaviour emerged for all the positions. The following discussion, therefore, is based mainly on the tests where the orientation of the door on the tailplane leading edge is presumed to be nearest to that of the accident door as given by witness marks on its surface.

The tests indicate that there is a significant increase in lift at low incidence and a similar reduction at high incidence. The change, which was accompanied by considerable shaking of the whole model, is presumably due to a change in flow regime over the tailplane. The resulting increase in drag is approximately equivalent to the undercarriage drag. A plot of the variation of pitching moment (C_M) (flaps up) with lift coefficient (C_L) and elevator deflection shows as might be expected, there is a reduction in stability and elevator power due to the reduction in dynamic head over part of the tailplane. At high lift coefficients (low speed) the presence of the door causes a nose-up change of trim while at low lift coefficients the result is a nose-down trim change. The major feature, however, is a marked discontinuity in the C_M to C_L relationship occurring at lift coefficients in the range 0.5 to 0.7 depending on elevator angle (a C_L value of 0.5 represents approximately 170 knots at sea level). The nose-up trim change at high C_L is replaced at the discontinuity by a nose-down change of a similar magnitude. The resulting effect of the door's presence, therefore, is the creation of a region of violent longitudinal instability with reversal of elevator power and in the tests the discontinuity was accompanied by heavy shaking of the whole model.

A constructed plot showing elevator angle required to maintain zero pitching moment against lift coefficient shows that as C_L decreases (that is air-speed increasing) into the critical region, progressively more down elevator is required until suddenly there is a reversal in the elevator requirement.

The second series of tests using a half model confirmed the pitching effects revealed by the earlier tests and showed that the presence of the door brings about a marked and progressive increase in elevator hinge moment as the incidence increases. The tests also disclosed that the discontinuity in pitching moment is accompanied by a large discontinuity in elevator hinge moment together with large hinge moment oscillations. The magnitude of the jump in hinge moment coefficient varies with elevator angle but is typically equivalent to a stick force of 100 lb at 150 knots EAS. This change is also in the direction to drive the elevator towards the new position required to trim the change in pitching moment. One further effect that was revealed by these tests is that in the regions either side of the discontinuity, the door causes a large negative change in the elevator floating tendency leading to negative stick-free stability. This would render the control of the aircraft extremely difficult in these regions which represent a significant speed range.

Wind tunnel tests with the door attached to the tailplane were also carried out with the application of both 15° and $22\frac{1}{2}^\circ$ of flap. The results show qualitatively similar effects to the flap retracted condition with a region of violent instability. However, the discontinuity occurs at much higher lift coefficients. Based on the first series of tests this displacement in the lift coefficient for pitching moment discontinuity suggests that if flap extension could be started while the aircraft is at a C_L below the discontinuity, flaps up, then the displacement could allow the speed to be reduced progressively as more flap is lowered and the aircraft would then remain at lift coefficient below the discontinuity throughout. The second series of tests, though, showed later ranges of lift coefficients over which the elevator hinge moments were adversely affected by the presence of the door on the tailplane, indicating that control of the aircraft would be extremely difficult over wide speed ranges which were previously thought to be little affected, flaps up or down.

Post-Accident Measures

Since the accident a number of instructions have been issued concerning the doors on BAe 748 aircraft. It is impossible to list these in full but the following information was circulated during the immediate period after the accident.

On 9 July 1981 British Aerospace sent Alert Service Bulletin No A52/90 by telex to all operators. The contents of the bulletin were declared mandatory by the CAA and were required to be brought to the attention of all aircraft crew members. The contents included the following extracts.

"1 Planning information

B Reason

With reference to BAe telex ref PSM/219/3793 dated 2 July 1981 and despite the recommendations contained in service bulletin 52/27 and repeated in 52/37 further incidents have occurred where the starboard rear baggage door has opened and become detached during flight.

Strict adherence to the correct operating procedures should prevent such incidents.

This service bulletin reiterates the importance of carrying out the checking procedures to ensure that the doors are fully closed and locked. An amended crew drill is introduced to emphasise that responsibility for ensuring that all doors are closed and locked from the aircraft interior rests with the flight crew, and ultimately with the Captain of the aircraft. The instructions in this bulletin will be amended or superseded as further information becomes available.

C Description

Procedures are given for closing and checking the security of all doors.

Instructions given in HS 748 service bulletin No 52/27 for the deletion of all external markings and indicators now become mandatory.

A check is introduced to ensure the integrity of the electrical door lock indication system.

2 Accomplishment instructions

A Pre-flight check

Rear passenger, rear baggage and forward freight doors.

1) On all three doors prior to the first flight of the day and on all three doors after a subsequent change of flight crew.

An accredited member of the flight crew/cabin staff must, from the interior of the aircraft, personally close the door(s) ensuring that the door is visibly closed and locked in accordance with A.2 below. The same procedure must be followed for any door(s) opened or re-opened during an intermediate stop.

2) Prior to starting the left engine and with all related circuit breakers in.

The accredited member of the flight crew/cabin staff must ensure that:

Each door is correctly positioned in its aperture with all claws engaged on the inner face of the door frame. Each door inner operating handle is in the locked position and securely lodged in its detent in the tufnol cam.

The visual indicators on each door show safe (ie, the green/yellow stripes completely fill the viewing aperture).

3) Prior to taxiing from the ramp, the Captain of the aircraft must be satisfied the checks described above are completed. (The aircraft check list to be amended to reflect this requirement.)

4) The door unsafe warning light must be checked out and the press-to-test operated to ensure that the lamp filament and circuit fuse are serviceable.

If the 'door unsafe' warning light is on, indicating door(s) unsafe, take-off must not be commenced for any flight unless the Captain opens and closes each door in turn and is satisfied all doors are correctly closed and mechanically locked before take-off.

The defect causing the illumination of the doors unsafe warning light must be cleared at the end of that day's operations, or first return to a station where rectification can be made.

Under no circumstances is aircraft despatch permitted with any mechanical defect or deficiency on the door locks and/or mechanisms on any door.

Under no circumstances is the steady door warning light on the Captain's panel to be inhibited".

In addition to this, the bulletin contained instructions to delete the external markings and indicators. This action was previously classified 'desirable' by service bulletin 52/27. There were also instructions on how to perform an additional mechanical check and repetitive electrical checks of the indicating system.

Following the discovery of the problems with the mechanical indicators detailed in section 1.12.2, the manufacturer issued an alert telex reference PSM/509/3816, the contents of which were classified mandatory by the CAA. The following is an extract from that telex message.

“BB In the course of an accident investigation an aircraft has been found with the window over the indicator drum reversed so that the window contour does not follow the contour of the drum. This can lead to the possibility of parallax errors giving misleading indication of the true state of the locking mechanism.

CC Within two days of the receipt of this telex all aircraft are to be inspected and if windows are found to be reversed they are to be removed and refitted correctly ensuring no foul between window and drum. Until this inspection and any necessary rectification has been accomplished the aircraft may not be despatched with any fault on the door unsafe warning light system (contrary to para 2A4 pre-flight checks of alert SB A52/90).

DD In the case of window part no 3N 1990 the transparent area within the painted surround must measure not less than one inch in height. In the case of window part no 20N 2651 ensure that the window has not been painted to restrict window height to less than one inch.

EE After refitting windows the relevant checks in para C1 of alert SB A52/90 are to be repeated.”

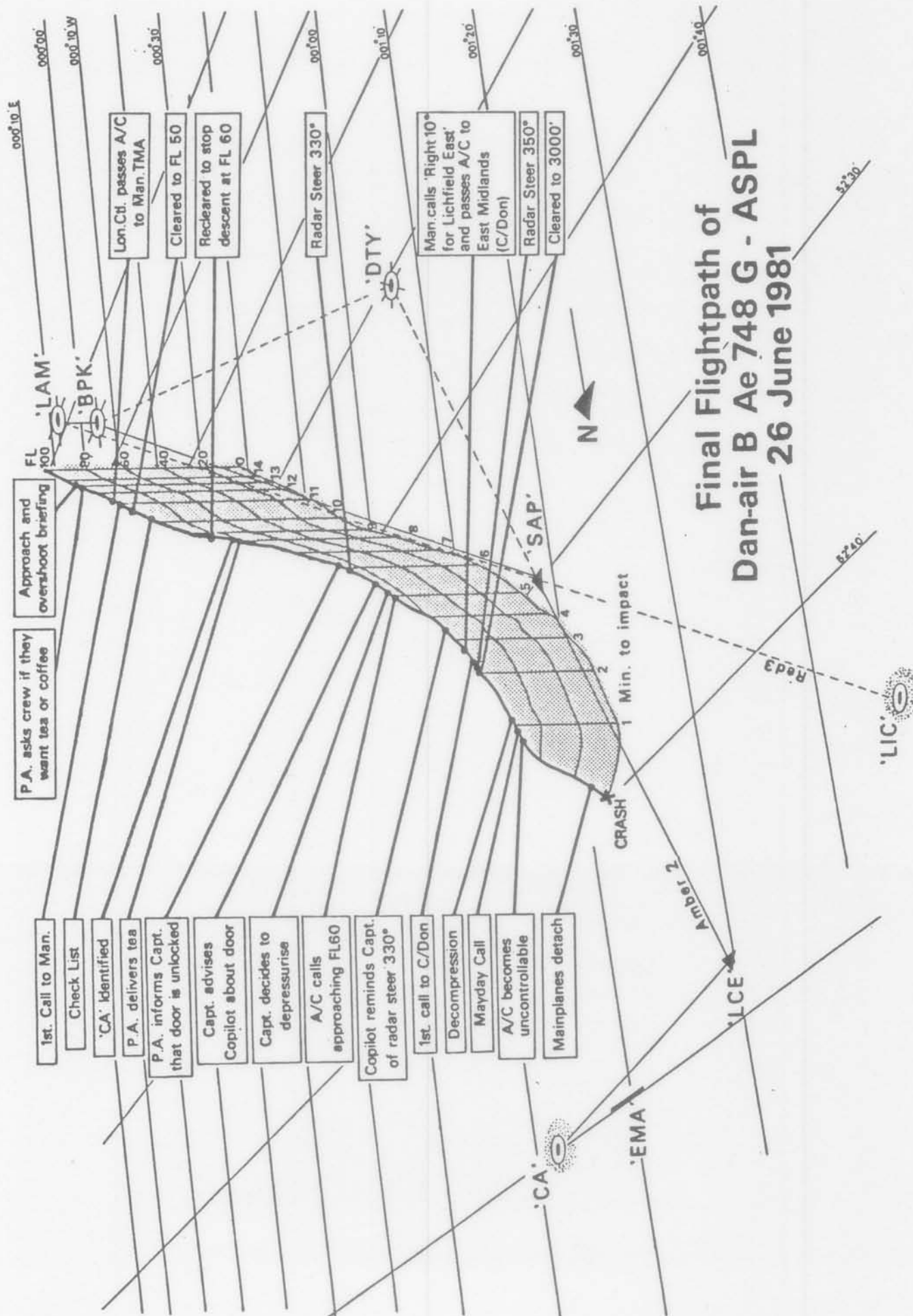
Subsequently a series of design changes were developed to improve door operation and warning system functioning. These included:

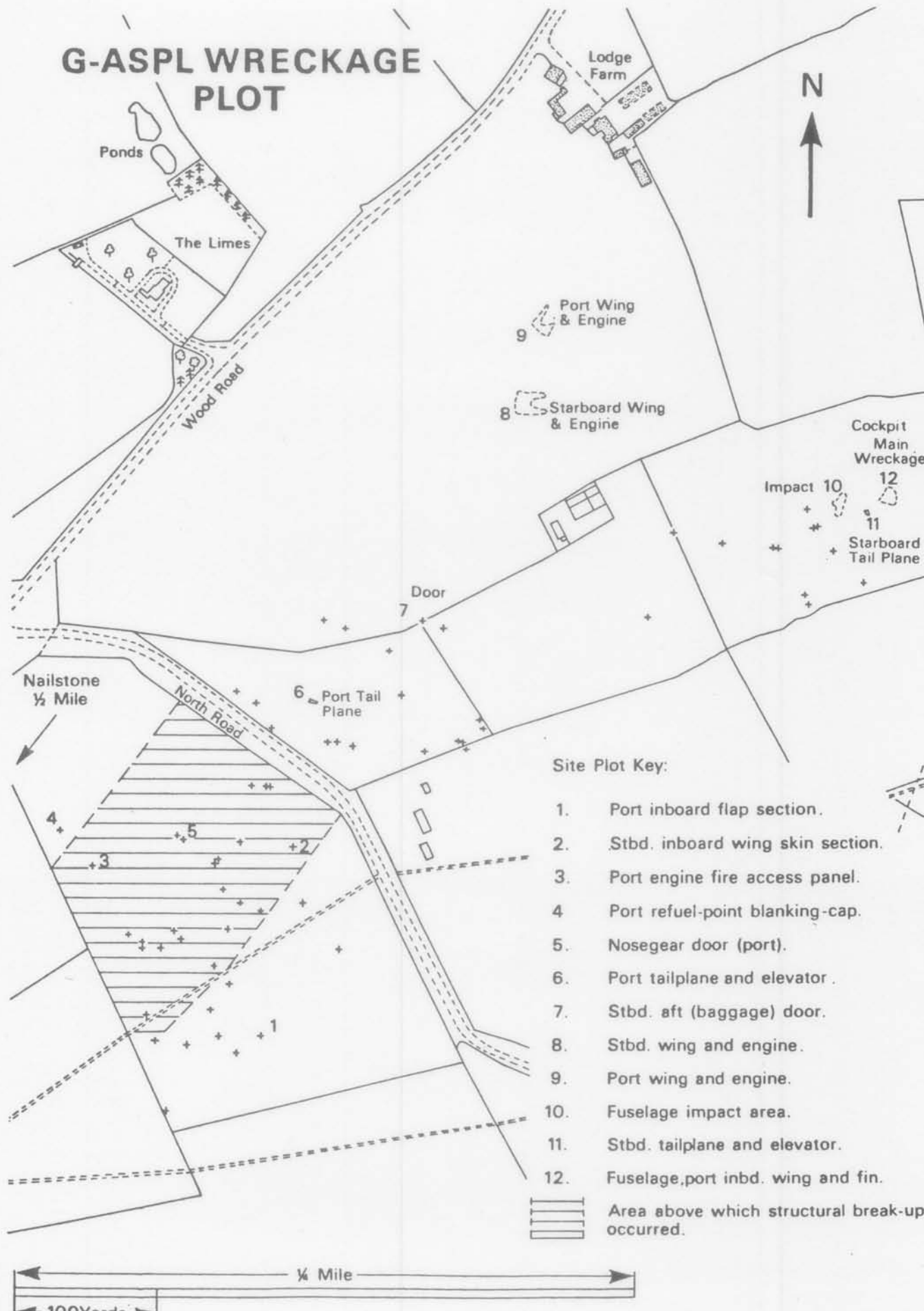
- 1) A modified fixed cam under the inner handle. This had an altered profile to render it impossible to close the door from outside. It was constructed of considerably greater thickness than was the original cam design and incorporated a metal wear indicator to ensure that appropriate replacement action was taken before wear became excessive.
- 2) A system of decals to be applied to the doors indicating to crew members the correct appearance of the mechanical indicators when the door is closed.
- 3) Modified windows for the mechanical indicators fitted directly to the door structure to enable them to remain undisturbed when the door trim is removed.
- 4) Modification to the mounting of the micro-switch positioned at the bottom of the door aperture, to increase its reliability of operation and to reduce the possibility of in-flight false warnings.
- 5) Modification to the electrical door unsafe warning to:
 - (a) introduce an aural warning horn in addition to the existing cockpit warning light.

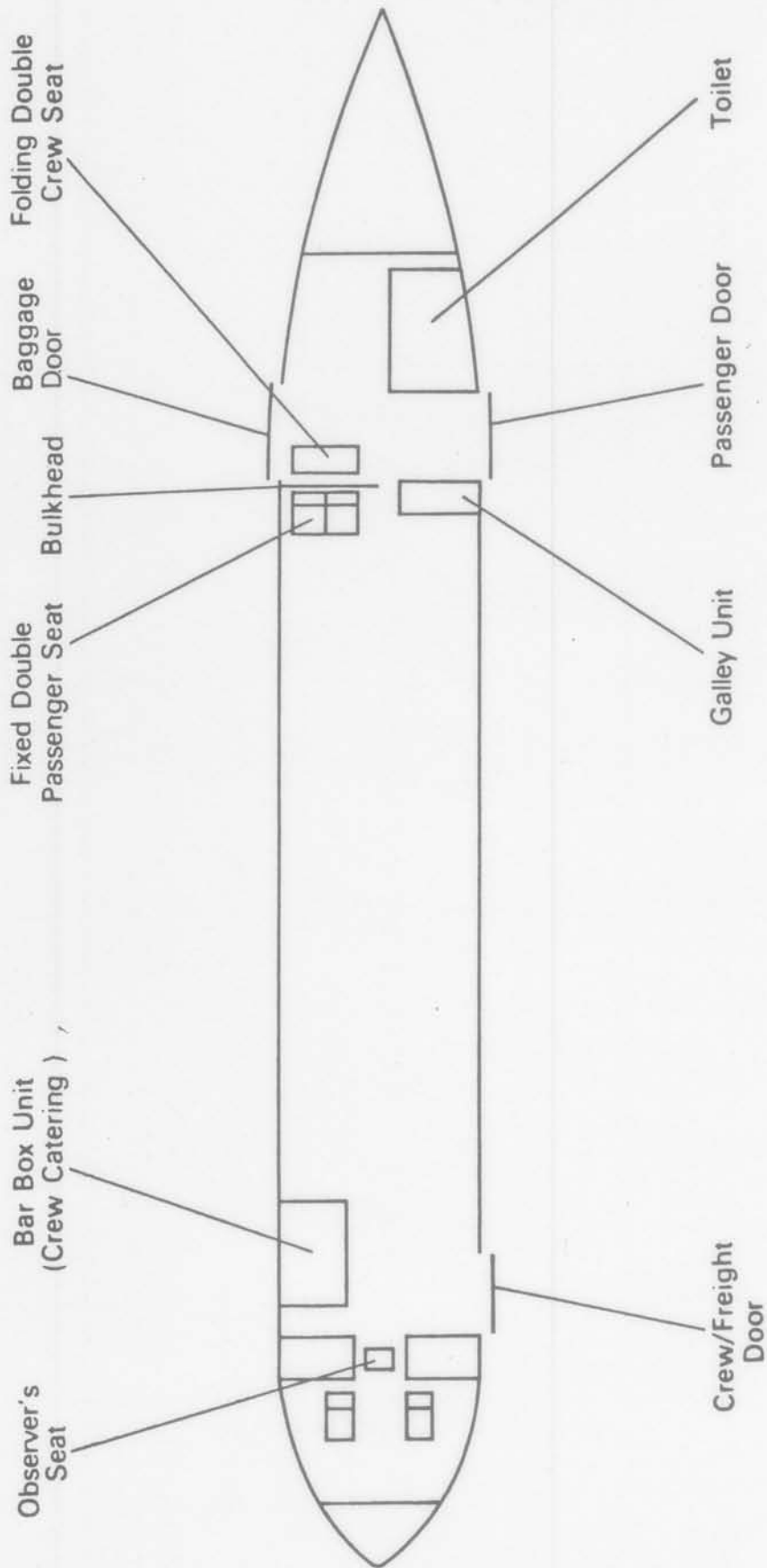
(b) revise the door unsafe warning electrical circuit so that failure of a circuit breaker or a relay will not invalidate the system.

6) A repetitive check on the functioning of the individual micro-switches in the door unsafe warning system and of electrical continuity in the associated wiring.

All these changes were declared mandatory with the exception of number 3.

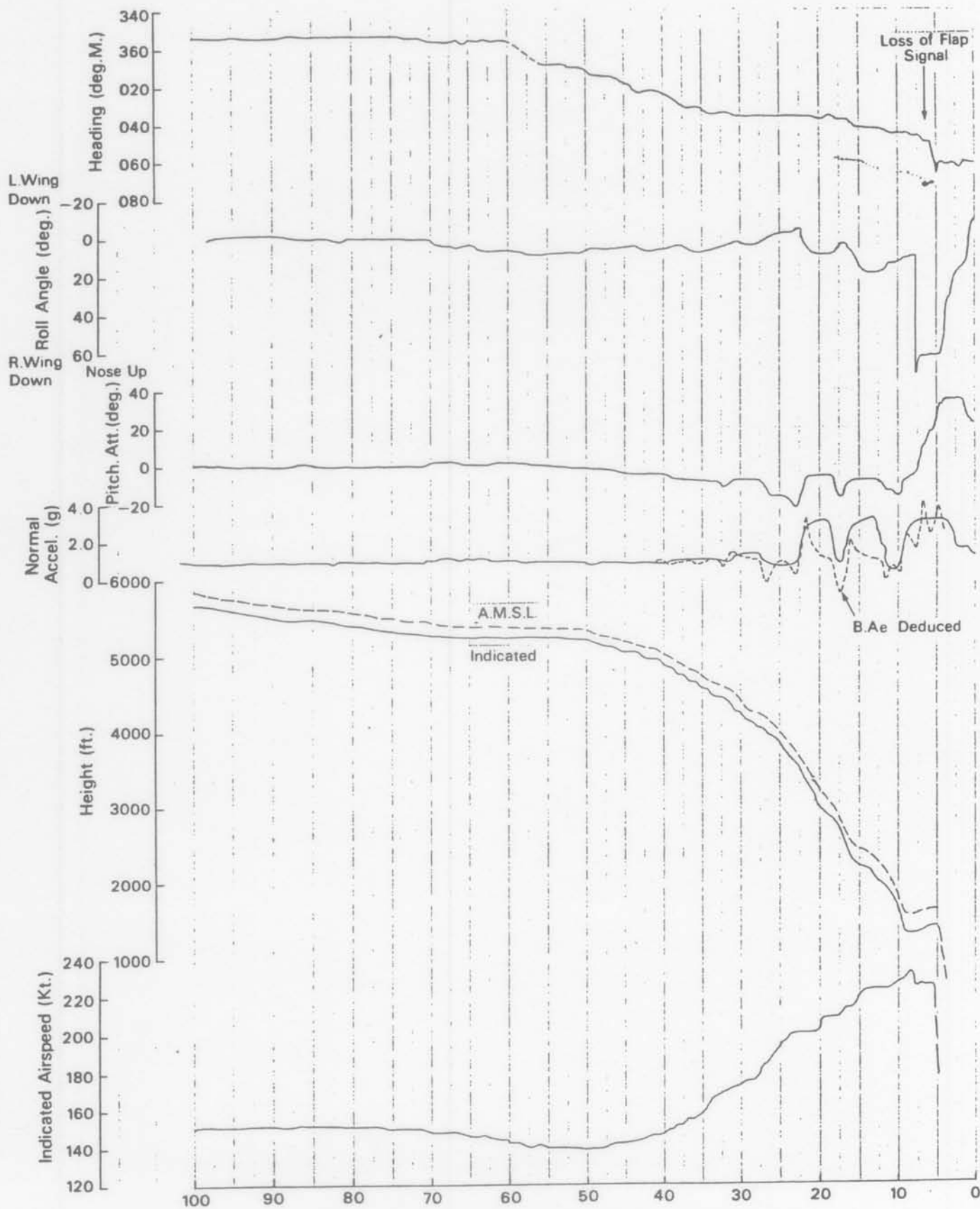




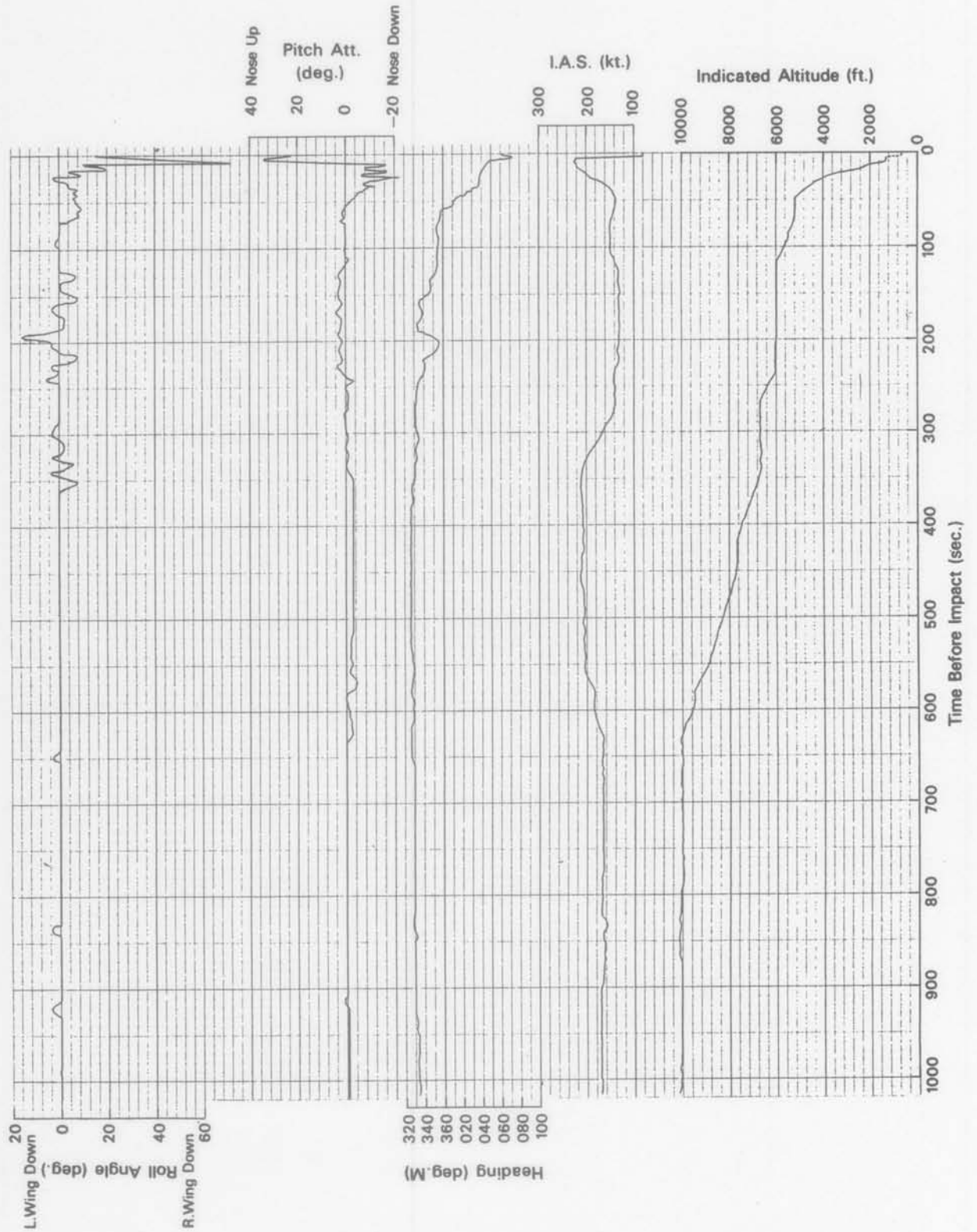


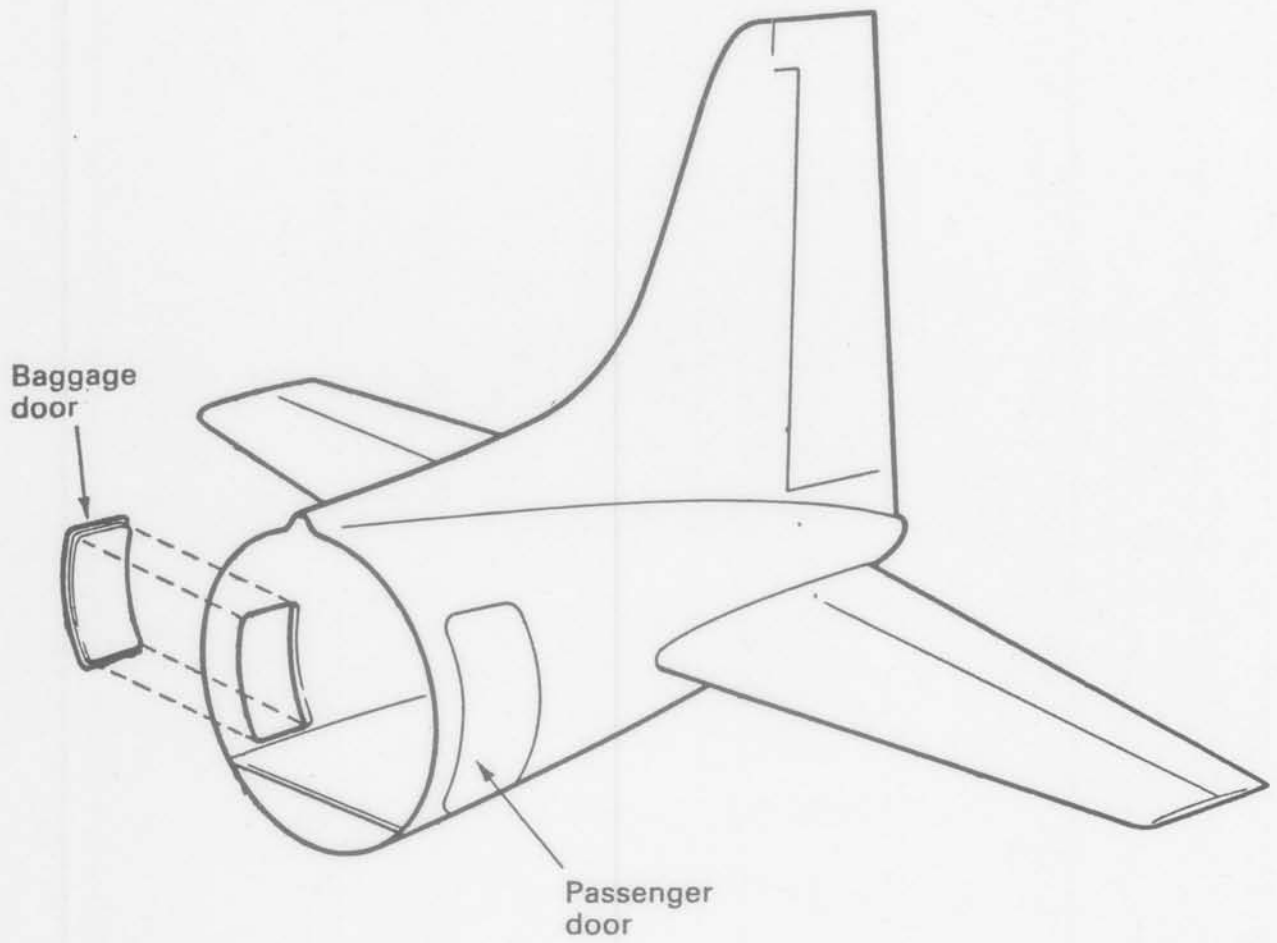
G-ASPL — CABIN CONFIGURATION

ACCIDENT TO DAN - AIR B Ae 748, G-ASPL, AT NAILSTONE, LEICS. ON 26 JUNE 1981
CORRECTED F.D.R. READOUT



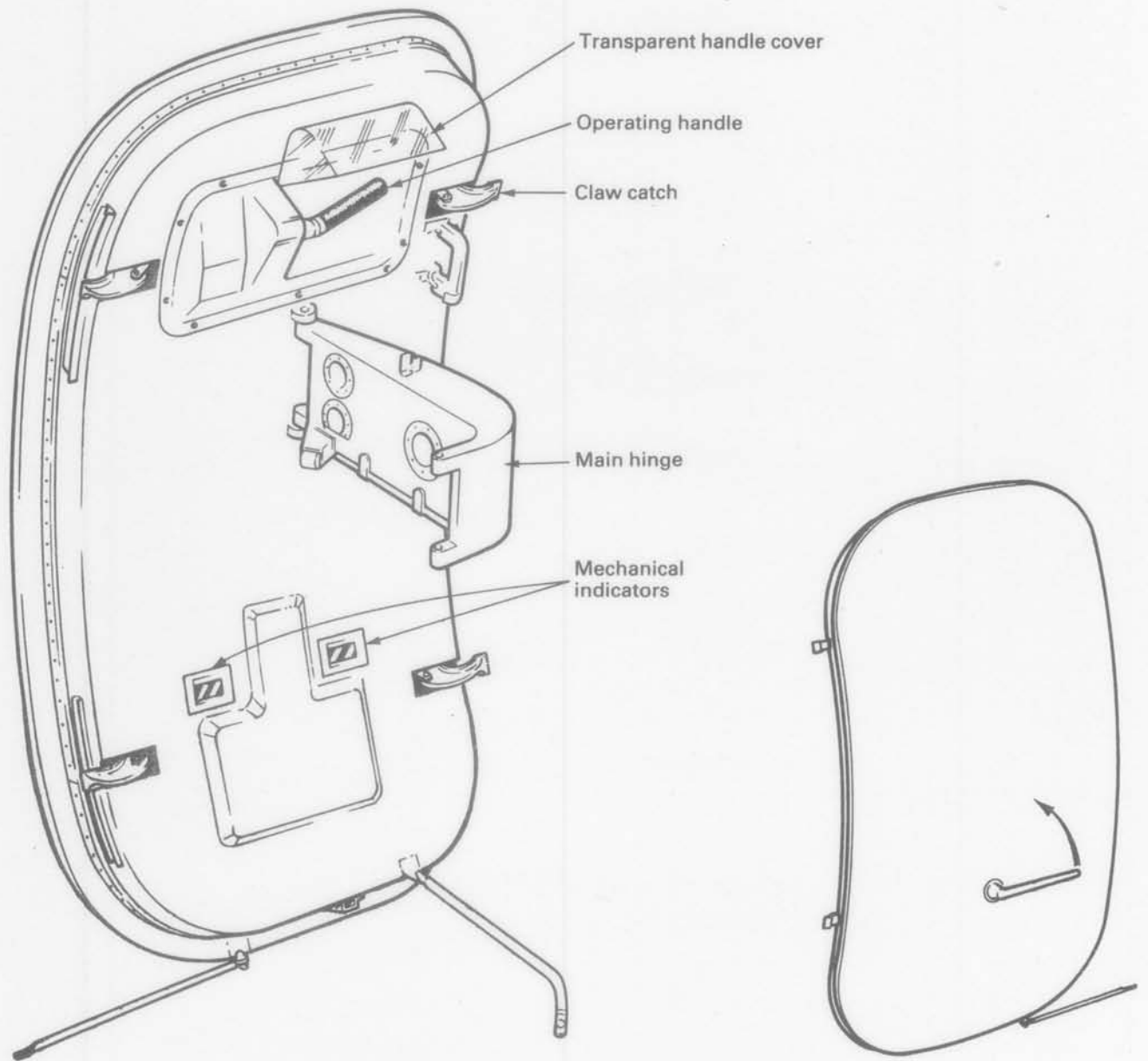
DAN-AIR B Ae 748, G-ASPL, ACCIDENT AT NAILSTONE ON 26th JUNE 1981
 CORRECTED F.D.R. READOUT





Position of doors at rear of aircraft

Figure 1 BAe 748

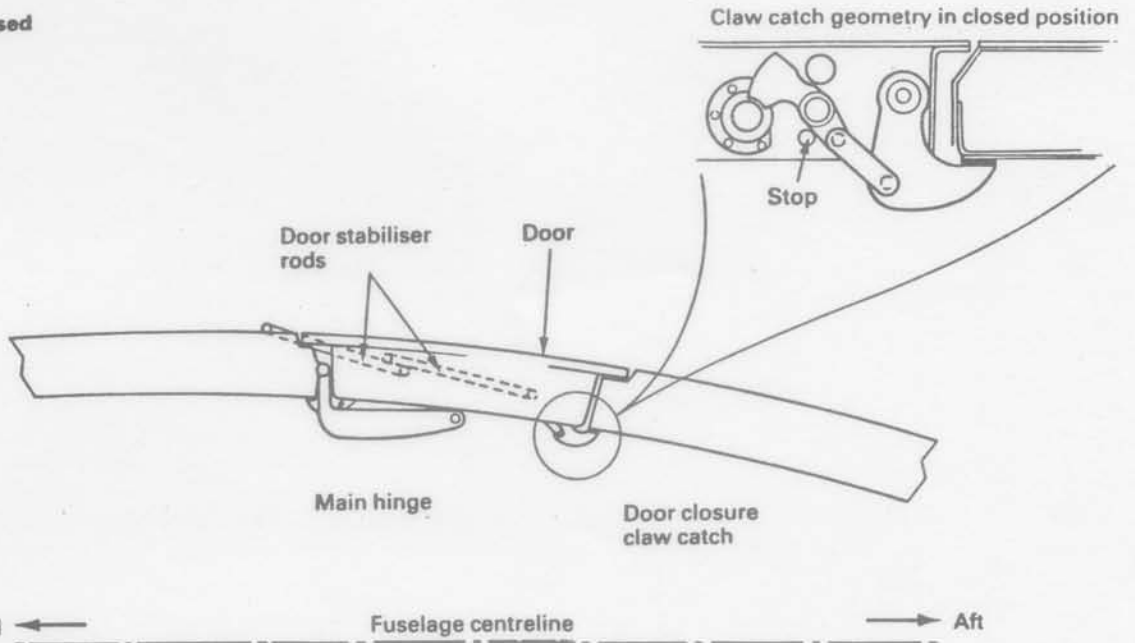


General door illustration showing hinge and stays, with plastic door trim in position viewed from inside aircraft.

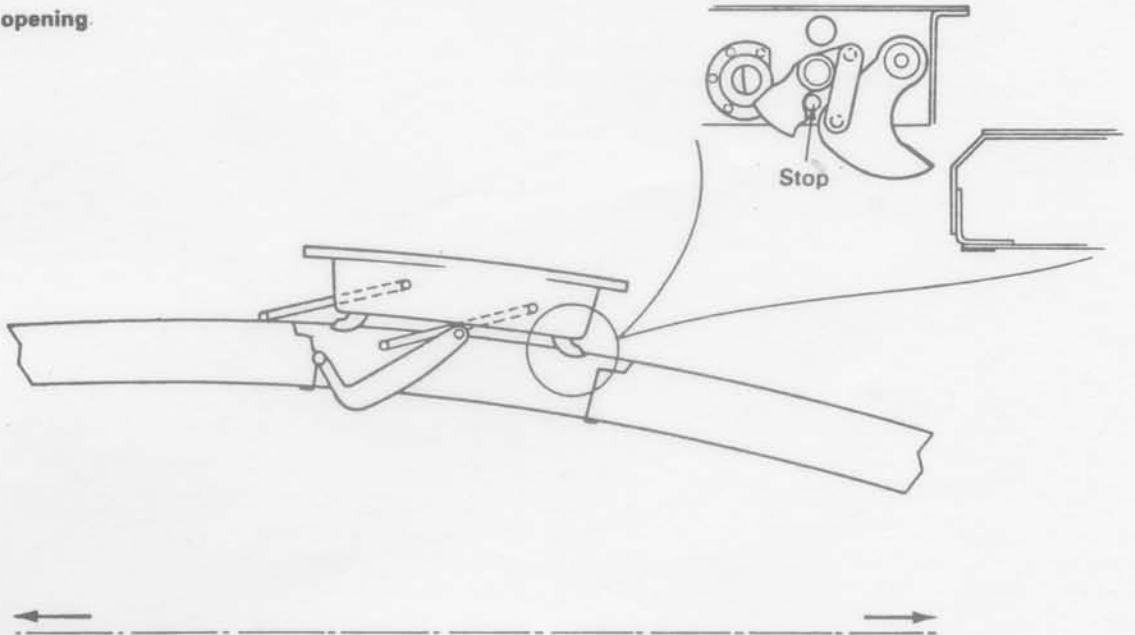
View from outside showing outside handle

Figure 2 BAe 748-Baggage Door

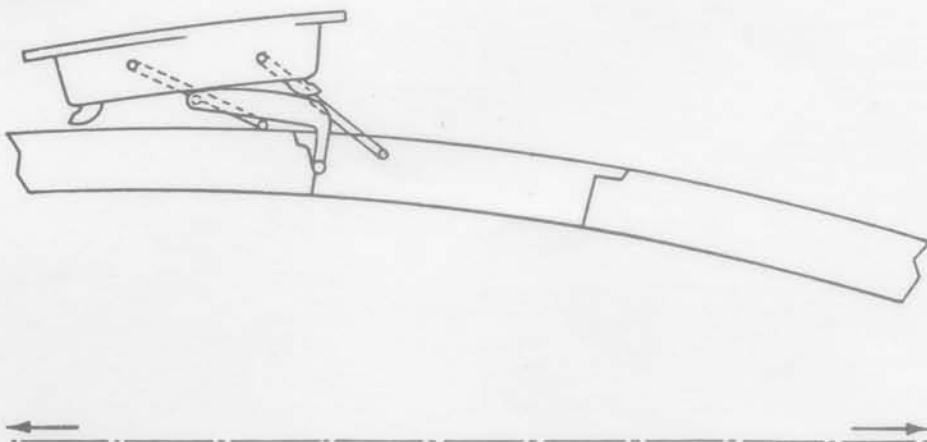
Door closed



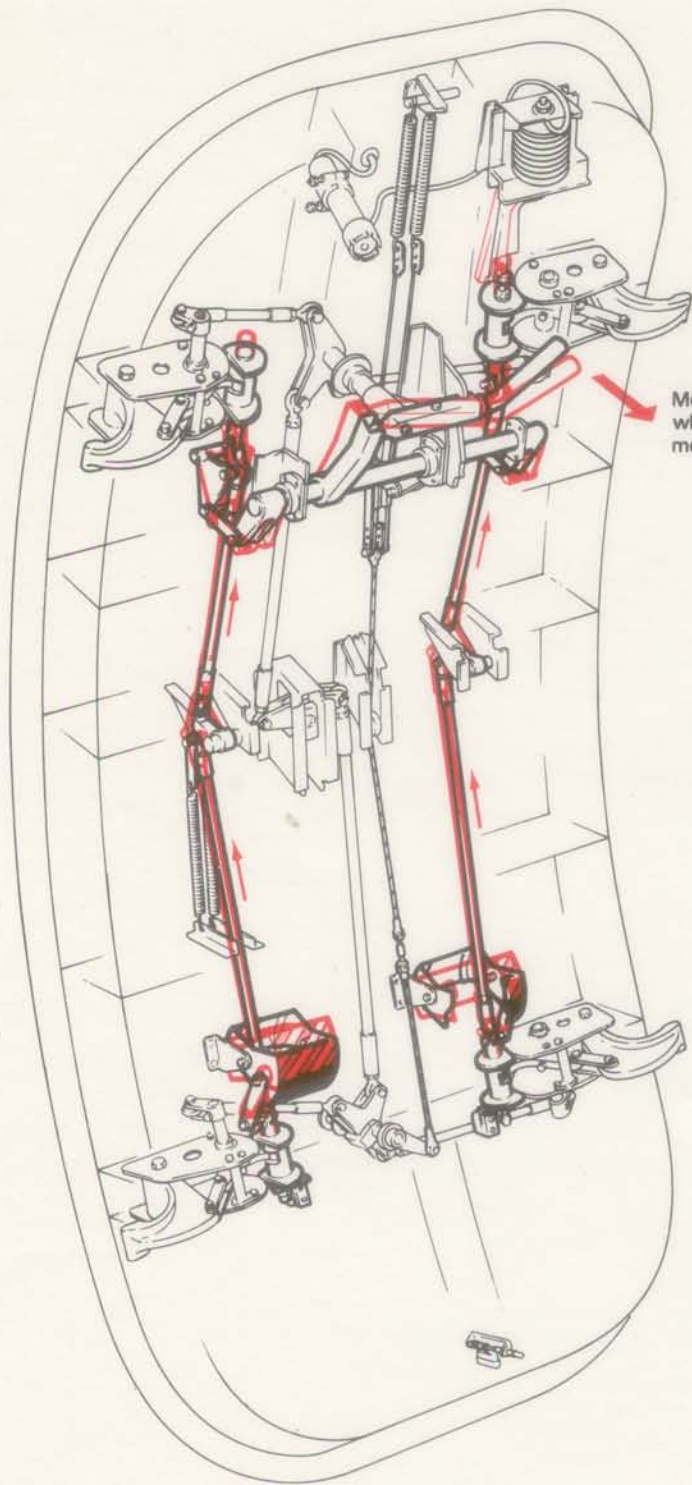
Door just opening



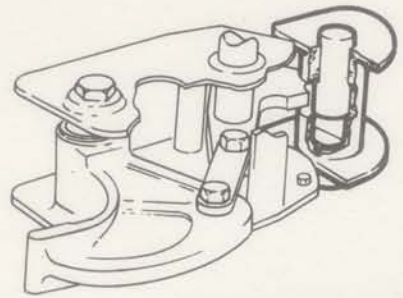
Door fully open



Plan view of door in closed, intermediate and open positions.
Figure 3 BAe 748-Baggage Door

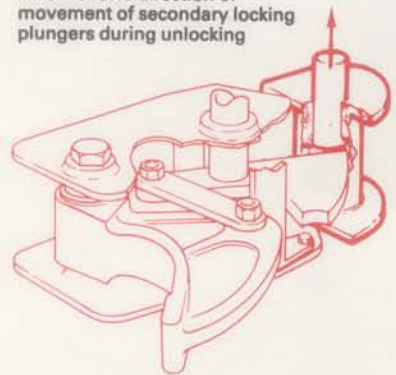


Movement of handle when operating secondary mechanism



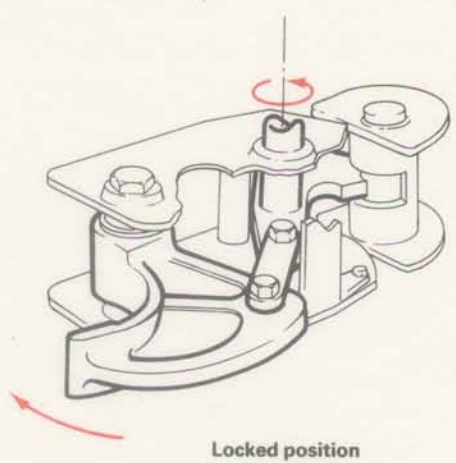
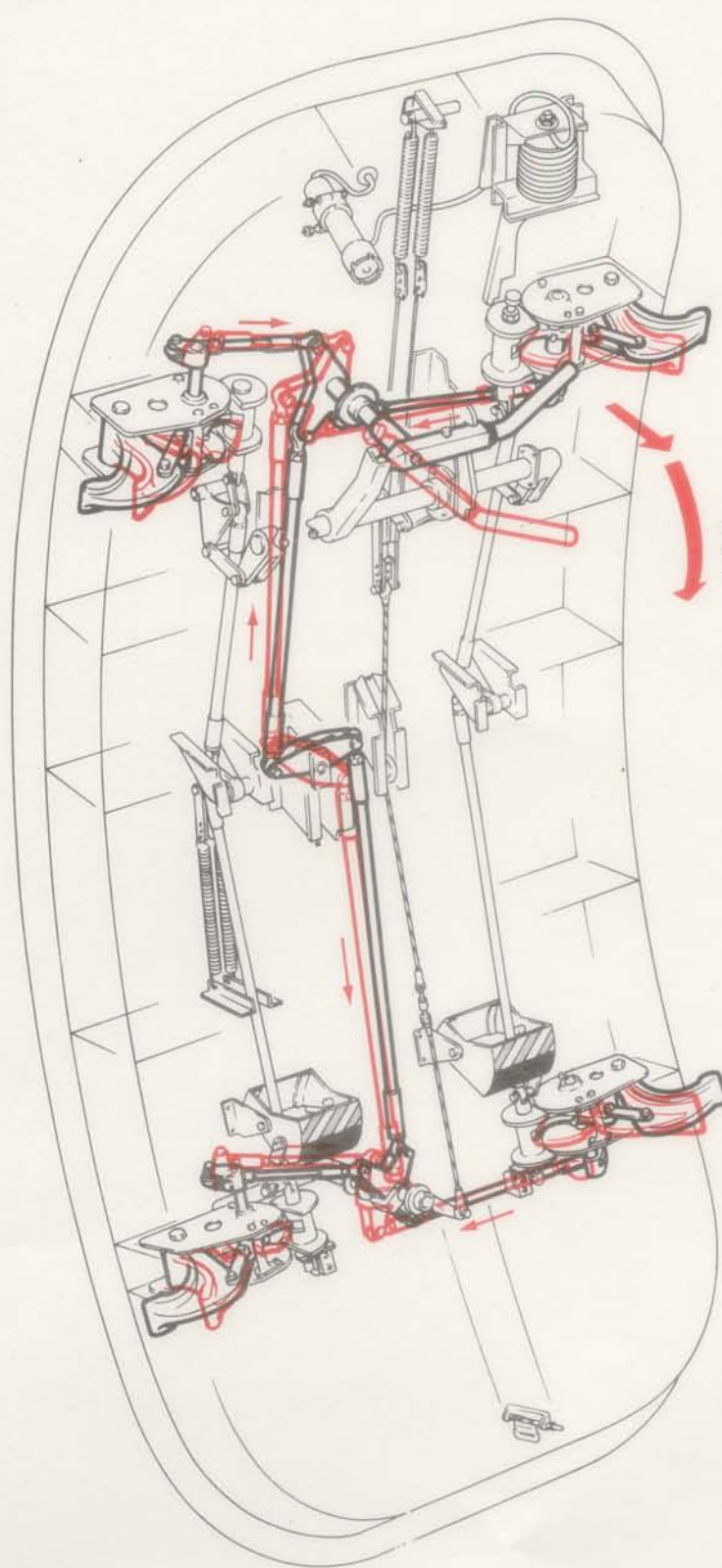
Locked position

Arrow shows direction of movement of secondary locking plungers during unlocking

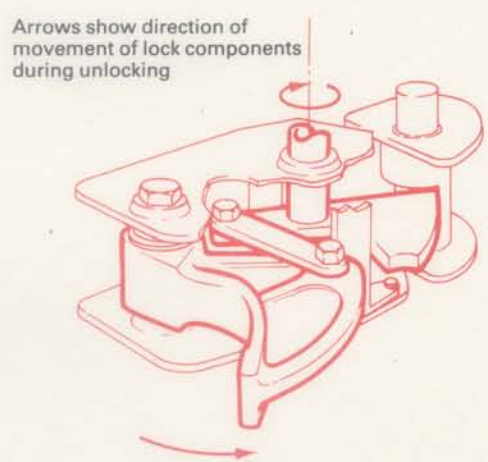


Open position

Figure 4 Secondary mechanism open/closed.



Movement of handle
when operating primary
mechanism



Arrows show direction of
movement of lock components
during unlocking

Figure 5 Primary mechanism open/closed.

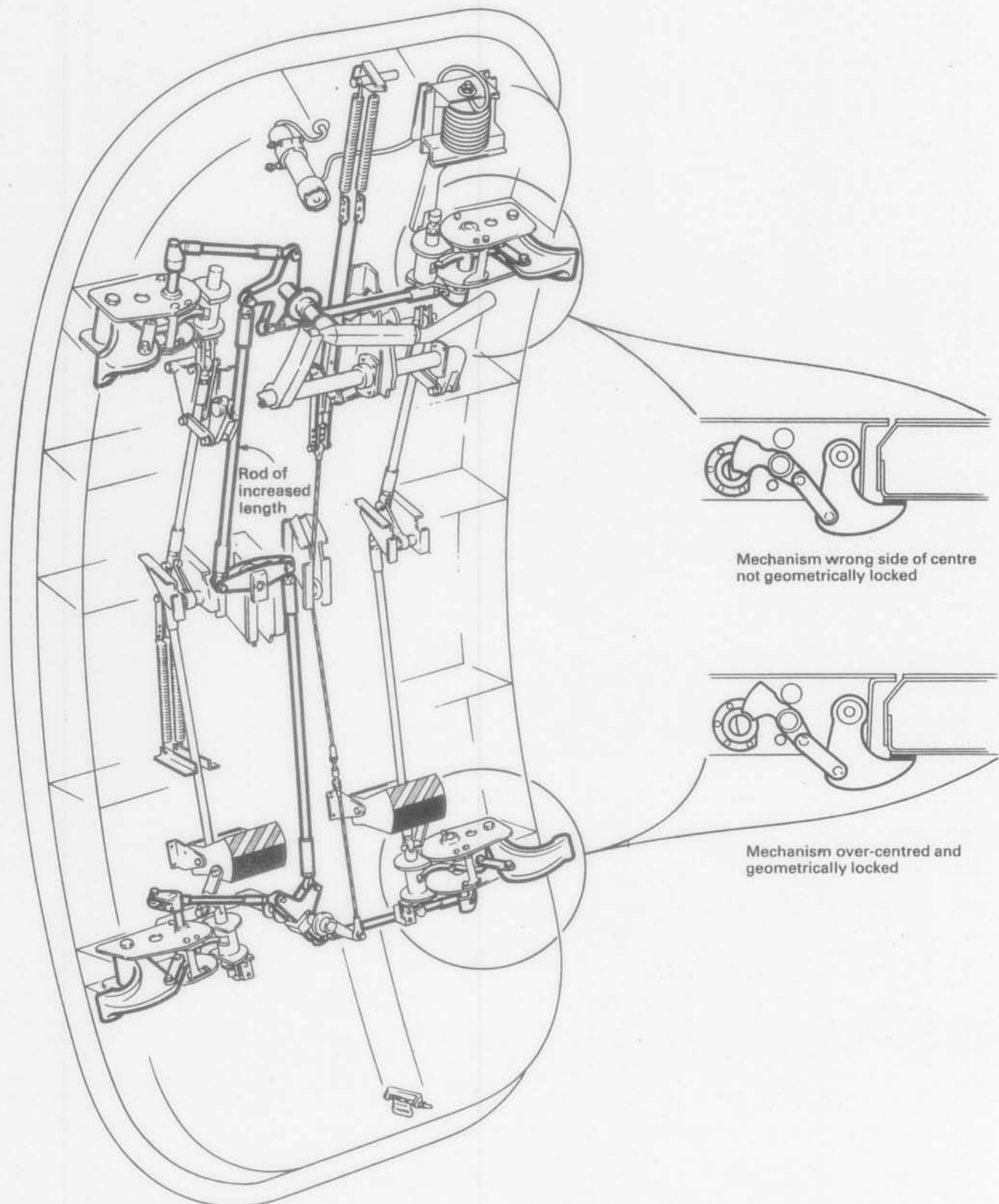
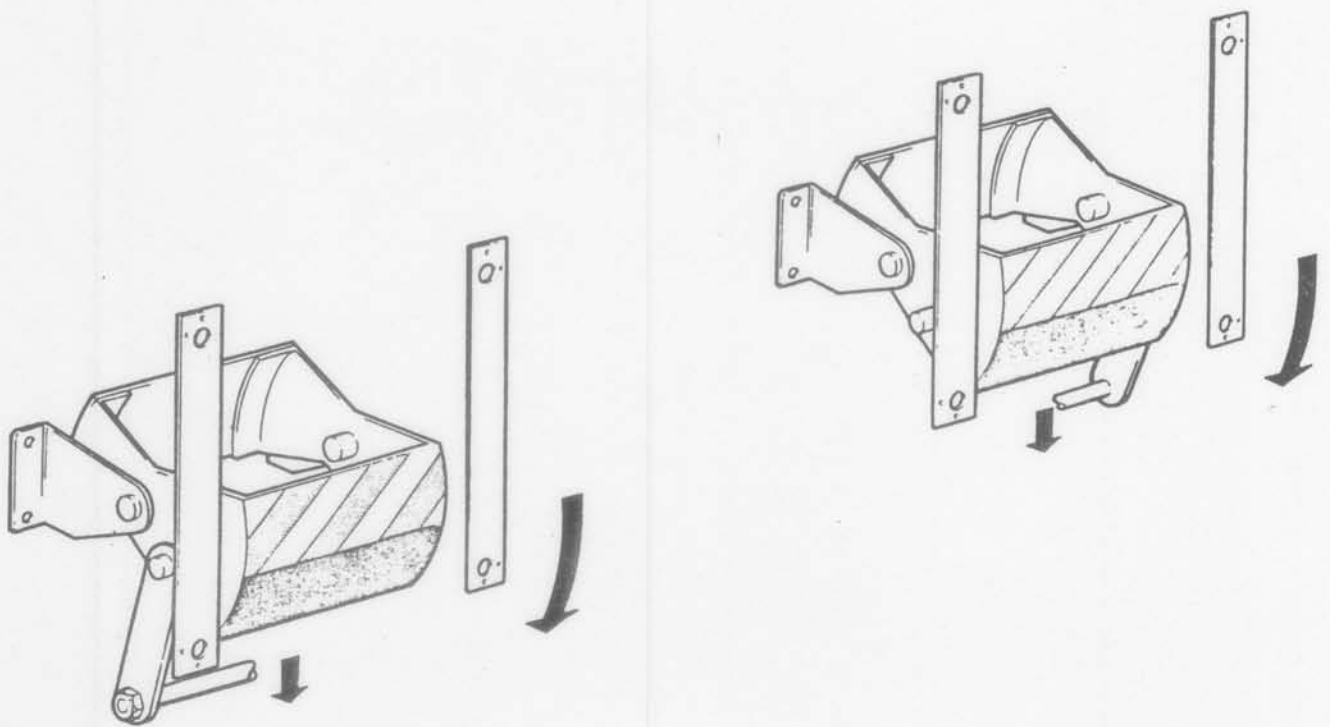
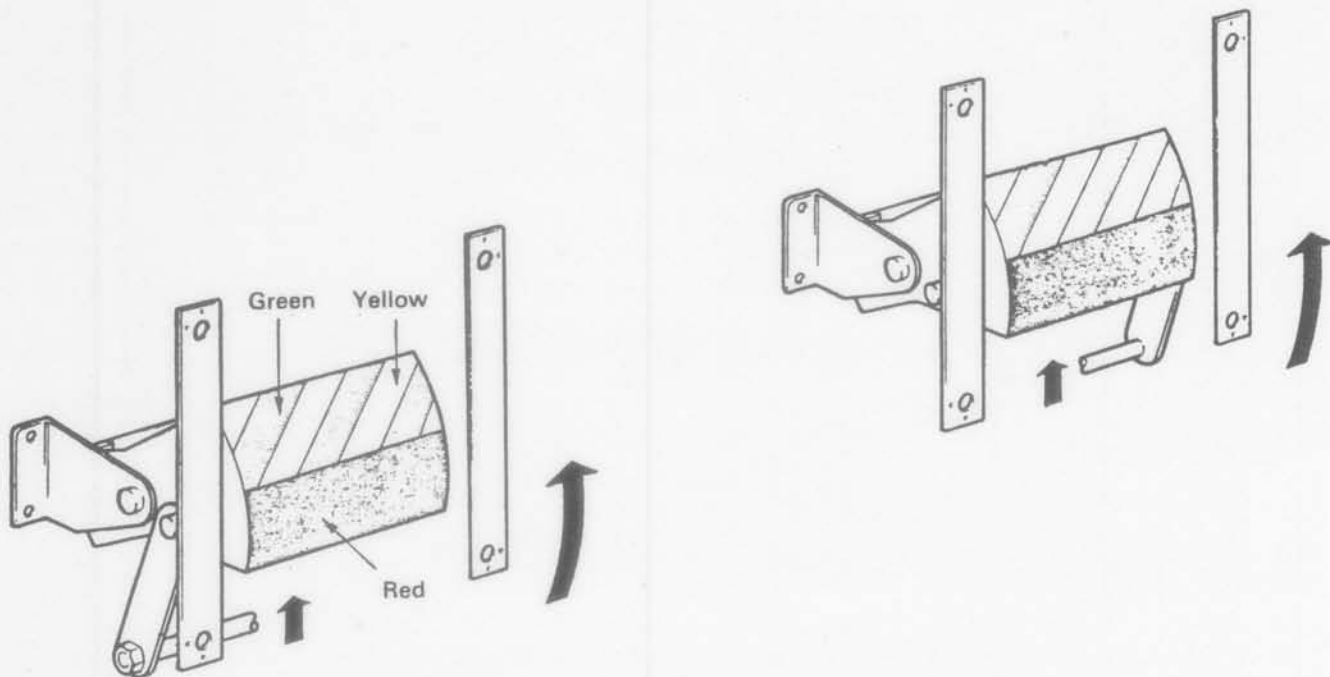


Figure 6

Diagram showing effect of variation of rod length on synchronisation of top and bottom pairs of claw catches. Movement of top rods and star lever exaggerated to emphasise effect of incorrect rod length. Inset diagrams show geometrically locked bottom claws and top claws with geometric lock not made as a result of incorrect rod length.



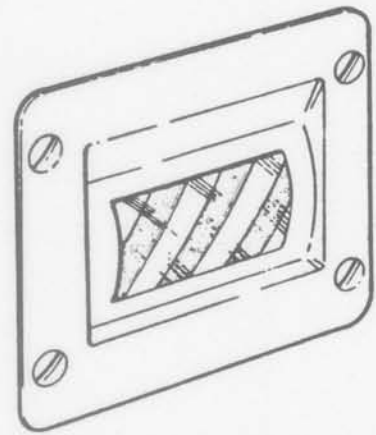
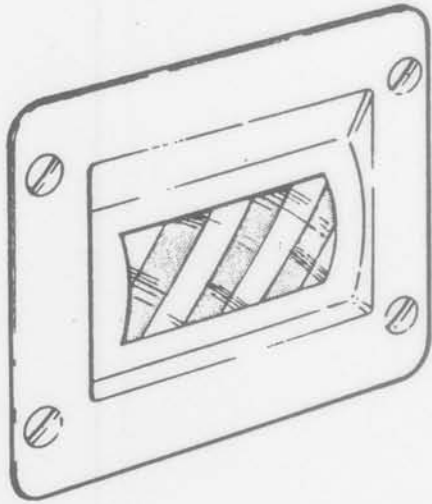
Position of indicator drums with door safe



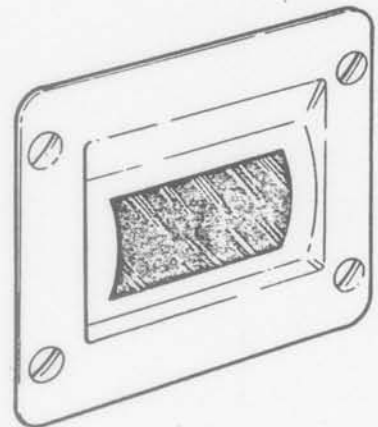
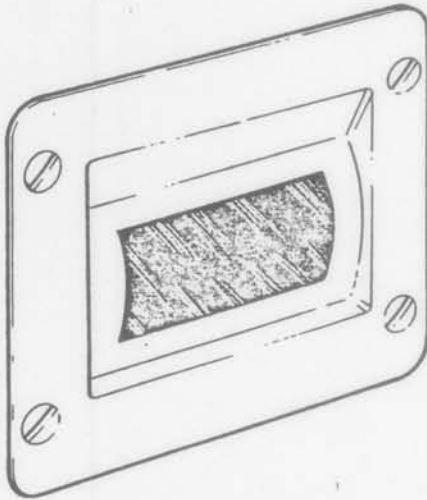
Position of indicator drums with door unsafe

Figure 7 Effect of secondary lock movement on indicator drum position

Note: Figures 7-14. These diagrams are for illustrative purposes only and are not to scale.



Normal door safe indication



Normal door unsafe indication

Figure 8 Views of indicators with windows in position

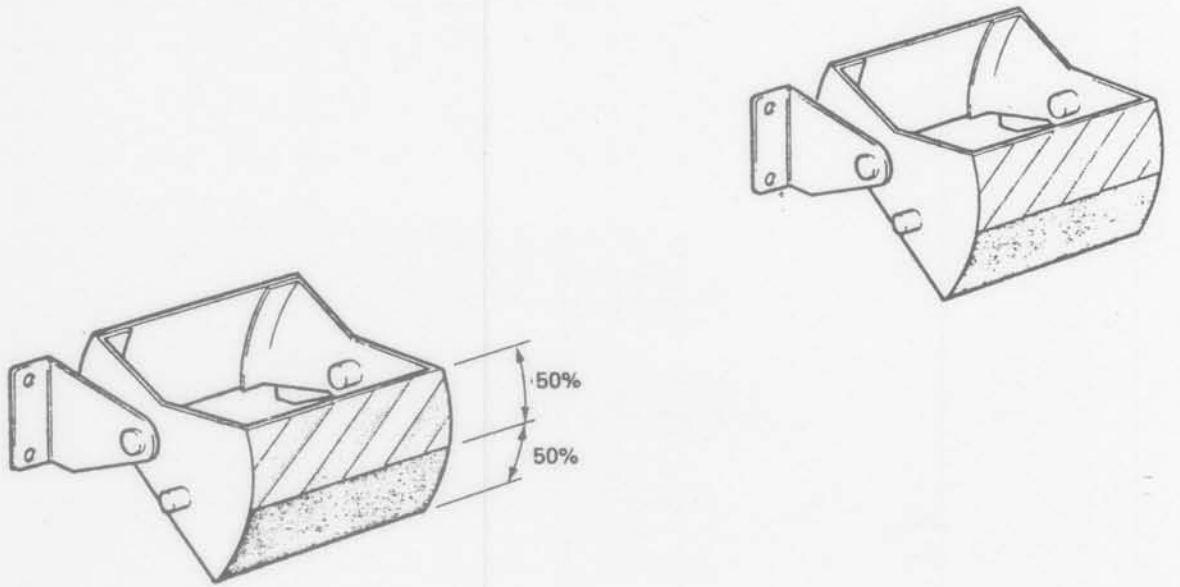


Figure 9 Drums on G-ASPL as apparently manufactured

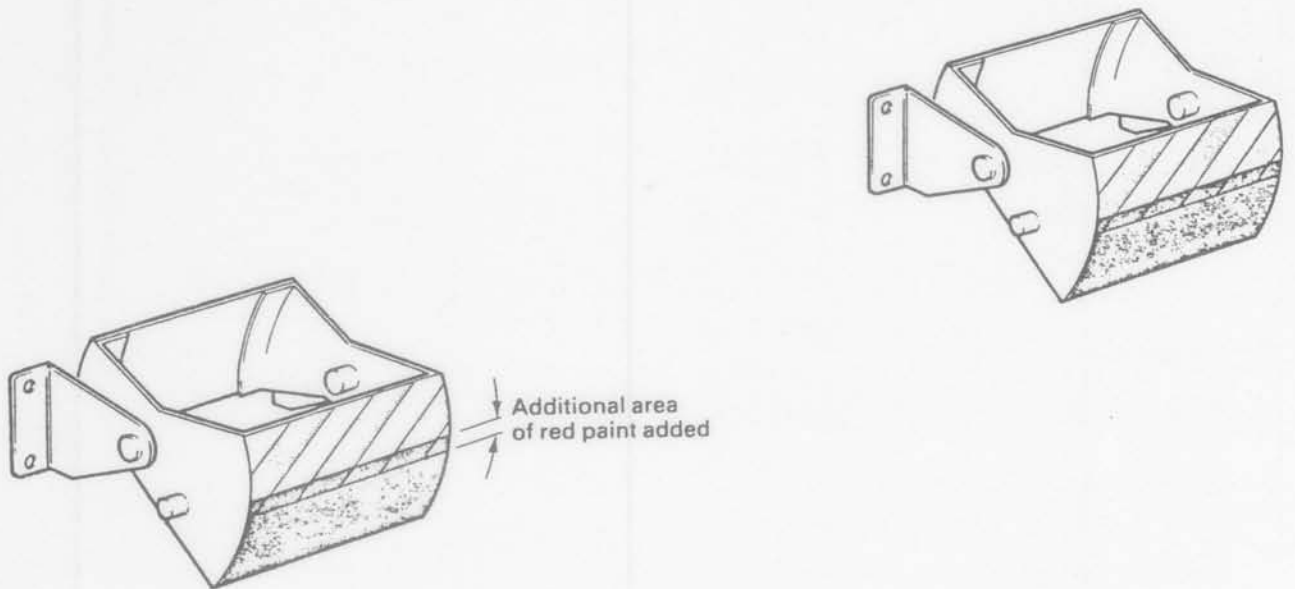


Figure 10 Drums with red over-painted and extended upwards (as applied at some time to G-ASPL)

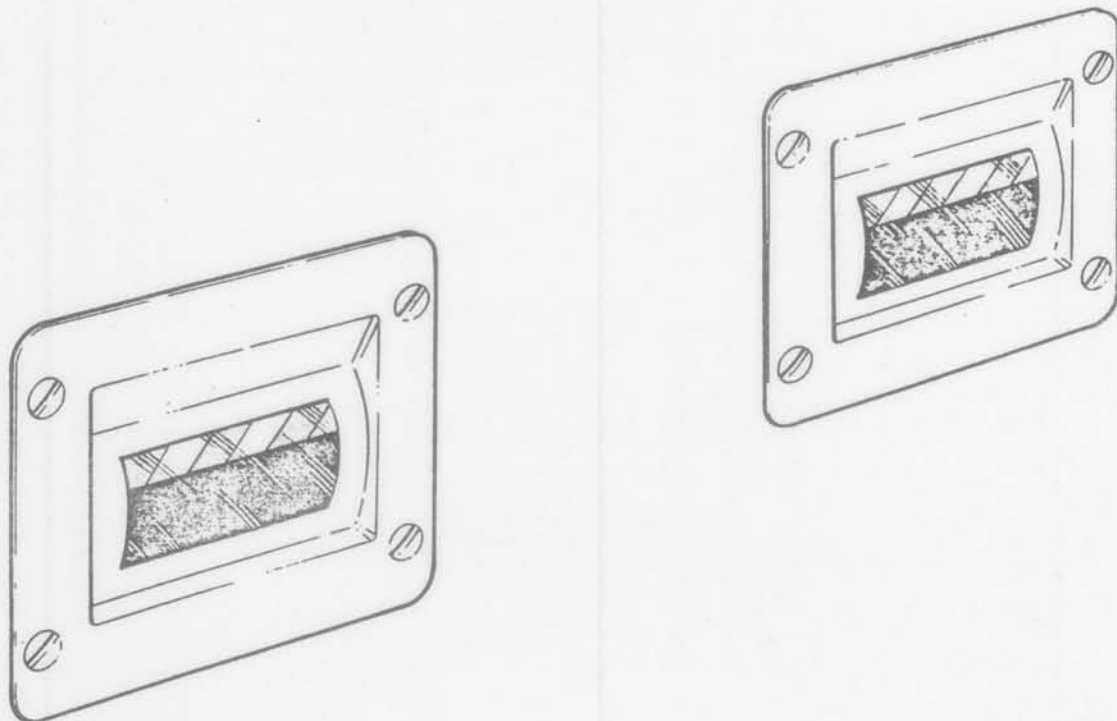


Figure 11 Approximate indication which would have been given by indicators with over-painting as in Fig. 10 when secondary mechanism is just disengaged.

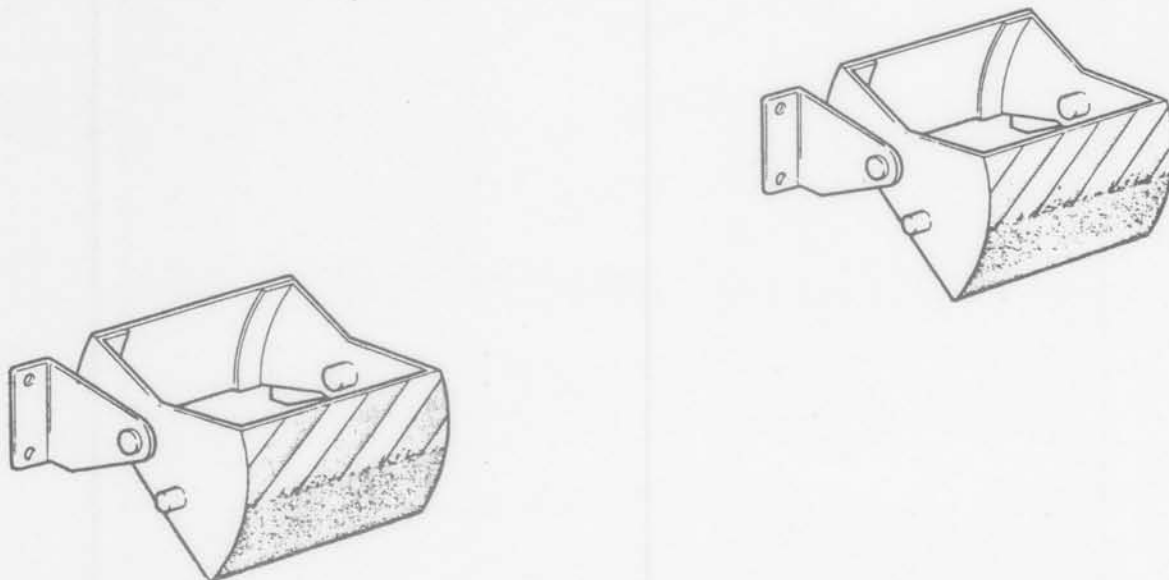


Figure 12 Drums with signs of red paint over green/yellow partly worn away, as found on G-ASPL

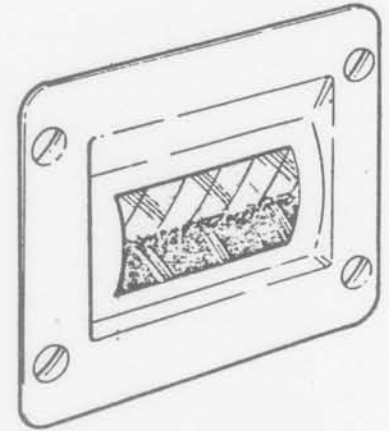
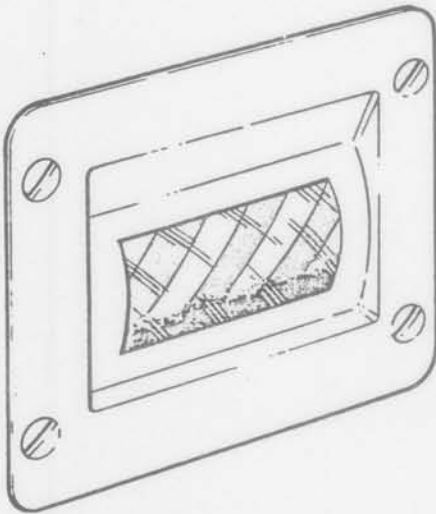


Figure 13 Effect of wearing away of over-painted layer on indication with mechanism in the same position as in Fig. 11

Note: Wearing away of red paint layer was unsymmetrical

Note: The diagrams on this page are for illustrative purposes only and are not to scale.

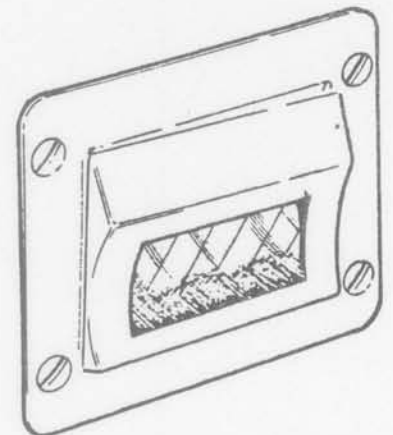
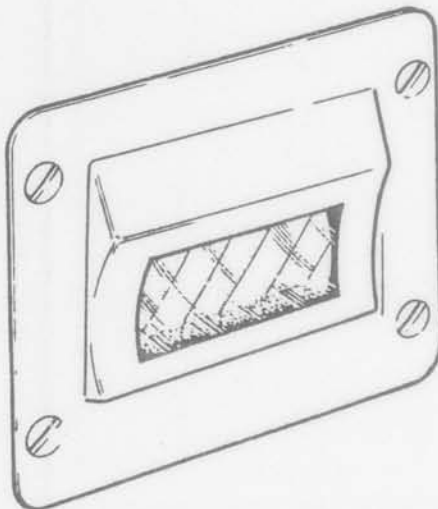


Figure 14 Additional effect brought about by incorrect fitting of windows as found on G-ASPL.

Note View of indicator drums in conditions as found, is affected by:

1. Parallax errors resulting from different eye positions i.e. standing close to door handle looking downwards or standing on other side of fuselage, adjacent to passenger door looking across to baggage door.
2. Backlash in indicator drum drive mechanism allowing drum to adopt a range of angular positions.
3. Shadows over lower half of concave window space can obscure red section under normal cabin lighting, leaving only green yellow colouring visible.