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Civil Aircraft Airworthiness Data Recording Programme

Special Events of Meteorological Origin (January 1966 to November 1968)

by

The CAADRP Special Events Working Party

(Co-ordinated by G. E. King, RAE)

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C.P. No. 1188*
January 1971

CIVIL AIRCRAFT AIRWORTHINESS DATA RECORDING PROGRAMME

SPECIAL EVENTS OF METEOROLOGICAL ORIGIN

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SUMMARY

A small number of jet aircraft in normal airline service were fitted with recorders which produced continuous trace records of airworthiness data for 14 parameters. Throughout the recording period the records were searched for unusual occurrences, and each one has been studied to determine its nature and, where possible, its cause.

This Report describes a selection of events of meteorological origin which were found in records taken between January 1966 and November 1968.

CAADRP Technical Report 24

Departmental Reference: Structures YSE/B/0338

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* Replaces RAE Technical Report 70253 - ARC 33163

CONTENTS

1 INTRODUCTION

The object of the Civil Aircraft Airworthiness Data Recording Programme is a systematic study of the normal operational flight of civil transports. A small number of aircraft in regular airline service were fitted with analogue paper trace recorders which collected data in the form shown in Fig.1. The whole programme is described fully elsewhere[1].

From time to time unusual or extreme events (special events) are noted and this Report, being one of a series[2-11], contains a selection of such events of meteorological origin which occurred to pure jet rear engined transport aircraft in scheduled airline operations between January 1966 and November 1968. They are presented in the form of a reproduction* of the original record, together with a description of the event, any relevant supplementary information and comments which represent the opinion of a Working Party comprising members of RAE, ARB, CI Data Centre Ltd., and the airlines concerned.

2 NOTE ON SELECTION OF SPECIAL EVENTS

After the photographic record has been developed, it is examined and annotated by the airline concerned. It is then scrutinized by a member of the Working Party for Special Events, and finally examined in detail at the Data Centre during routine analysis. There are thus three stages in which a Special Event may be detected.

It is not possible to lay down a hard and fast guide as to what is regarded as an unusual or extreme event, but the following is a summary of the type of thing which is looked for in the search:-

(a) Normal acceleration increments of about ±1.0 g or larger in turbulence and about ±0.5 g or larger for manoeuvres.

(b) Rapid and large changes of height or airspeed.

(c) Excessive application of a control.

(d) Infrequent operational events such as abandoned take offs, missed approaches, engine failures, engine out landings etc.

(e) Unusual oscillations of any of the traces.

(f) Exceedences of operational limitations such as maximum operating speeds.

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*Definition is necessarily lost in the reproduction of records and comments are based on the original records.

Despite the fact that each record is examined at least three times, it is unlikely that every unusual event will be detected; this is particularly true of certain of the operational events such as engine failure. Thus, whilst this Report contains examples of the more severe events found in records from 22000 flying hours, precise frequencies of occurrence are not meaningful.

3 SPECIAL EVENTS

3.1 General comments

Fig.1 shows a sample of normal flight to familiarize the reader with the recorded parameters. The events have been grouped according to type.

3.2 Temperature changes

Two events in this category are shown in Figs.2 to 4 with their respective descriptions (3.2.1 and 3.2.2).

3.3 Horizontal gusts

Three events in this category are shown in Figs.5 to 7 with their respective descriptions (3.3.1 to 3.3.3).

3.4 Turbulence encounters

Seven events in this category are shown in Figs.8 to 15 with their respective descriptions (3.4.1 to 3.4.7).

4 CONCLUDING REMARKS

The events described in this Report are a selection from the more extreme or interesting ones found in the records over the four year period. They have been grouped into three types but, as can be seen, some have aspects common to more than one group. The problem, by no means new, common to all the groups is trying to understand the local air motion using information relating to a much larger volume and in this respect the Report only shows the need for more detailed measurements in certain fields. For instance, Figs.5a and 5b show 10 to 12 kt shears across a very thin layer of air, indicating that it may be rewarding to investigate the air motion near inversion layers.

Figs.6 and 7 are examples of larger than usual airspeed fluctuations of long and short duration respectively which occurred on the approach and are relevant to the field of automatic approach and landing.

The severe turbulence encounters in Figs.8 to 15 are related to the available meteorological information and illustrate how the aircraft are flown

in rough air. Figs.10, 12 and 15 in this group are examples of the same type of aircraft successfully negotiating patches of both convective and shear severe turbulence with height lock engaged. Although the use of manometric locks is not recommended in turbulence it may be that this particular type of autopilot, or autopilot/aircraft combination, has a good tolerance to external disturbances.

REFERENCES

No.	Author(s)	Title, etc.
1	The CAADRP Technical Panel	The Civil Aircraft Airworthiness Data Recording Programme. RAE Technical Report 64004 (1964)
2	The CAADRP Special Events Working Party	Special Events of an operational nature (February 1964 to December 1964). RAE Technical Report 65242 (1965)
3	The CAADRP Special Events Working Party	Special Events of meteorological origin (November 1963 to December 1964). RAE Technical Report 65243 (1965)
4	The CAADRP Special Events Working Party (coordinated by G.E. King)	Special Events of meteorological origin (January 1965 to December 1965) RAE Technical Report 67071 (1967)
5	The CAADRP Special Events Working Party (coordinated by A.C.G. Seal, ARB)	Special Events relating to autopilot induced control disturbances (May 1963 to December 1965). RAE Technical Report 67157 (1967)
6	The CAADRP Special Events Working Party (coordinated by G.E. King)	Special Events relating to airspeed control and handling (February 1966 to December 1967). RAE Technical Report 68195 (1968)
7	The CAADRP Special Events Working Party (coordinated by R. Ashford, ARB)	Special Events - missed approaches (February 1963 to July 1967). ARB Technical Note 93 (1969)
8	The CAADRP Special Events Working Party (coordinated by A.W. Cardrick and K.D. Mephan)	Special Events related to airspeed control practices (February 1963 to February 1966). RAE Technical Report 69113 (1969)
9	The CAADRP Special Events Working Party (coordinated by A.W. Cardrick and K.D. Mephan)	Special Events relating to handling and control (January 1963 to February 1966). RAE Technical Report 69023 (1969)

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No.	Author(s)	Title, etc.
10	The CAADRP Special Events Working Party (coordinated by G.B. Hutton)	Special Events relating to severity of landings. RAE Technical Report 70187 (1970)
11	The CAADRP Special Events Working Party (coordinated by G.E. King)	Special Events relating to airspeed control and handling (January 1968 to February 1969) RAE Technical Report 69238 (1969)

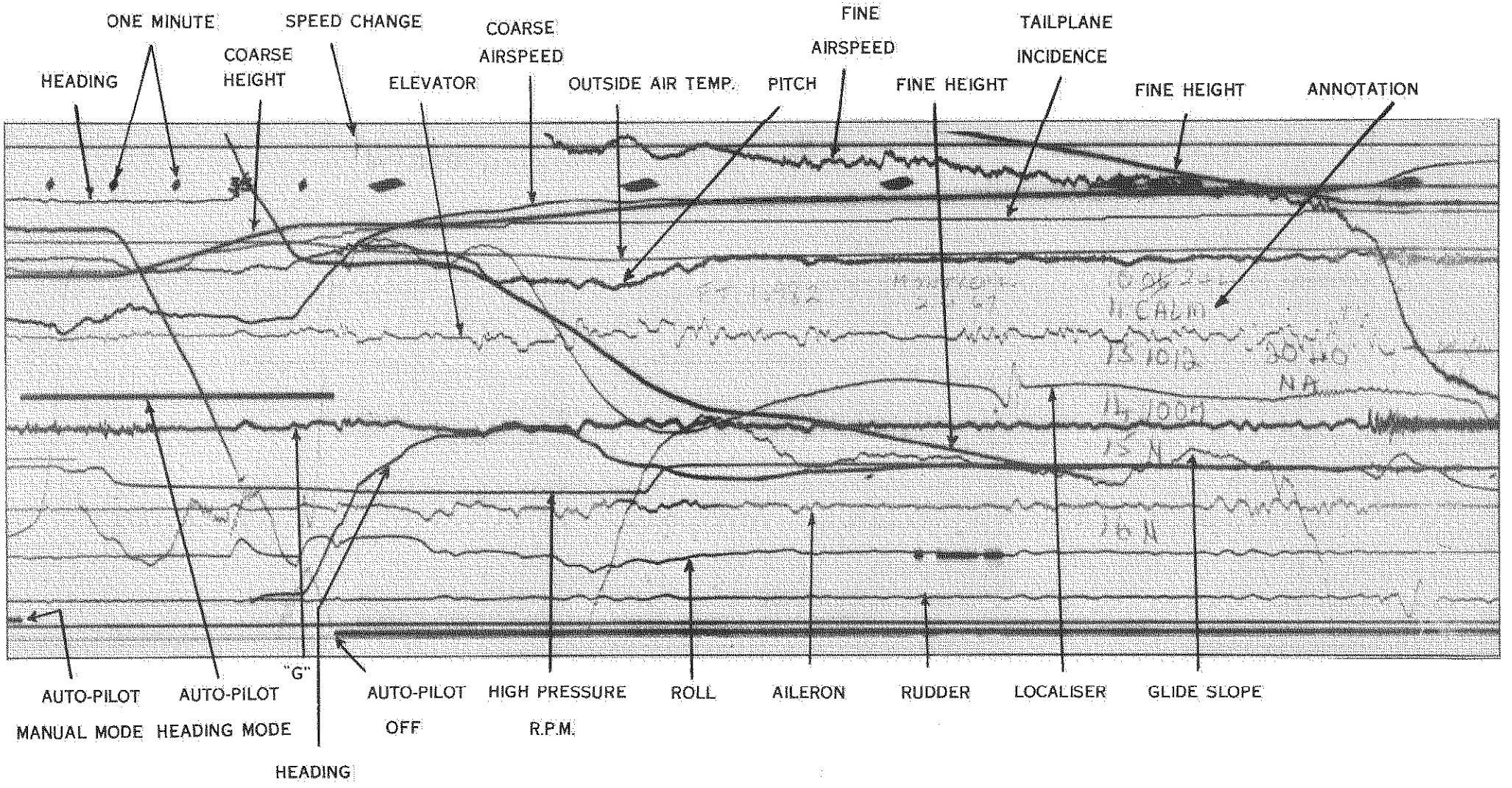

Fig.1. Sample record

3.2.1 EVENT IN FLIGHT 10666

Sector: New York/London - November 1966

DESCRIPTION

During the cruise at 30000 ft, the recorded air temperature rose by 13°C over a distance of 240 naut miles with a maximum rate of change of 6°C in 16 naut miles. No turbulence was encountered (see Figs.2a and 2b).

METEOROLOGICAL INFORMATION

"A very strong temperature gradient associated with a sharp upper trough is evident just west of Charlottetown at 0000Z. This rise in temperature is probably due to a rapid descent of air through the 300 mb level associated with strong horizontal convergence within the trough. By 03.00Z this temperature gradient would have moved just east of Charlottetown where it was encountered by the aircraft. Clear air turbulence would be expected in this situation".

Fig.3a shows the temperature-distance profile calculated from the aircraft readings and Fig.3b shows the 300 mb temperature field.

COMMENTS

The aircraft and meteorological data in Figs.3a and 3b agree in the 10°C increase in temperature over 100 naut miles; however the more detailed aircraft results show rates of change much greater than 10°C in 100 naut miles. Although turbulence was forecast, this part of the flight was smooth, but, as can be seen from other events in this Report, turbulence can be very localised.

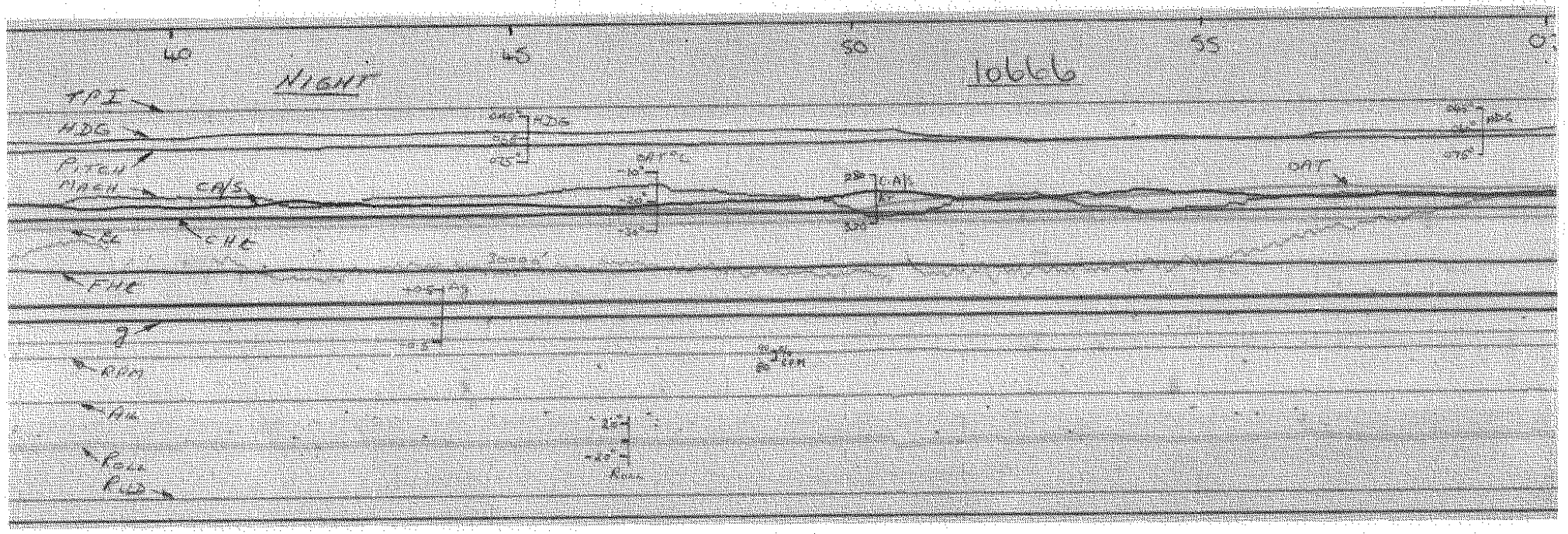

Fig.2a

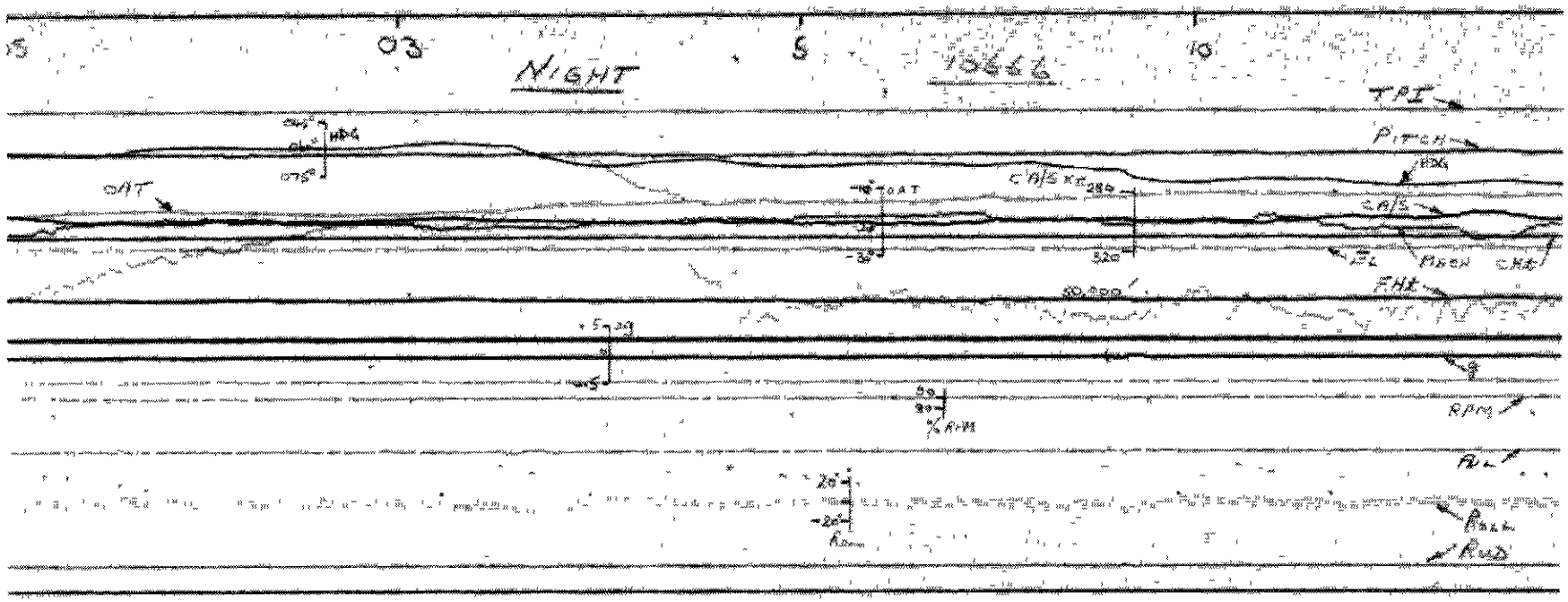

Fig.2b

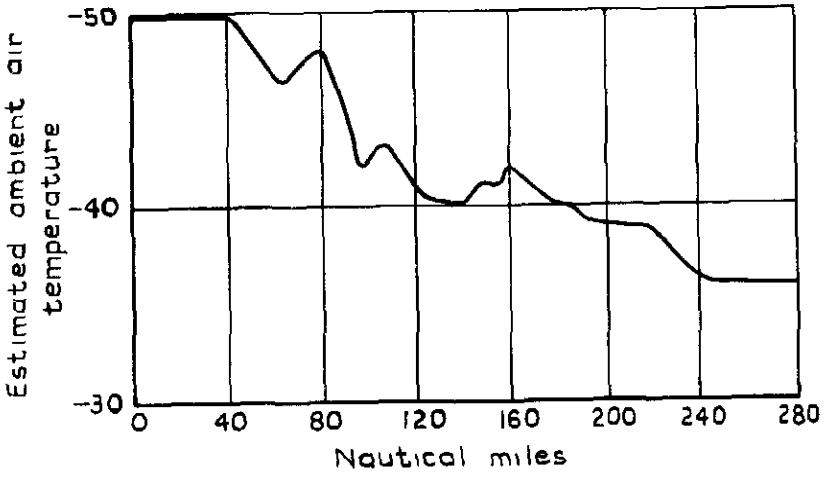

Fig 3a Estimated ambient air temperature from aircraft data

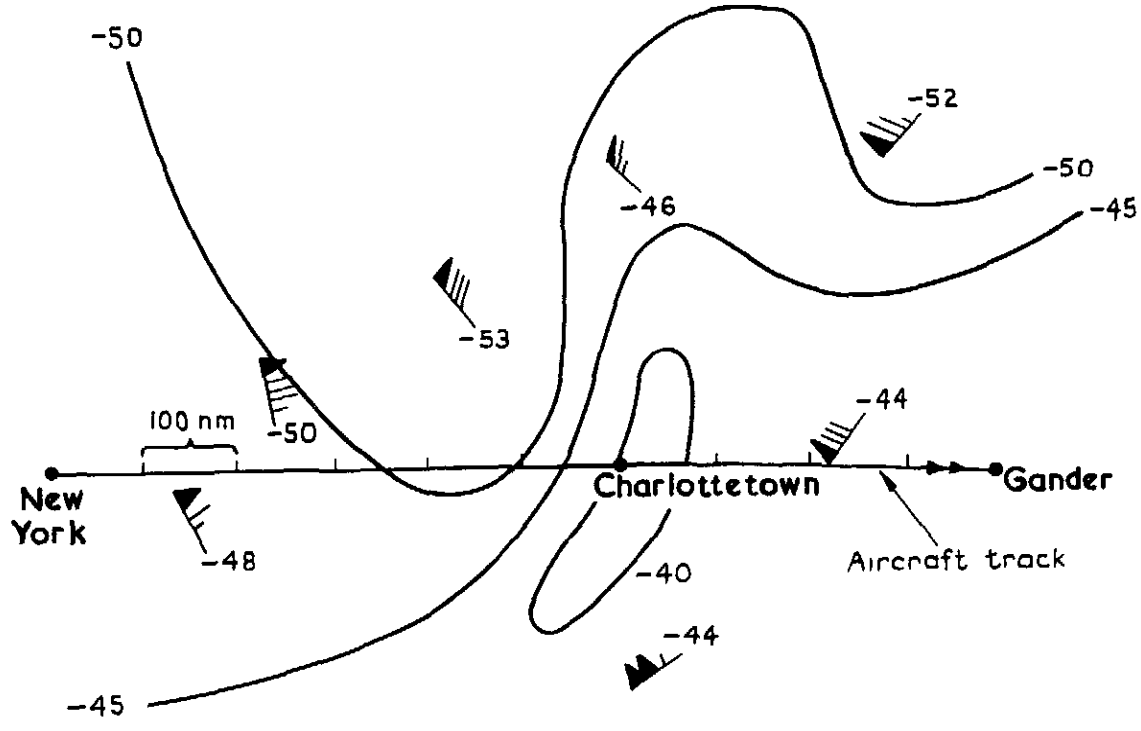

Fig. 3b 300mb temperature field 0000Z

3.2.2 EVENT IN FLIGHT 12056

Sector: London/New York - May 1968

DESCRIPTION

Whilst cruising at 35000 ft an isolated -0.6 g normal acceleration increment was experienced together with a 10 kt spike on the indicated airspeed trace. The event occurred during a 20°C rise in recorded air temperature over approximately 600 miles (see Fig.4).

METEOROLOGICAL INFORMATION

"The relevant upper level charts show that the flight was passing from an area of high (cold) tropopause to one of low (warm) tropopause and the tropopause was crossed at about 28° W, which is roughly where the turbulence was experienced. No actual jet stream core was indicated on the charts across the route of the aircraft but the 300 mb wind at Ocean Weather Station 'C' was 190°/60 kt. There would be a maximum wind in the neighbourhood of the tropopause".

COMMENTS

The 10 kt 'gust' on the airspeed trace makes it almost certain that the -0.6 g acceleration increment was caused by turbulence and not, as sometimes happens, by a control input.

The turbulence was most probably associated with crossing the tropopause, which was sloping at 1500 ft per 600 miles; this shallow angle makes it impossible to say whether the aircraft was at, above or below the tropopause at the time of the encounter.

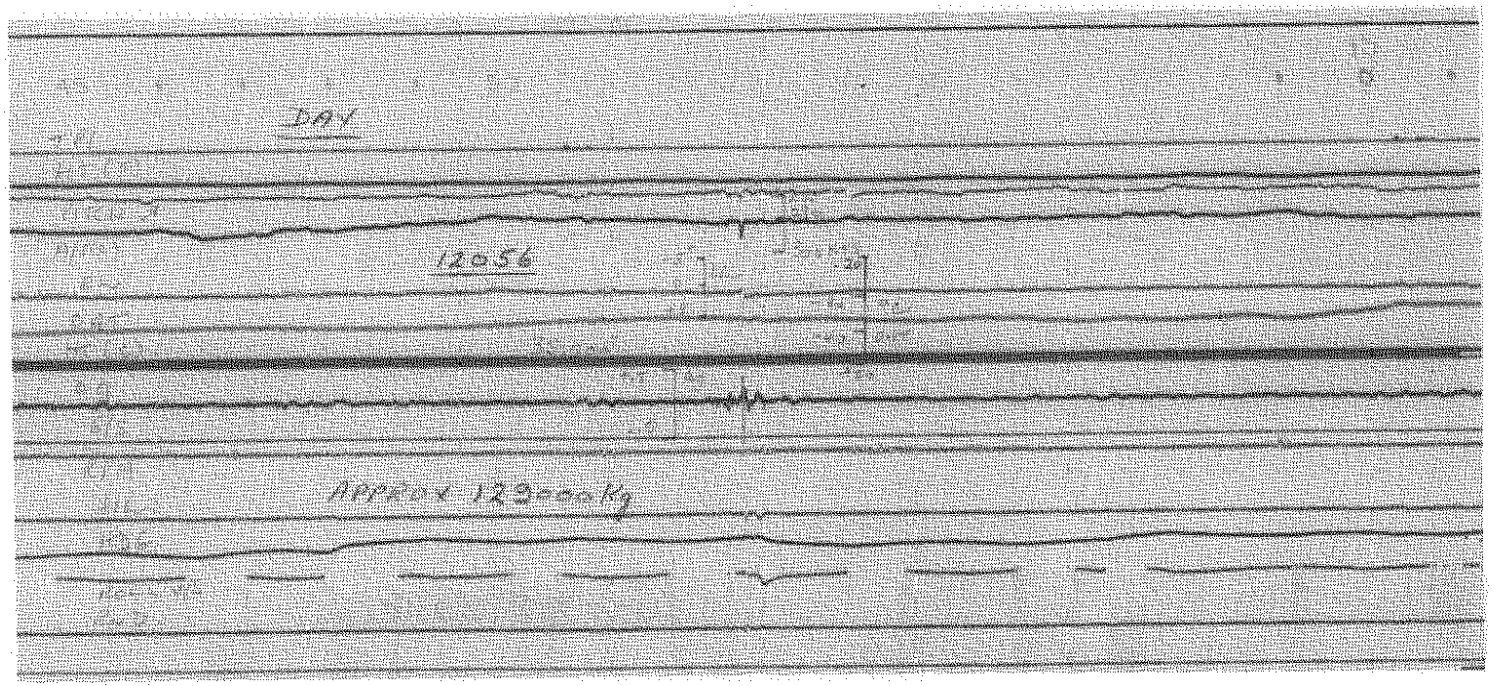

Fig.4

3.3.1 EVENTS IN FLIGHTS 52293/4

Sectors: Paris/London and London/Paris - January 1968

DESCRIPTION

During the climbs from Paris and London, a rapid decrease in indicated airspeed occurred of 10 kt at 2000 ft and 12 kt at 3200 ft above the respective airfield levels. In both instances the airspeeds increased to their former values over about 14 seconds. (See Figs.5a and 5b)

METEOROLOGICAL INFORMATION

The following radio sonde data are available:-

Trappes: Anticyclonic inversion - 5°C at 950 mb to +6°C at 870 mb
(2300 ft and 4400 ft approximately AMSL)

Crawley: Anticyclonic inversion - 5.1°C at 899 mb to +4°C at 871 mb
(3500 ft and 4300 ft approximately AMSL)

The wind at 850 mb was 260°/18 kt.

COMMENT

The meteorological information shows that the inversion started at a higher altitude at London than Paris and that the speed losses occur near the start of the inversion in each case. Some of the speed loss may be caused by a temperature/density change but most of the loss must be due to wind shear at the inversion. Since the aircraft was heading roughly into wind on both occasions, the drop in airspeed means a reduction of wind speed or a large change of direction at the inversion.

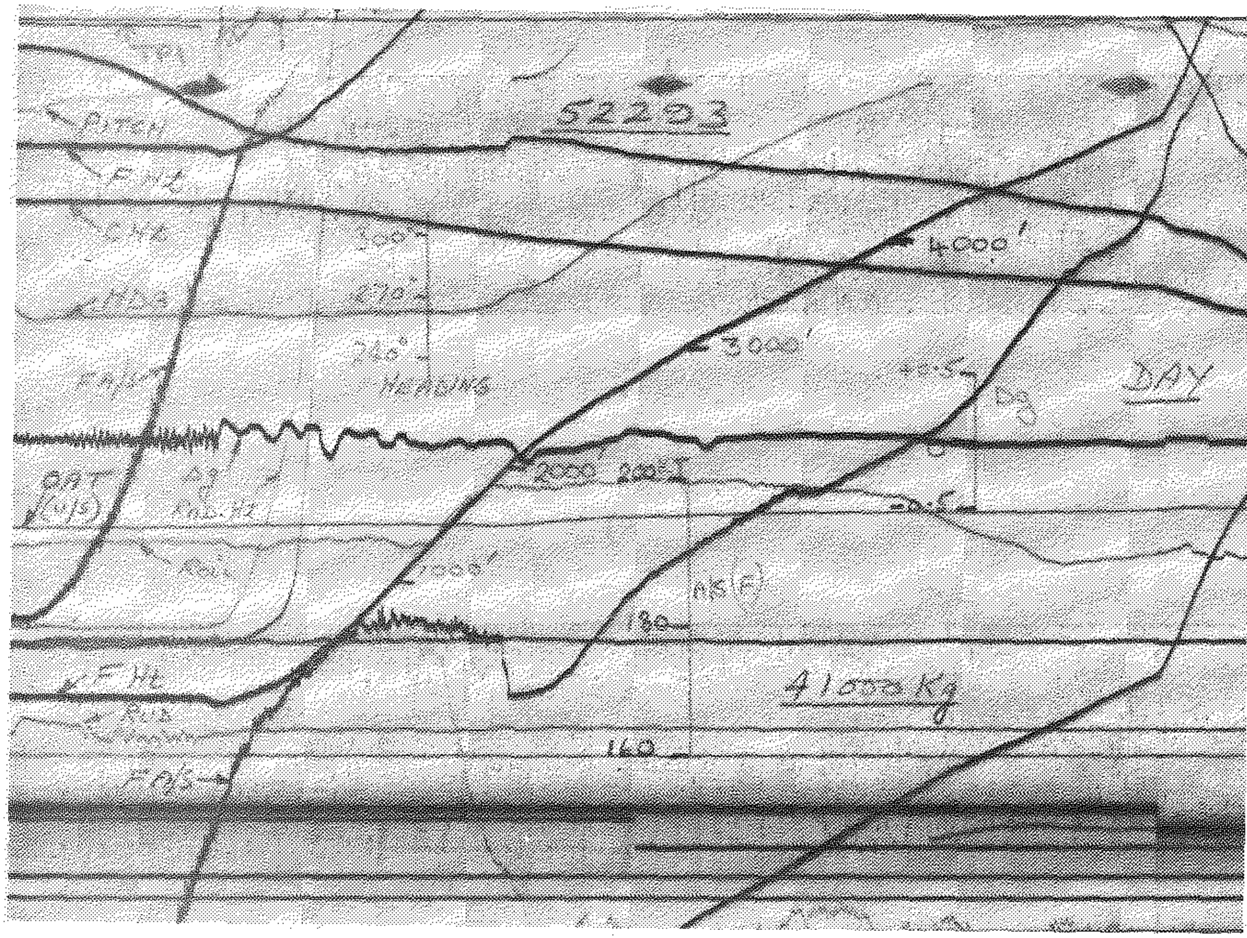
52293
PITCH
HDG
300°
270°
240°
HEADING
DAY
4000'
3000'
2000'
1000'
OAT
ROLL
180
160
41000 Kg

Fig.5a

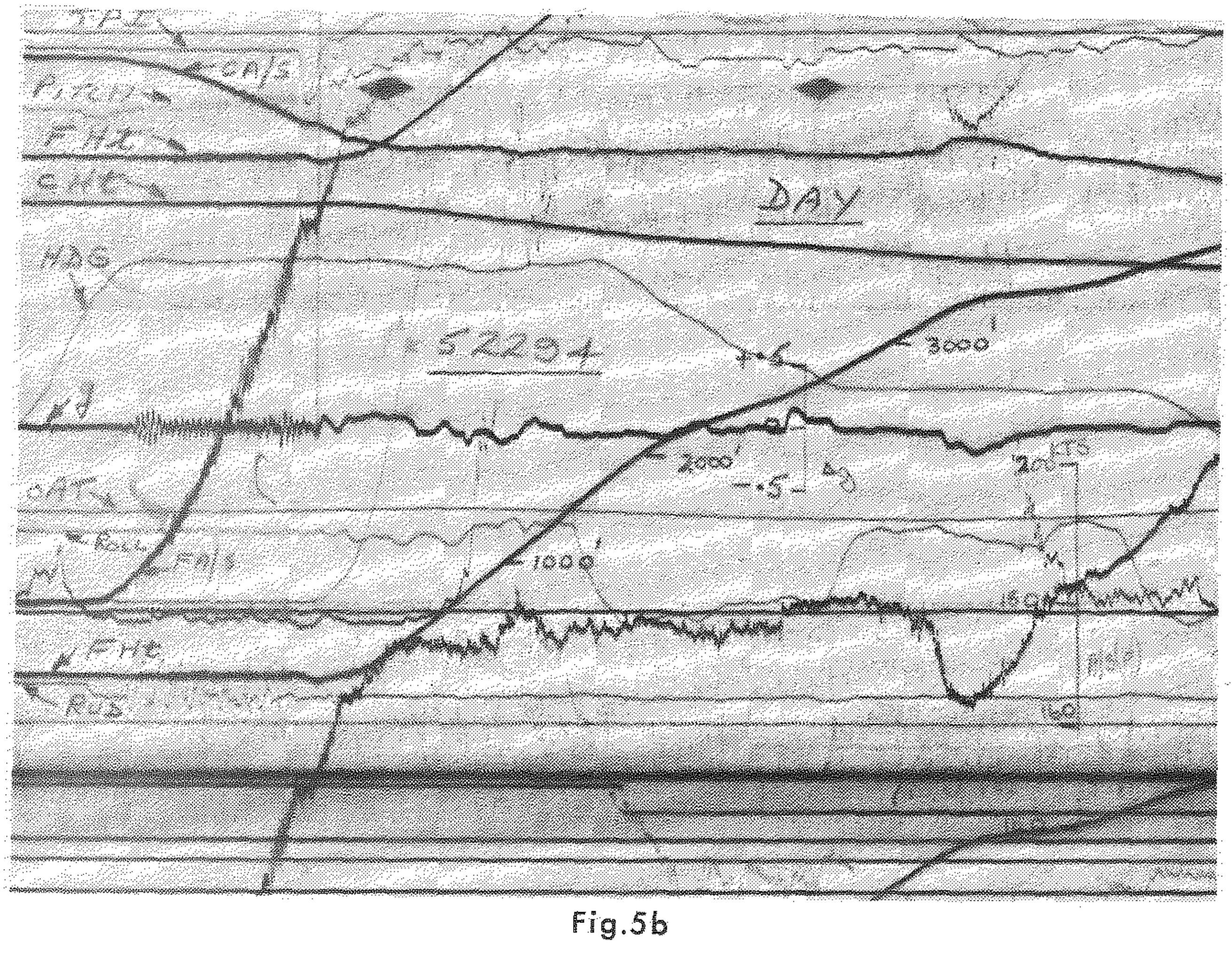
PITCH
CHt
HDG
DAY
52294
3000'
2000'
1000'
OAT
ROLL
RUD

Fig.5b

3.3.2 EVENT IN FLIGHT 11299

Sector: Detroit/Boston - August 1967

DESCRIPTION

When at 500 ft on the approach, the indicated airspeed increased rapidly by 10 kt and reduced to its former value over about 15 seconds. (See Fig.6.)

METEOROLOGICAL INFORMATION

Heavy rain showers, which became thunderstorms a half an hour later, were going through at the time of the event. The wind was given as $360^{o}/7$ kt at the time of the event and $320^{o}/10$ kt gusting 25 kt 7 minutes later.

COMMENT

The other traces do not show any deviations which would account for the increase in airspeed. It is therefore most likely that the increase was caused by the precipitation downdraught associated with large cumulus/cumulo nimbus type clouds.

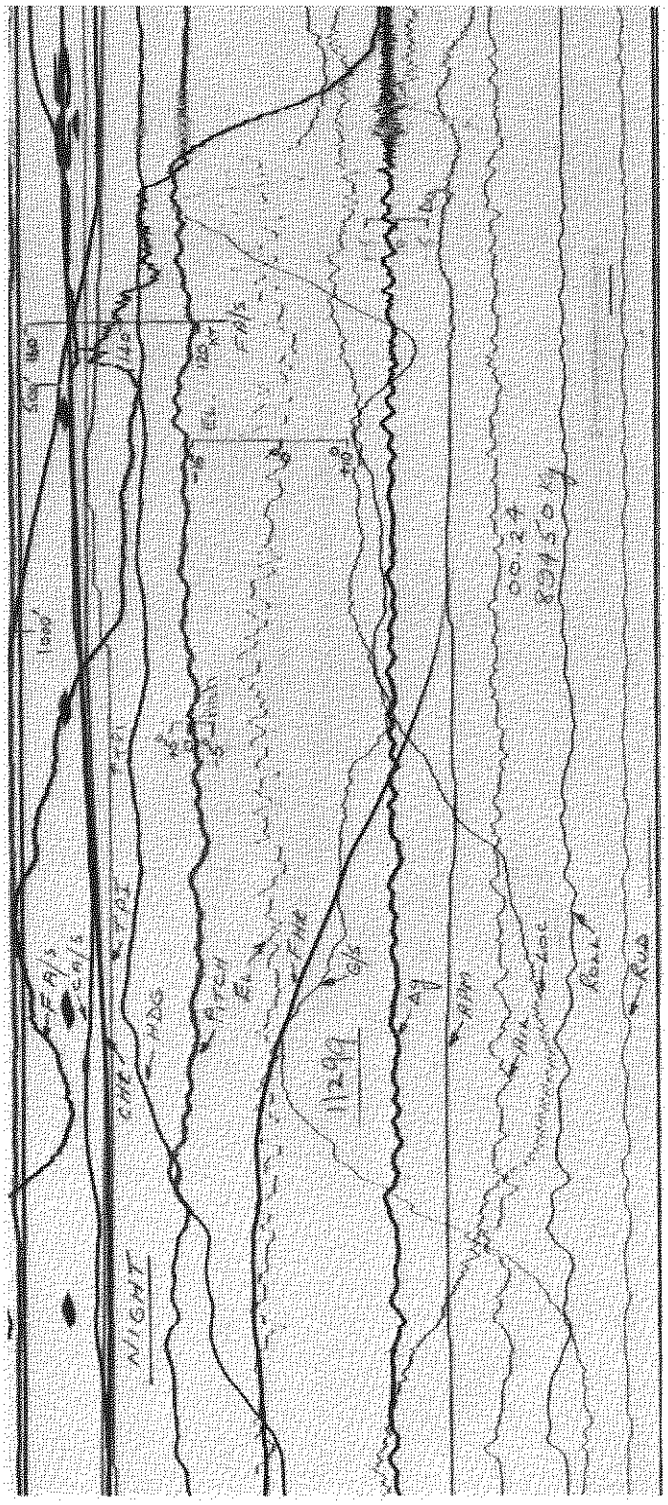

Fig.6

3.3.3 EVENT IN FLIGHT 11504

Sector: Prestwick/Manchester - October 1967

DESCRIPTION

After an approach which was made in turbulent conditions, at the instant of touchdown the indicated airspeed dropped by 15 kt and recovered again in 3 seconds. (See Fig.7.)

METEOROLOGICAL INFORMATION

The weather at Manchester was as follows:-

wind 310°/20 kt, visibility 12 km, rain, cloud 1/8 1500 ft, 3/8 2500 ft, 8/8 8000 ft.

COMMENT

The loss of 15 kt airspeed at this critical stage appears to have caused no difficulty apart from perhaps initiating a small bounce on landing. A heavy landing might possibly have occurred if the event had taken place a few seconds earlier.

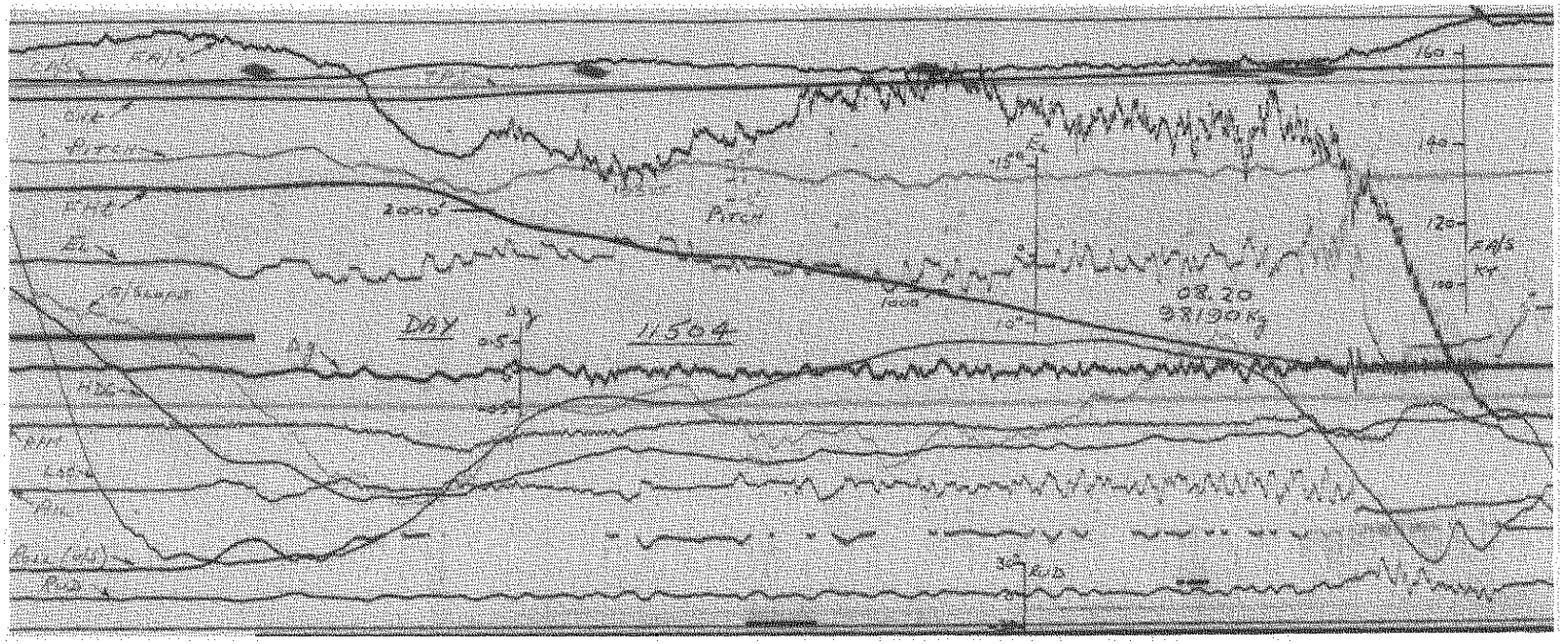

Fig.7

3.4.1 EVENT IN FLIGHT 10142

Sector: New York/London - January 1966

DESCRIPTION

During the cruise at 32000 ft, moderate turbulence was encountered for 7 minutes prior to meeting a patch of severe turbulence lasting 6 minutes, at the start of which the autopilot became or was disconnected. There was a rapid increase of 27 kt in indicated airspeed and variations in height, airspeed and power occurred at about 1 cycle per minute. (See Fig.8.) Although the acceleration trace was not recording, the mandatory recorder showed an extreme acceleration increment of 1.0 g.

METEOROLOGICAL INFORMATION

The following information was obtained from Kennedy airport:-

"Turbulence related factors apparent in the tropopause analysis are (1) proximity of a well developed jet stream, (2) marked anticyclonic curvature, (3) marked horizontal wind shear, (4) proximity of the tropopause (250 mb at Nantucket, 263 mb at Sable Island). On this basis one would expect turbulence from Nantucket northward along the route through Nova Scotia."

COMMENT

The initial increase in airspeed, which was undoubtedly external, was countered by reducing power and climbing the aircraft 1500 ft. This produced a lowest airspeed of 249 kt from the highest value of 310 kt. The subsequent variations in height (1000 ft), indicated airspeed (25 kt) and power (85 to 95%) are a result of the initial disturbance.

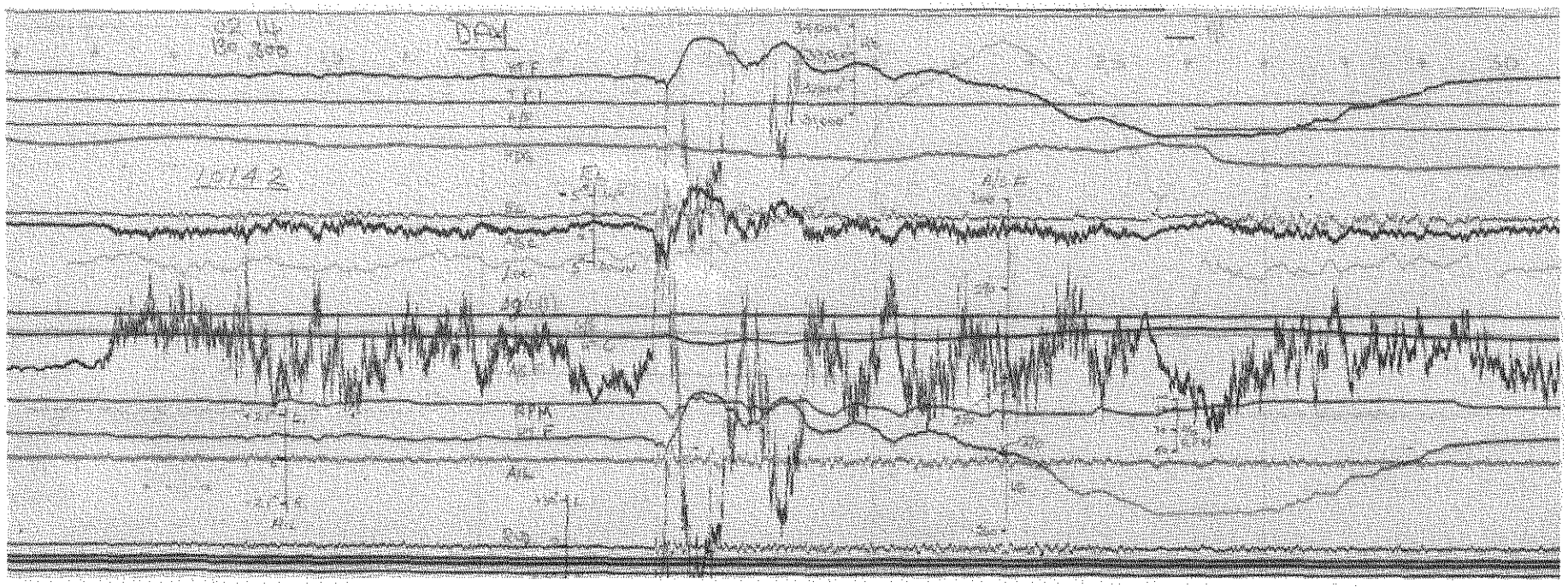

Fig.8

3.4.2 EVENT IN FLIGHT 20014

Sector: New York/Freeport - June 1967

DESCRIPTION

During the climb at 7000 ft a patch of turbulence lasting 1½ minutes was encountered at about 250 kt indicated airspeed, whereupon the airspeed increased to 300 kt and fell to 270 kt before finally settling at 290 kt. These variations, which occurred at constant power, were accompanied by pitch attitude changes of up to 8^{o}. (See Fig.9.)

METEOROLOGICAL INFORMATION

A marked cold front went through New York two hours after the event and the aircraft presumably flew through it.

COMMENT

The required airspeed in the New York area is 250 kt whilst for this aircraft 290 kt is the normal climb as well as the turbulence penetration speed. An increase in airspeed was therefore needed whilst in turbulence; this can be difficult to achieve if horizontal draughts are present.

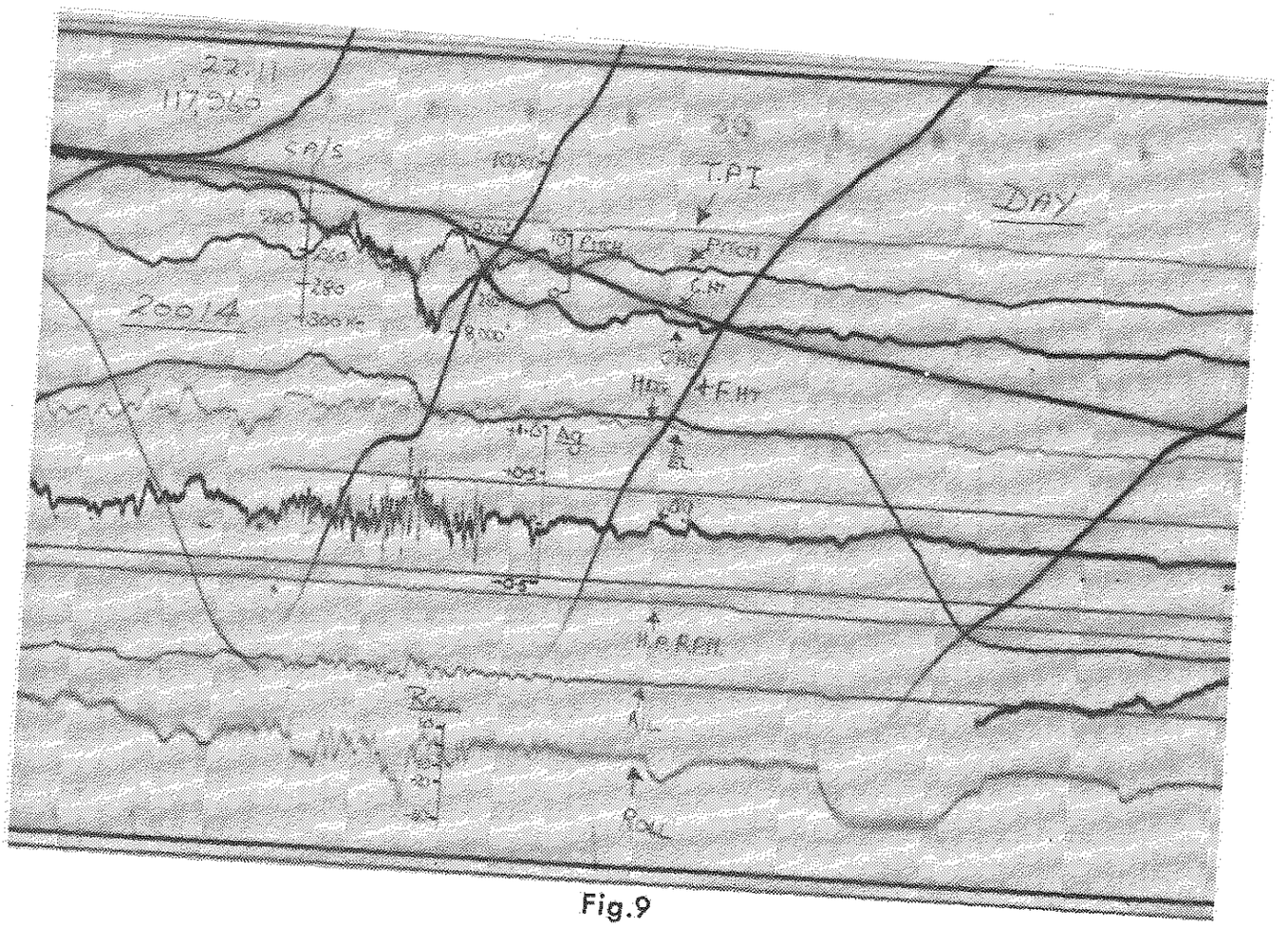

Fig.9

3.4.3 EVENT IN FLIGHT 51950

Sector: London/Zurich - September 1967

DESCRIPTION

During the cruise at 23400 ft just prior to descent a patch of turbulence of 3 minutes duration was encountered which produced a deviation from cruising altitude of ±300 ft. (See Fig.10.)

METEOROLOGICAL INFORMATION

There was a cold front in the area at the time of the event.

COMMENT

In view of the symmetry of the changes in height about a mean cruising level it is very likely that the height lock was kept engaged. Although this is not recommended, in this case the autopilot remained in. Possibly in larger draughts the excursions would be greater, increasing the risk of autopilot disengagement.

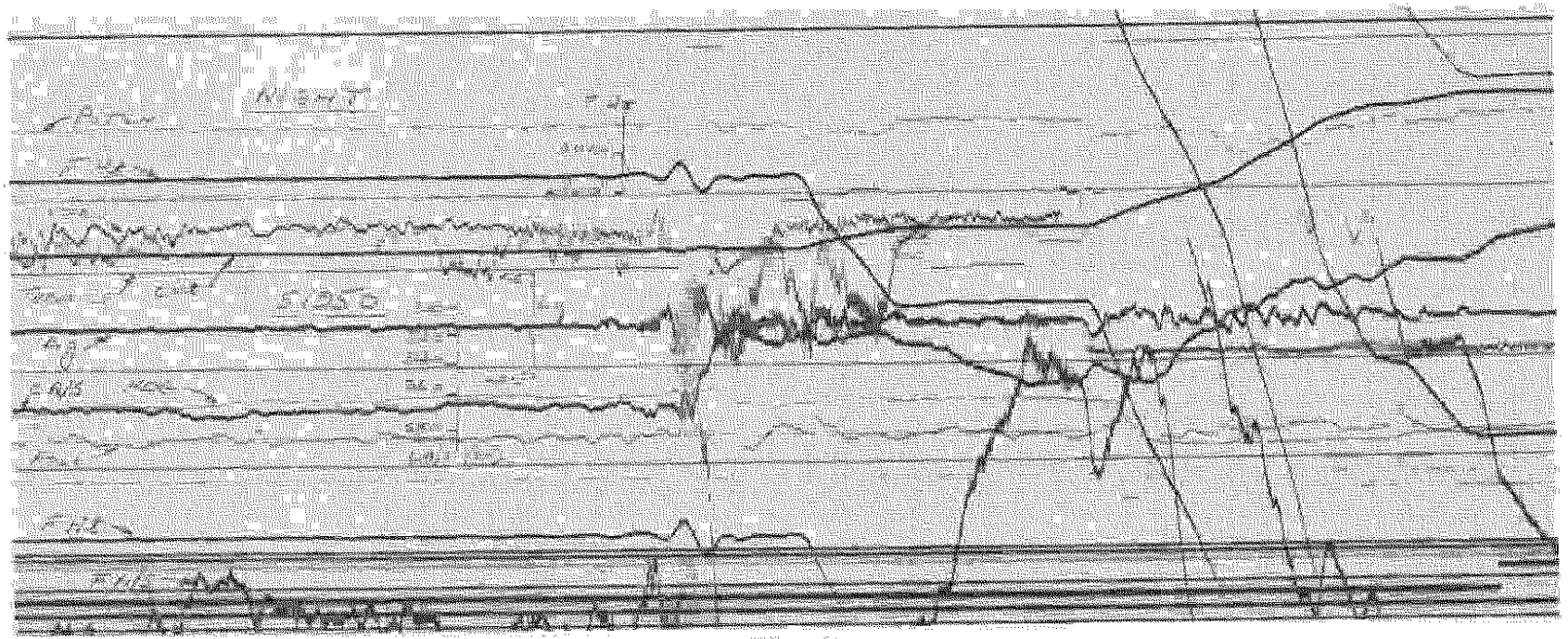

Fig.10

3.4.4 EVENT IN FLIGHT 10637

Sector: Prestwick/New York - November 1966

DESCRIPTION

After flying for 5 minutes in moderate turbulence, the aircraft encountered a short intense patch which produced a sudden increase in indicated airspeed of 18 kt and 2 or 3 seconds later acceleration increments of +0.8 g and -0.7 g. Thereafter the previous level of turbulence returned for a further 4 minutes. (See Fig.11.)

METEOROLOGICAL INFORMATION

"The event occurred between Davey and Nantucket at 1945 hours and the relevant 300 mb chart shows a deep trough over the Mississippi Valley with a complex jet stream to the east. The easternmost and weaker of two northward flowing jets was located near Nantucket at 1200 hours. An 'airep' in the vicinity of Nantucket reported moderate to severe turbulence from 32000 ft to 35000 ft. Another 'airep' shows severe turbulence betweem Washington and Pittsburg from 29000 ft to 31000 ft. By 0000 hours this jet had diminished and the 30000 ft wind at Nantucket was SSW 45 kt and at Kennedy SSW 70 kt. The tropopause throughout the area was near or above 150 mb."

COMMENT

The sudden increase in turbulence intensity during a period of jet stream turbulence is unusual. The meteorological information makes no mention of significant convection although this cannot be ruled out.

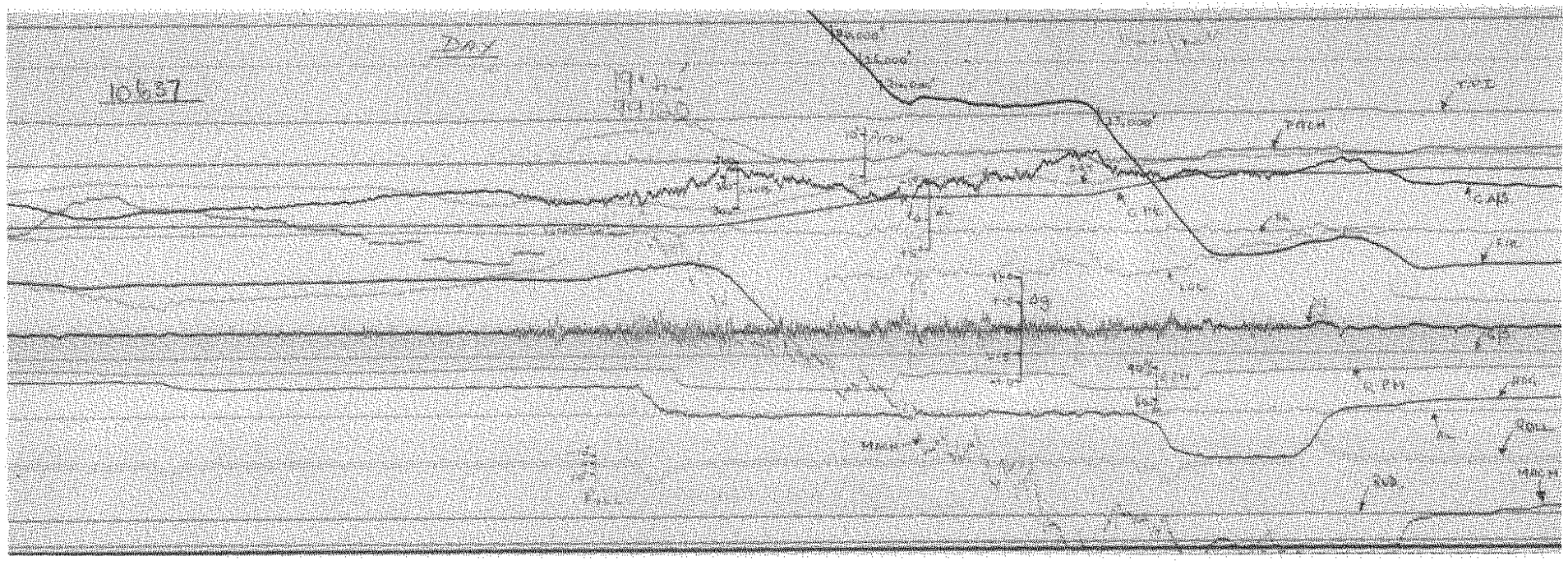

Fig.11

3.4.5 EVENT IN FLIGHT 51696

Sector: Copenhagen/London - July 1967

DESCRIPTION

Whilst cruising at 28400 ft a patch of turbulence of increasing intensity which lasted for 3½ minutes was encountered. The most severe part of the patch, which was met at reduced airspeed, produced extreme normal acceleration increments of -0.96 g and -1.26 g. (See Fig.12.)

METEOROLOGICAL INFORMATION

"The aircraft flew through an exceptionally strong horizontal wind shear with a maximum gradient of around 2 or 3 kt per nautical mile. There was probably an associated strong vertical shear. Turbulence in this situation is to be expected." (See Fig.13.)

COMMENT

The patch of turbulence ended abruptly which means that an aircraft flying in the reverse direction would probably have sustained loads of even greater magnitude through lack of warning and consequent inability to reduce airspeed soon enough.

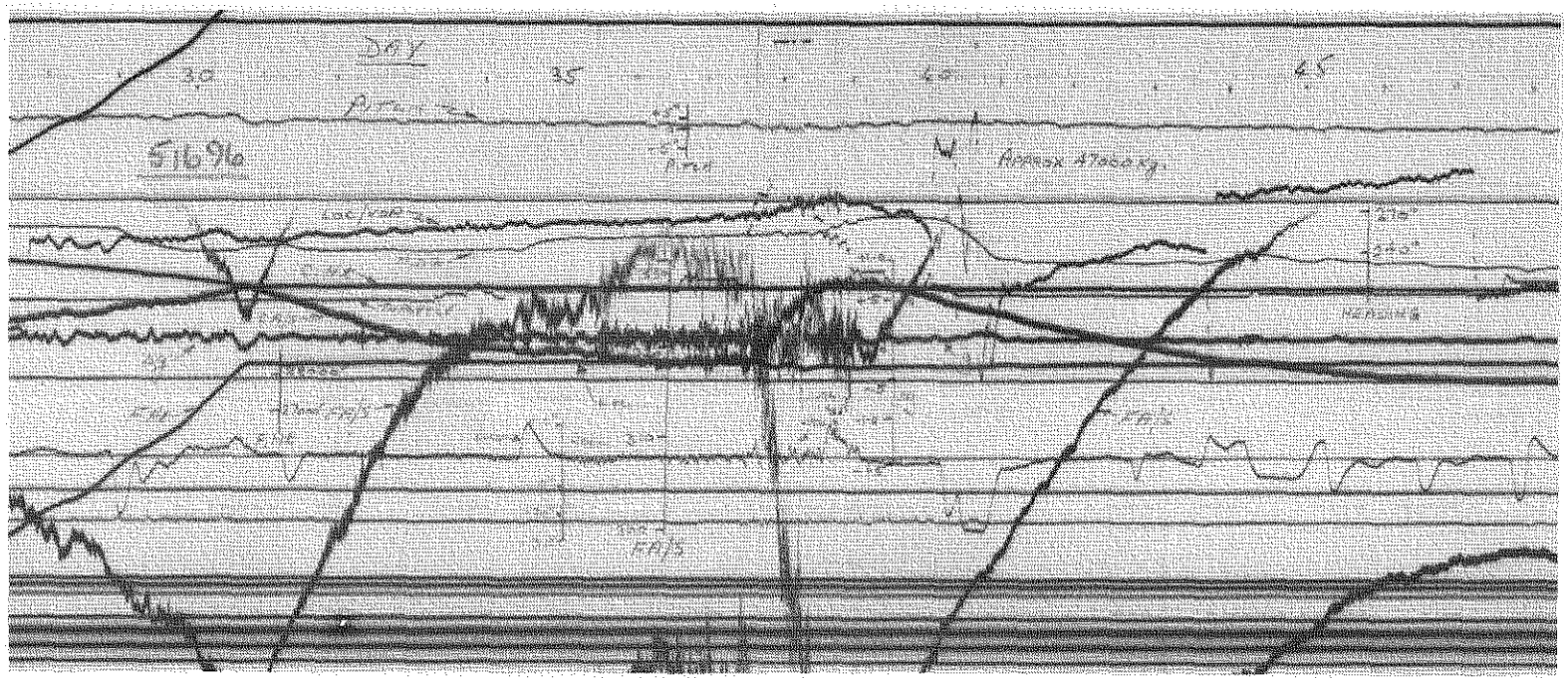

Fig.12

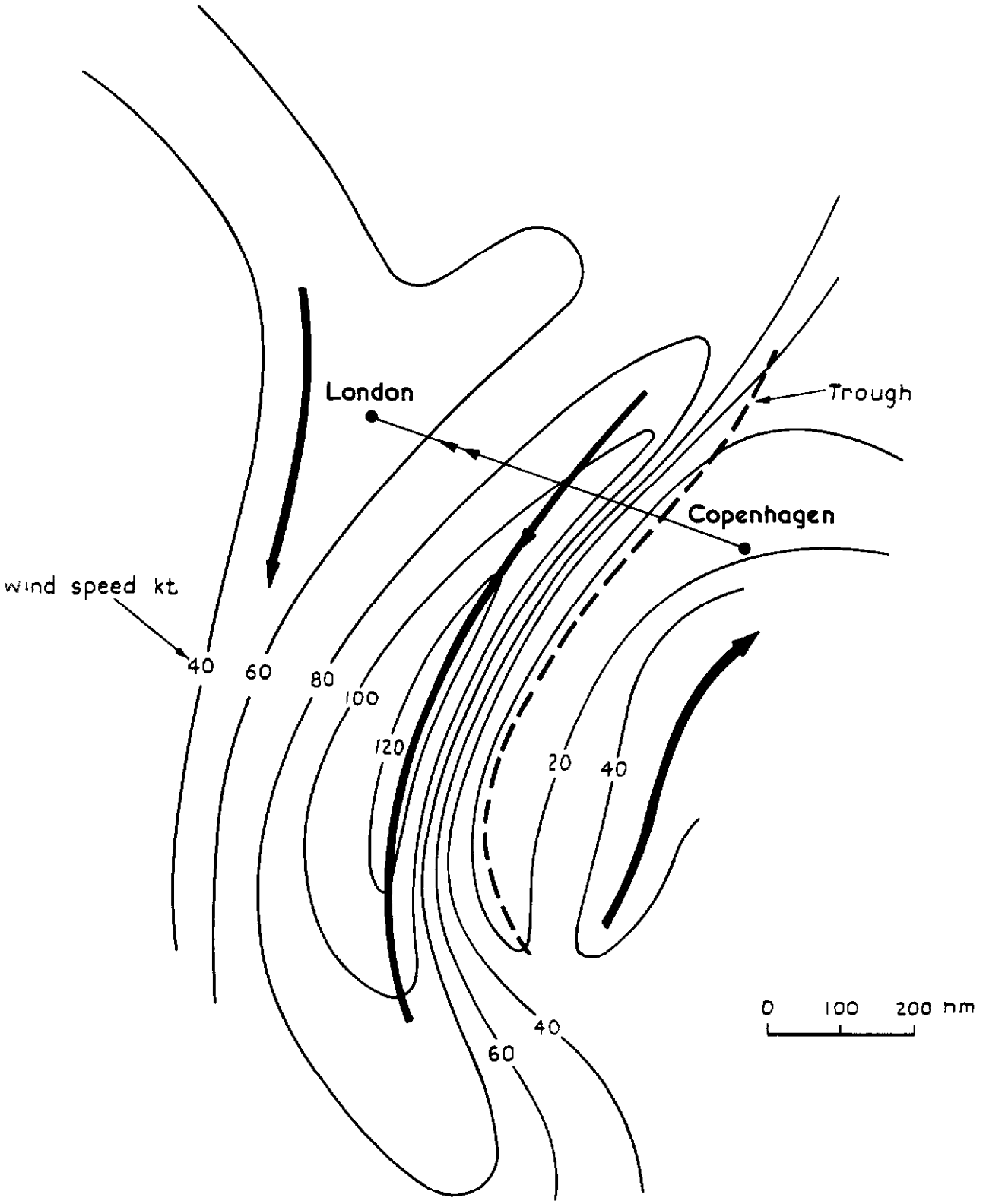

Fig.13 300mb wind chart

3.4.6 EVENT IN FLIGHT 12096

Sector: London/New York-June 1968

DESCRIPTION

At 34000 ft the aircraft encountered a 1 minute duration patch of turbulence which produced extreme acceleration increments of +1.07 g and -0.82 g. The autopilot became or was disconnected at the time of the largest load and the indicated airspeed fell by 30 kt over the next 12 seconds. (See Fig.14.)

METEOROLOGICAL INFORMATION

New York airport was closed because of a line squall and the aircraft diverted to Montreal.

COMMENT

The loss in indicated airspeed of 30 kt appears to be due to external causes as there are no pitch or power changes which could account for it.

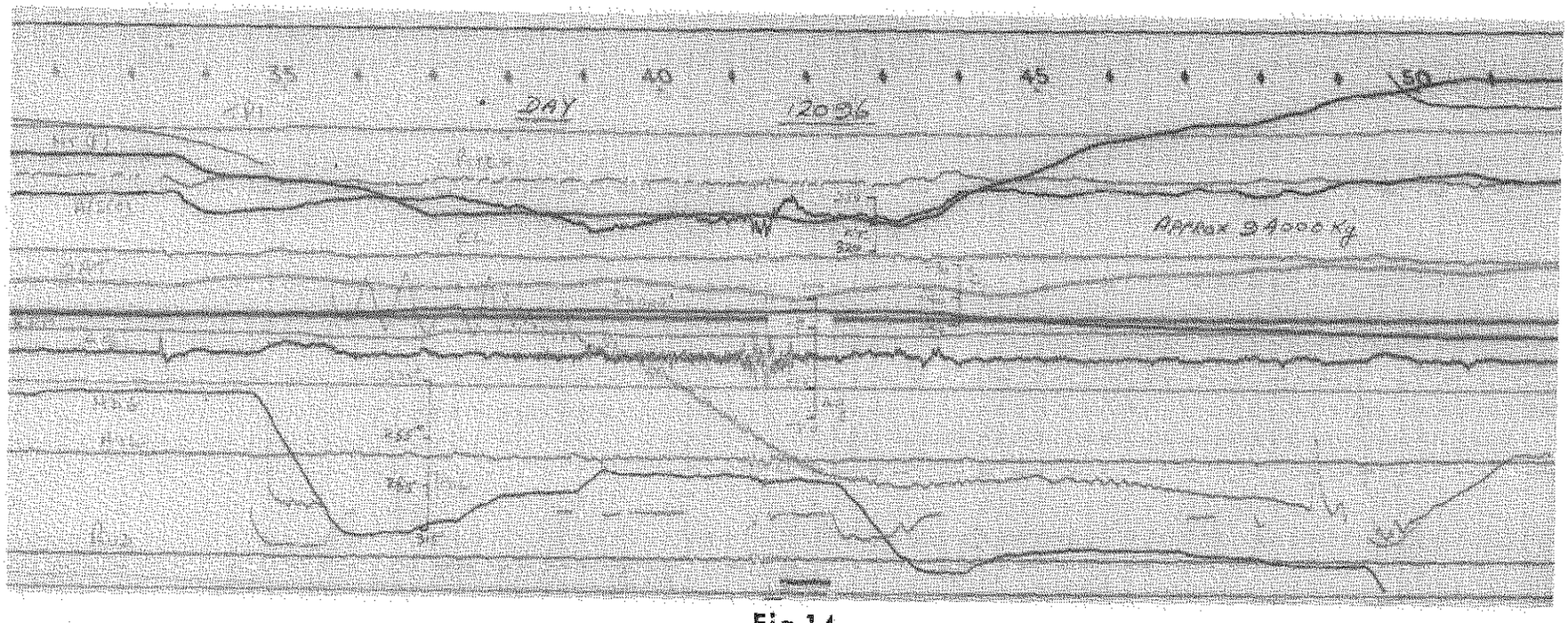

Fig.14

3.4.7 EVENT IN FLIGHT 53572

Sector: Dusseldorf/London

DESCRIPTION

Whilst cruising at 2400 ft just before commencing the descent, a patch of turbulence lasting 3 minutes was encountered, this produced extreme normal acceleration increments of +1.00 g and -0.94 g. (See Fig.15.)

METEOROLOGICAL INFORMATION

"During the encounter the aircraft was probably near Clacton, where the upper air charts suggest the likelihood of clear air turbulence.

A very pronounced trough was shown on the 500 mb chart extending from N Norway over UK and into Spain with a probable Col in the Midlands. A wind shear of some 40 kt in 100 mb existed over E Anglia. This upper trough moved very slowly east during the next 24 hours. The shear in the vertical over Hemsby was some 6 kt per 1000 ft between 500 mb and 300 mb so it appears probable that the sharp wind change in the horizontal was the cause of the turbulence."

COMMENT

Although the aircraft was on height lock during the encounter, any large scale vertical air motions would have caused some deviation from the constant altitude shown on the record. It is therefore most likely, as the meteorological information shows, that this was shear turbulence of high intensity, rather than turbulence associated with convection.

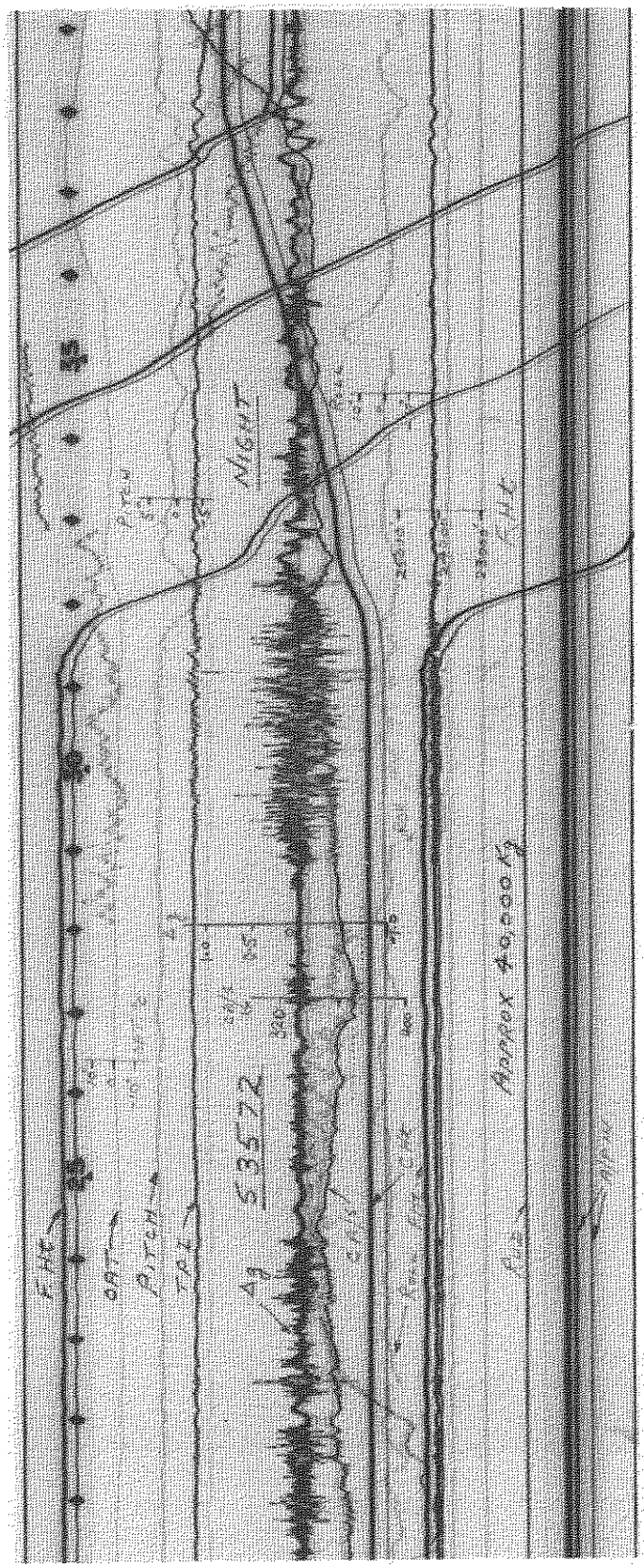

Fig.15

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