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# Civil Aircraft Airworthiness Data Recording Programme

# Achievements in Recording and Analysis of Civil Aircraft Operations 1962-1969

*by*

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# THE CIVIL AIRCRAFT AIRWORTHINESS DATA RECORDING PROGRAMME

## ACHIEVEMENTS IN RECORDING AND ANALYSIS OF CIVIL AIRCRAFT OPERATIONS 1962-1969

by

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(Secretary of CAADRP Technical Panel)

SUMMARY

Analogue, continuous trace, multi-parameter records of airworthiness data, representing more than 65000 flying hours, were taken from jet transport aircraft in regular airline service from 1962-1969. In Phase 1 (1962-1965) data were recorded on aircraft well proved in service; in Phase 2 (1966-1969) newer aircraft were instrumented and the records were augmented by additional parameters chiefly directed to obtaining more detailed landing data. More parameters were recorded than in any previous operational research programme, and much valuable information was acquired in the fields, among others, of airworthiness, flying hazards, operating practices (including autoland) and meteorology, and of assistance for accident investigations.

The success of the programme depended on close co-operation between representatives of ARB, BOAC, BEA, CI Data Centre Ltd., RAE and a number of other organizations. This Report describes briefly the work undertaken and the benefits derived by each organization, and by others using CAADRP data.

No plan is being made to acquire further data from specially installed analogue trace recorders. The need for new data has not abated, but further information is being and will be taken from digital versions of the mandatory recorders carried by all UK aircraft.

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* Replaces RAE Technical Report 71034 - ARC 33038

## CONTENTS

## 1 INTRODUCTION

Many thousands of flying hours of airworthiness data have been recorded on operational aircraft since 1940, using V-g recorders, counting accelerometers and NASA V-g-H recorders. These instruments provided valuable information on the size and frequency of the flight loads sustained. However the nature and cause of the loads could not be determined without more comprehensive records; to fulfil this purpose the Civil Aircraft Airworthiness Data Recording Programme (CAADRP) was planned in 1961 and introduced in 1962 to record multi-parameter airworthiness data on operational jet passenger transport aircraft.

Data were recorded as continuous analogue traces on photographic paper and were more comprehensive than any previously recorded on operational aircraft. The success of the programme depended on close co-operation between representatives of a number of organizations each with specialist knowledge to contribute. The part played by each participant is described in this report, and the knowledge each gained is outlined.

The basic aims of the programme are cited; these remained unchanged throughout; the emphasis shifted as the meaning and usefulness of the data became apparent, and as particular problems related to airworthiness arose. Two phases of the programme were run; the first provided general data from aircraft well-proved in service and also served as a learning period for the participants; the second phase involved newer types of aircraft and the records were biassed towards gaining information on landing problems.

The second phase of the programme ended in 1969 and no plan is being made to gather further data from analogue recorders. However plans are in progress for the continuance of CAADRP by purchasing digital data from airline recording systems originally installed for accident investigation; CAADRP experience of problems related to aircraft recording instrumentation and of methods of data interpretation has influenced requirements, design and development of these systems; they are now sufficiently advanced to provide airworthiness data on a much larger scale than previously if suitable computer assisted analysis techniques can be devised. A brief description is given of the reasons for making this major change.

## 2 THE PROGRAMME

The organization, aims, instrumentation and methods of analysis and data processing for Phase 1 of the programme have been fully described in a report[1] which also presents proposals for phase 2.

Quoting from Ref.1, the aims were to study:-

"(i) the effect of environment and operational usage on the aeroplane;
"(ii) the way the aeroplane is operated within the bounds of its inherent capabilities;
"(iii) unusual occurrences caused by environment, operational usage or malfunction of some part of the aeroplane."

These aims remained unchanged throughout both phases of the programme, but Phase 2 put particular emphasis on landing data, without diminishing the data available for studies of other phases of flight. Fig.1 illustrates the variety of the aspects of flight studied.

Appendix A gives brief information about the recorders employed in each Phase, lists the parameters, and gives the number of flying hours recorded. It should be noted that in Phase 1 data from five aircraft were suited to studies of climb, cruise and descent, and from three aircraft were suited to take-off and landing studies. The larger paper capacity of the recorders employed in Phase 2 enabled all the records to be used for all phases of flight; since the number of parameters was also greater the value of the data from each recorded flight was more than twice as great in Phase 2 as in Phase 1.

Appendix B describes the methods used to extract data for statistical studies in the two phases, and explains the necessity for the change from reading all parameters at regular intervals of five minutes in climb and descent and ten minutes in cruise (time slice reading) to flight indexing with subsequent extraction of selected data for special studies. This change is the principal difference between the data processing methods described in Appendix B of Ref.1 and the latest approach.

Appendix C describes two complementary index systems for special events. These are used for quick access to particular types of event.

## 3 ORGANIZATIONS INVOLVED

In the early stages of Phase 1 four organizations were represented:-

(i) The Air Registration Board (ARB)
(ii) British Overseas Airways Corporation (BOAC)
(ii) Aerodynamics Department, RAE
(iv) Structures Department, RAE

These representatives formed the nucleus of the Technical Panel and named the programme "The Civil Aircraft Airworthiness Data Recording Programme" (CAADRP). Plans were formulated relating to types of aircraft, recording instrumentation, analysis and data processing methods and equipment.

Within a few months the Technical Panel was enlarged by the inclusion of representatives of:-

(v) British European Airways (BEA)

(vi) Directorate of Civil and Transport Aircraft (DAC)

(vii) Benson-Lehner Ltd., Data Centre (now CI Data Centre Ltd.)

(viii) Mathematics Department, RAE.

This Technical Panel was responsible for the whole of Phase 1, supported by Working Parties drawn from the same organizations and the Meteorological Office. Occasionally representatives of other organizations, notably Directorate of Flight Safety (DSF), Blind Landing Experimental Unit (BLEU) and Air Operational Research Branch which later became Directorate of Operational Research and Analysis*(AORB/DORA), were invited to discuss particular problems. In Phase 2, when newer aircraft, which were to be fitted with auto-landing equipment, carried CAADRP recording instrumentation, these three organizations were represented on the Panel. DORA (then AORB) had started a complementary programme, to record aircraft take-off and landing performance using ground-based cameras and radar, towards the end of Phase 1; interchange of experience was obviously profitable.

## 4 APPORTIONMENT OF WORK

### 4.1 The Technical Panel and Working Parties

General responsibility for the smooth running of the whole programme was taken by the Technical Panel. Current progress, difficulties to be overcome and future plans were discussed at meetings which took place monthly in the early stages.

One Working Party had the task of examining in detail every unusual occurrence (Special Event) recorded, meeting six or seven times per year for this purpose. Special Event searchers, representatives of the Meteorological Office and Airline Pilots formed the basis of the Working Party.

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* On 1 December 1970 the section became Operations 3 Group of the Air Traffic Control Evaluation Unit (ATCEU) of the Department of Trade and Industry. Throughout the period described in this Report they were AORB or DORA and this nomenclature is retained in the text.

The Analysis and Data Processing Working Party was formed to discuss particular problems encountered (such as data storage) and to exchange ideas on suitable analytical methods. After the early stages meetings were infrequent, problems usually being resolved by discussion between the Data Centre and those directly concerned with the problem in hand.

### 4.2 The Airlines

Although the Airlines were working under contract to the Ministry of Aviation (later, Technology) they provided the type of support to the Programme which can never be written into a contract, but depends on the goodwill, readiness to co-operate, and expertise of the individual concerned.

The contracts called for purchase of recording equipment, installation in selected aircraft, equipment maintenance and calibration, changing cassettes on the aircraft, and photographic processing and subsequent annotation of the rolls of records. In addition the Airlines gave much useful advice on record interpretation, provided facilities for Special Event searchers to examine the records at London Airport and supplied as much supplementary information as they could immediately a Special Event was identified. Both Airlines also arranged for a Senior Pilot to attend Special Event Working Party meetings to help in identifying causes of events. Investigations of ways of improving the actual records and recording equipment were also undertaken.

Before the programme started BOAC had considerable experience of continuous photographic trace recording using NASA V-g-H and other recorders. This experience proved invaluable to the Technical Panel, particularly in the early stages.

Both Airlines took part in CAADRP activities throughout the two phases of analogue continuous photographic trace recording.

### 4.3 The Air Registration Board

The ARB proposed the inception of the programme, basing their needs on earlier analyses of NASA V-g-H records; these analyses highlighted the lack of information on control-surface movements and meteorological environment, i.e. the basic causes of the phenomena detected.

Representatives of ARB organized the Special Events Working Party; they also provided the Chairman for many of the Analysis and Data Processing Working Party meetings. They initiated numerous special studies, principally short-term, and shared information and results with the other members of the Technical Panel. A number of CAADRP Technical Reports were prepared by ARB staff[6,8,9,16,19,20,21] and many other studies were reported as internal documents because of the transitory value of the data.

4.4 CI Data Centre Ltd.

The Data Centre was started in 1962 by Benson Lehner Ltd., whose data processing equipment was chosen for reading and processing data from the CAADRP continuous trace records. The RAE could not spare from existing staff a sufficiently large group of suitable people to start a Data Centre. Outside RAE the only Data Processing Units with appropriate expertise were run by Aircraft Companies. Although the special Data Centre was set up to process CAADRP records it was permitted to accept other contracts to make it commercially viable.

The staff of the Data Centre brought expert knowledge not only on processing and analysing data, but also on such appropriate subjects as Meteorology and the analysis of experimental flight trials.

4.5 Aerodynamics Department, RAE

The representative from Aerodynamics Department, RAE, Flight Division, brought considerable knowledge of using recorders on flight trials, and consequently could advise on suitable aircraft instrumentation and data processing equipment.

Responsibility was taken for drawing up requisitions for contracts for the work to be done by the Airlines. The representative was always one of the Special Event searchers and took an active part in the interpretation of Special Events.

4.6 Mathematics Department, RAE

Expertise on Statistics and Computer Programming was provided by Mathematics Department during Phase 1. The Department also provided programmes and computer facilities for calibrating the data, based on transducer calibrations provided by the Airlines. During Phase 2 the Department acted only in an advisory capacity.

4.7 Directorate of Civil Transport Aircraft (DAC)

The successive DAC representatives took an active interest in CAADRP throughout Phases 1 and 2; they advised the panel on matters of financial and administrative procedure and also provided technical knowledge and experience.

## 4.8 Structures Department, RAE

For almost twenty years before CAADRP was initiated Structures Department had provided instrumentation for, and analysed airworthiness data from, both civil and military operational aircraft. This fund of experience was brought to CAADRP and strongly influenced activity especially in turbulence and landing studies.

Representatives of the Department always included the Chairman and Secretary of the Technical Panel. The Department also provided two Special Event Searchers, and took an active part in the Analysis and Data Processing Working Party, sometimes providing both Chairman and Secretary.

Responsibility was taken for preparing cases for the continuation of CAADRP and requisitions for Data Processing Contracts with the Data Centre. Latterly the responsibility for aircraft recording equipment also passed to Structures Department, partly because the present Chairman, who joined the programme shortly before Phase 2 started, is an expert in the design and development of operational flight recording equipment.

A number of reports[2-5,7,10-15,17,18,22,25,26,27] on Special Events and individual studies have been prepared by the Department's staff; some of these took no active part in running the programme, but used the data.

## 4.9 Directorate of Operational Research and Analysis (DORA)

When DORA started a programme to record landings and take-offs of aircraft at London Airport, using ground based cameras and radar, they were invited to be represented on the Technical Panel. The object was to co-ordinate records taken by DORA and CAADRP, particularly when the same landing was recorded by both organizations, and to interchange results of analyses. Co-ordination was simplified by the employment of the CI Data Centre Ltd. to process the DORA records.

## 4.10 Blind Landing Experimental Unit (BLEU)

BLEU were invited to join the Technical Panel before Phase 2 started so that plans could be laid for special recording of landing data; this was of particular importance because the Airlines were making preparations to install automatic landing equipment. In the event the decisions on suitable parameters had to be taken before BLEU appointed a representative; the suitability of the choice was largely due to the wide-ranging knowledge of the Technical Panel as a whole.

The representative from BLEU took a very active part in the work, acting as a Special Event Searcher as well as making studies of landing data to provide a basis for comparison of human and autoland performance. The landing analyses aimed at certification of autoland were performed outside CAADRP, but also had access to CAADRP data.

### 4.11 DIRECTORATE OF FLIGHT SAFETY (DSF)

DSF took an interest in CAADRP from the start, but were represented on the Technical Panel for only about three years. Particular interest was taken in the reason for recording various parameters, with reference to the DSF responsibility for Mandatory Recorders. Active part was also taken in Special Events interpretation, and a DSF representative continues to attend Special Event Working Party meetings. DSF participation provides a valuable link between CAADRP and Mandatory Recordings and CAADRP personnel have been used as consultants in defining requirements for Mandatory Recorders and analysis of flight data from civil aircraft accidents.

## 5 BENEFITS DERIVED FROM THE PROGRAMME BY PARTICIPATING ORGANIZATIONS

### 5.1 General remarks

The benefits derived from the programme were not necessarily proportional to the effort supplied by each participating organization. Whilst the Airlines and the Data Centre performed the accountable parts of their work under contract to the Ministry, the programme could not have been run without their active co-operation, their many constructive ideas on instrumentation, data processing and analysis and record interpretation and their provision of relevant knowledge and information on such subjects as pilot training, airport procedures, and the development of data processing equipment.

The following paragraphs are mainly derived from brief papers written by representatives of each organization, and from the present author's own knowledge. It is noteworthy that many of the benefits cited were not anticipated when the programme was initiated.

### 5.2 The Airlines

BOAC produced a paper on CAADRP analogue data acquisition which, quoting verbatim, states:-

> It is probably true to say that CAADRP was launched and has been administered during the most significant period of development in the history of flight data acquisition. Much of this significance is due to

CAADRP adoption of analogue techniques at a time when encoded formats for the acquisition of large samples of routine data were already *fait accompli* by the use of magnetic tape.

The disciplines adhered to by the use of analogue techniques has enabled the airlines associated with CAADRP to better assess the validity of the parameters selected for airworthiness purposes, and in addition have confirmed and in some instances rejected, the claims made for encoded techniques. In this latter sense CAADRP has been useful to BOAC in as much as it has supplemented the data sample already available within the airline, albeit the administrative procedures by which the programme has been managed are cumbersome by airline standards and would need major revision in any future programmes of a similar nature.

BOAC believing as it does that any experience in the flight data acquisition field is useful to a better understanding of the ultimate specification of both mandatory and non-mandatory requirements has found the CAADRP parameters useful in monitoring the non-airworthiness aspects of current aircraft operation. Specifically the CAADRP recordings have been of benefit to a review of aircraft handling techniques, and have provided data of considerable interest on the malfunctions of autopilots.

Recalling that the origins of CAADRP are to be found in BOAC's recording of meteorological phenomena during flight development of the Comet 2E, evidence of a meteorological nature obtained from CAADRP records has been of particular interest in BOAC. Because of the difficulty in collecting sufficiently large samples by conventional CAADRP methods this aspect of the activity has been very limited but nevertheless the phenomena which have been found have been instrumental in arousing international interest in the need for further co-ordinated work in this field.

In conclusion it may be said that CAADRP has posed more problems and questions than it has provided solutions or answers but, in so doing it has opened up discussion and thinking not only on the need for specification and development of integrated data acquisition systems, but also pointed to the problems of management and administration which are elements essential to the application of the end product. In as much as CAADRP has done any or all of these things it has been a useful and worthwhile experience.

BEA had similar experience of the usefulness of CAADRP. Information useful when considering aircraft operating and handling techniques and a better understanding of the effect of meteorological phenomena on flight were anticipated benefits. The choice of analogue continuous photographic paper trace recorders to do the work was derided by those who considered them obsolescent in 1962, because of the availability of magnetic wire and tape recorders, but has been proved correct; CAADRP analogue records have provided information of great value when parameters, recording speeds and frequencies and required reliability of these same magnetic recorders were discussed before mandatory recording systems were chosen. The analogue records also showed the necessity to use digital systems and computers when records from many aircraft are to be scanned. The data interpretation techniques evolved for the analogue records also gave a lead in the preparation of computer programmes for the analysis of the digital data. Possibly the most important feature was the provision of a standard by which to judge the reliability of the data from mandatory recorders.

5.3 <u>The Air Registration Board</u>

The ARB provided considerable effort in the analysis of CAADRP records. The main source of interest, and indeed the fount of many special studies of operational behaviour, concerned the Special Events which were recognised, interpreted and finally collated throughout the programme. Over 900 Special Events were discovered in the 65000 flying hours recorded. The main areas of interest related to Special Events are described briefly in (i) to (iv), while (v) indicates the scope of special studies and (vi) the papers issued.

(i) <u>Airspeed control and handling</u>

An important area from a design airworthiness requirements' viewpoint concerns the limitations and variability of the crew in manually controlling their aircraft under typical airline conditions. Special events on extremes of airspeed deviation, pilot response and large and sudden control inputs which occur in spite of normally good airmanship fall into this category, and these bear on the improvement of design features of future aircraft to cope. Flap speed control, cruise speed exceedences are important examples of this.

(ii) <u>Airworthiness and structural integrity</u>

Aspects of autopilot design, structural strength and failure, failure of systems and equipment have been collated under this heading. A large number of events, and subsequent studies, have been examined to determine the characteristics of autopilot nuisance disconnects, autopilot-aircraft coupled oscillatory behaviour, turbulence encounters and manoeuvring acceleration profiles.

(iii) Meteorological extremes

Several special events have indicated the presence of meteorological phenomena which, while broadly understood, have not previously been predicted precisely or even measured before. Limited recording has precluded extended evaluation of these, but sudden ambient temperature variations, and certain gravity wave encounters have stimulated further work.

(iv) Operational aspects

Certain special events have highlighted a significant number of cases of flight management where it was suggested that the root source of difficulty was some shortcoming of training rather than the characteristics of the aircraft. Much work has to be done in this area in attempting to separate these so-called operational difficulties from the airworthiness design features. However, recognition as an airworthiness design responsibility of the existence of serious problems for airline pilots in their inter-communication with their aircraft, i.e. in the basic information/flight director/flight management regime, has been one of the products of CAADRP. It may be that more comprehensive recording, i.e. greater numbers of parameters, could give more definition to this operational/airworthiness interface.

(v) Special studies

In many cases studies in depth of certain forms of behaviour have been initiated by the discovery of several Special Events demonstrating extreme cases of such behaviour. Other special studies were made as a result of a need for particular information or a request from another organization. Data for special study are extracted from a sufficiently large amount of randomly selected data to ensure that the extracted data form a statistically significant sample. With very rare occurrences all the data available are scanned, and even then the sample can be smaller than is convenient for analysis.

(vi) Papers issued

Numerous ARB White Notes, with a circulation limited strictly to those with a need to know, have been issued as a result of Special Studies. Those of more general interest have been published as ARB Technical Notes[9,16,19,20,21]. ARB also took part in the preparation of a number of RAE Technical Reports on Special Events, co-ordinating one of these[6] and issuing a similar ARB Technical Note[8]. These, together with other reports co-ordinated or prepared by RAE staff, form a series with CAADRP Technical Report numbers. Further reports will be issued in due course.

The examples of studies depicted in Fig.1 include many of those made by ARB.

5.4 CI Data Centre Ltd.

The following statement on the development of the Data Centre was prepared by the CAADRP Project Manager at the Data Centre.

> In 1961 the Ministry of Aviation invited tenders for a contract covering the analysis of analogue airborne flight data recordings which were to be acquired via eight jet transports of the State Airlines, under the Civil Aircraft Airworthiness Data Recording Programme. Benson Lehner Ltd. (now Computer Instrumentation Ltd.) who are a manufacturing company producing semi-automatic trace readers, electro-plotters and other computer peripherals, submitted a tender which was accepted.
>
> In November 1962 Benson Lehner Ltd. established a Data Centre in Aldershot to handle the analysis work. The Data Centre was equipped with three Benson Lehner OSCAR trace readers, one Benson Lehner electro-plotter, three Benson Lehner record editors, plus auxiliary items of ICT punch card handling equipment. A manager was engaged who had considerable experience not only in managing a Data Centre equipped with the above Benson Lehner machines, but also in the evaluation of aircraft performance from in-flight recordings. A small team of school leavers was recruited and trained to operate the equipment. The type of analysis initially required for CAADRP Phase I involved analogue/digital conversion of all the acquired flight recordings on a time slice basis, together with more detailed digitising of the take-off and landing phases of flight. Calibration and processing of the digitised output from the trace readers was undertaken by the Maths Dept of RAE Farnborough using their DEUCE computer. Processed data were subsequently autoplotted by the Data Centre largely as scatter diagrams. A small number of Special Analysis Studies were requested by CAADRP from time to time. For the first three years

of operation little specialist knowledge was required, and once the Data Centre staff had become familiar with the recording system the analysis work was relatively simple. During this period the project did however enable the Data Centre to build up a team of trained machine operators with limited but useful appreciation of civil aircraft operational procedures.

During 1963 the decision was taken by Benson Lehner to expand the Data Centre capacity and to undertake scientific data processing for other clients. Experience gained from CAADRP was invaluable for this purpose and the new venture proved successful. As a result of the increased business it became necessary early in 1964 to engage a suitably qualified Project Manager to assume sole responsibility for supervising the CAADRP analysis work.

In January 1965 the Data Centre installed an IBM 1620 computer as part of their expansion programme, and subsequently took over the data processing work from RAE Maths Dept. (The IBM 1620 was replaced by an IBM 1130 computer in February 1967.)

CAADRP Phase II came into effect during 1965 with the delivery of a new generation of jet transports to the State Airlines. Four aircraft were instrumented to a more comprehensive standard of CAADRP recording. The analysis requirements were reviewed and it was decided to transfer the emphasis to Special Studies, and to drop the routine 'time slice' analysis used in Phase I. The new analysis programme implied less machine operating work and more skilled interpretation of the flight records. It was therefore necessary for the Data Centre to engage additional CAADRP staff with higher academic qualifications as junior analysts rather than machine operators, and to train them in the skills of assessing operational performance by intelligent interpretation and discrete measurement of the flight recorded parameters. Re-building the CAADRP team on this basis progressed from mid 1965 onwards. In addition to the Project Manager and Technical Secretary, the new team comprised one senior and five junior analysts who between them possessed considerable expertise in the evaluation of aircraft performance and piloting techniques from in-flight recordings, together with useful experience in numerical analysis and statistical methods of data presentation. Programming support was made available from within the Computing Dept., and back-up trace reading support was provided by the general machine operating staff of the Data Centre.

In brief summary, the continuing CAADRP project has been a valuable asset to the Data Centre and has formed a sound base from which to expand operations into wider fields of scientific data processing. Experience and technical skills acquired by employees through CAADRP have made a measurable contribution to the growing strength of the Data Centre.

The success of CAADRP depended on the success of the Data Centre in providing the effort needed to process the large amount of data recorded. Many useful ideas on interpretation of records have come from close co-operation between Data Centre personnel and users of the processed data.

5.5 Aerodynamics Department RAE, Flight Division

The following paragraphs, prepared by one of the Flight Division representatives on the Technical Panel, indicate the use made of CAADRP by Aerodynamics Department, RAE.

The CAADRP has produced a number of items of interest and value during the first five years it has been in progress. The earliest result, and one whose value has increased rather than diminished, has been that information has become available to research scientists and experimental test pilots on the way in which civil aircraft are flown in routine operations. Relatively little qualitative and almost no quantitative data had been available to RAE prior to the start of CAADRP, and the provision of trace records giving this information has been most valuable. These records have shown for the first time how aircraft behave under the constraints of commercial operation and an Air Traffic Control system on a year round basis.

A second result has been in the study of special events; members of Aero Flight Division have from the outset of CAADRP been concerned with the detection (by visual inspection of analogue trace records) and subsequent investigation of these occurrences. In a number of cases the incidents have been relevant to other work being carried out in Flight Division. Investigation of these special events has meant that research workers have become better informed as to the type of unforeseen incident which can occur and of the reactions of aircraft and crew to them.

The third area which may be mentioned is that valuable experience has been gained of the problems of instrumentation for long term projects. In research work it is customary for experiments to be completed in a relatively short time; in CAADRP the emphasis has been on instrumentation with a high degree of reliability and a reasonable standard of precision. Part of this experience has been an appreciation of the problems involved in operating a research project in a commercial environment.

It would be wrong to claim that CAADRP had produced spectacular results in relation to the work of Flight Division, or that problems have been solved through CAADRP which would otherwise have remained unanswered. What can be stated is that a great amount of background information has been derived which has influenced the work of those associated with the project and through their staff working on other problems.

5.6 Structures Department, RAE

Structures Department has been concerned with airworthiness recording on operational aircraft since the early 1940's. The main object at first was to measure the normal accelerations and speeds employed by RAF fighters, bombers and other aircraft and relate them to the design flight envelopes and service limits. After 1946 work was extended to civil aircraft and assessment of the gusts encountered. Aircraft fatigue became a major concern and special instruments were designed to count the frequency of occurrence of normal accelerations of chosen magnitudes. Throughout the 1950's the need for more information on the basic causes of the structural loads (e.g. aircraft attitudes during manoeuvres; landing accelerations; the location, size and nature of turbulence) and other aspects of airworthiness and aircraft operation, became increasingly apparent; in particular there was a need to be able to separate gust and manoeuvre accelerations. It was appreciated that the requirement was for multi-channel continuous trace records, but neither the manpower nor the financial backing needed was then available. The proposal in 1961 to mount such a programme as a co-operative effort between ARB, Aerodynamics and Structures Departments was therefore warmly welcomed.

Studies of Special Events were of particular interest, and staff of Structures Department prepared a number of the reports published[2,3,4,7,11,12,17]. Some of the Special Events were of value in consolidating findings of accident investigations; for example, it was noted that oscillatory climbouts occurred frequently after overshoots; these events showed many characteristics subsequently found when analysing flight data recorded immediately before an eventual aircraft accident[23]. The trace interpretation expertise of several members of the Technical Panel was employed to decipher the data from the mandatory recorder carried. A probable correlation of poor pitch handling performance with the slow response of primary flight instruments was established.

A group of officers of Structures Department who were investigating the causes of undercarriage failures used CAADRP data and techniques to find the size of landing accelerations: they found that in certain cases of hard landings the aircraft bounced and the wheels struck the ground several times before finally rolling down the runway[10]; more disturbing was the discovery that the second impact was frequently as severe as or more severe than the first impact. The problem was traced to undesirable elevator usage during and after touchdown. A change in operating technique was initiated and resulted in reduced loads. This work illustrates that rate of descent at touchdown measured by flight recorders or ground based cameras may be unreliable in the prediction of the fatigue and ultimate strength requirements of aircraft undercarriages and related structure.

Study of vertical accelerations during taxying resulted in complaints of poor runway surface maintenance at specific airports, and initiated theoretical studies by Hall[24] on how to improve the undercarriage performance during take-off and landing runs without degrading landing performance.

Similar effects were found during turbulence investigations. When there is warning of turbulence ahead a pilot slows the aircraft to the recommended turbulence airspeed. This reduces the effect of the turbulence provided the speed reduction is effected before the turbulence is encountered. King[5,13] found that such action occurred on only 50% of the severe turbulence encounters and that these encounters were usually of 15 to 60 seconds duration. Special Events have shown that when speed reduction is attempted after the encounter, frequently by a pull-up technique, the result can be very severe mixed manoeuvre and gust accelerations and even, in extreme cases, loss of control. The auto-pilot also, in attempting to alleviate the effect of gusts, may aggravate the turbulence severity. This infers that if turbulence is encountered unexpectedly the pilot should do nothing except hold the aircraft in the condition suited to level flight in still air.

These are examples of findings in special studies by staff of Structures Department. The reports produced to date[5,10,13,14,15,18,22] do not include all the studies so far conducted; further reports will follow.

CAADRP data have been used by members of the Department to supplement experimental data or to test theoretical work[25]. They have also been supplied to other organizations having particular problems. The usefulness of CAADRP has not been confined to the fields anticipated when the programme was initiated.

CAADRP has demonstrated that the operational events leading to severe structural loads are very complex and that caution must be used when analysing data with the aid of a digital computer. Eckford[25] has separated the contributions of the autopilot and the turbulence to normal accelerations on a VC 10 for three instances totalling 27 seconds of flying, but economic quantitative evaluation of the contributions of the pilot, autopilot and environment to the total operational structural loading must await the provision of digital flight data with many parameters and considerable programming effort.

## 5.7 Directorate of Operational Research and Analysis (DORA)

The DORA programme to record landing and take-off of civil aircraft at London Airport using ground-based equipment was initiated several years after CAADRP started. The following paragraphs outlining the programme very briefly and showing co-ordination with CAADRP were prepared by the DORA representative on the Technical Panel.

> The Board of Trade Civil Aviation Department has recognised for some time the need for comprehensive and continuing studies involving precise measurements of the approach, landing, surface movement, take-off and overshoot of civil transport aircraft. The fact that about 60 per cent of civil transport aircraft accidents occur during these phases of operation supports this conclusion.
>
> The DORA programme is designed to increase and expand knowledge of aircraft operations in this field and to provide a rational approach to the many decisions which have to be made in the management of aircraft operation. It is complementary to the CAADRP programme in that CAADRP is concerned with detailed airborne recording of flight parameters for a few aircraft over a long period of flight time, whereas the DORA scan of civil transport aircraft operations is over a representative sample of

the whole population of aircraft types and operations for the critical part of the flight near London (Heathrow) Airport.

A further point of difference between the programmes is that the DORA measurement method is in general ground based and does not involve measurements of parameters on board the aircraft themselves. In the case of landing aircraft, however, aircrew are debriefed whenever possible to obtain information about the type of approach; e.g. manual, ILS, autocoupled, uncoupling height etc. This is essential to the proper understanding of the trajectory data.

A joint programme for the statistical analysis of DORA and CAADRP data has been arranged in conjunction with BLEU and special attention is given to simultaneous recording by DORA instruments of CAADRP equipped aircraft which is valuable in assessing autoflare and autoland performance under operating conditions.

Of particular interest in the air safety field is the attempt by DORA and BLEU to provide a system of inspection and quality control of aircraft performance with emphasis on the landing phase. Both CAADRP and DORA measurements are being analysed to provide standards of performance which can be incorporated in the inspection and quality control system. The aim is to provide the operational organisations with a means of detecting quickly any deterioration in overall performance of airborne and ground equipment particularly in difficult weather conditions and which can be used by operational management.

A further advantage to DORA was the availability of the CI Data Centre Ltd. to process their records. Using the same Data Centre simplified co-ordination considerably; the expertise gained by Data Centre staff in the understanding of CAADRP flight records was a help in initiating analysis of the DORA records. As with CAADRP, the need was for a Data Centre independent of an airline or aircraft manufacturer.

## 5.8 Blind Landing Experimental Unit (BLEU)

It was evident in the early 1960's that automatic landing would be installed in operational aircraft within a few years. At the introduction of CAADRP Phase 2 plans had been made for detailed recordings of landings to provide data for the assessment of automatic landings in operational conditions.

Paraphrasing a note prepared by the BLEU representative on the Technical Panel, the main BLEU interest in CAADRP was in obtaining statistics describing manual and automatic landing performance. Analysis of CAADRP analogue data would prove useful in defining the sort of computer programme to be used later to analyse digital records.

In addition CAADRP highlighted problem areas such as the following examples:-

(i) ILS interference: The ILS interference caused by aircraft taking off over the ILS localizer whilst the landing aircraft is in the final stages of the approach was shown both by a study of CAADRP records and by a complementary controlled experimental study by Radio Department RAE. The combined results of these studies clearly showed the need for BLEU to embark on a detailed experimental study of the problem under flight test conditions. The frequency of occurrence of interference due to other causes was also provided by CAADRP data.

(ii) Airport capacity: The capacity of an airport is dictated by the time occupied by an aircraft in taking-off and landing. Although measurements of such periods of time are provided by the DORA programme, each set of measurements requires the presence of an observer. Apart from the inconvenience of working at night, the DORA photographic techniques are planned for daylight use. CAADRP data can fill the gaps in information by providing samples of data from take-offs and landings occurring at any time. BLEU co-operated closely with DORA in this study.

(iii) Aircraft operating techniques: BLEU obtained CAADRP data on the percentage of automatic approaches and the height down to which the autopilot is used. This study was modified as needed when completely automatic landings were introduced.

### 5.9 Directorate of Flight Safety (DSF)

The following note was prepared by the DSF representative on the Technical Panel.

> In the Directorate of Flight Safety it has long been felt that the recording of data on the operation of public transport aircraft is a potentially valuable method of obtaining information which might reveal dangerous incidents or even bad operating practices, thus enabling corrective action to be taken before accidents occur.

CAADRP has provided an opportunity for obtaining such data, albeit from only a small number of aircraft, and the Directorate has, consequently, maintained a close interest in the programme.

DSF was represented on the Technical Panel of CAADRP for several years and has strongly supported the inclusion of a sample of mandatory recorder data from independent airlines in the programme. In order to make the best use of recorded data for flight safety purposes, it is necessary to detect unusual operational events. In other words one wants to be able to detect potential accidents. It is, therefore, the work of the 'Special Events Panel' which has been of particular interest to the Directorate.

The several hundred 'Special Events' detected since CAADRP began have revealed some areas of operation where corrective action has been possible. For example:-

(i) A considerable scatter of rotation speeds was detected and the airline concerned brought this to the notice of its pilots - a subsequent check indicated a marked improvement in technique.

(ii) It was found that wing flaps were being used over a wider range of speeds and altitude than had been assumed for the aircraft design requirements - an Aeronautical Information Circular was issued on this.

It is, however, surprising, and to some extent disappointing, that relatively few trends have been revealed by the Special Events, where remedial action in the flight safety, as opposed to the purely airworthiness, field has been possible. This may, in part, be due to the small number of aircraft engaged in the programme, and in part to the difficulty in determining the dividing line between the potentially unsafe operation and the acceptable deviation from optimum performance criteria.

5.10 Other participants

It cannot be said that other organizations represented on the Technical Panel - DAC and Mathematics Department RAE - derived any direct benefit from participation in CAADRP. However, the knowledge acquired in relation to processing and analysing bulk data from operational aircraft, methods of recognising spurious data, identification of false readings from the recorder or data processing equipment and similar information can be of use in many fields. The Meteorological Office, through study of Special Events, has gained a better appreciation of the problems facing pilots and the weather information they need. The Airline Pilots gained an understanding that the purpose of 'black boxes' on aircraft is to help the pilots not spy on them; also they profited by improvements in training programmes, operating instructions and aircraft equipment.

## 6 NON-PARTICIPATING ORGANIZATIONS

CAADRP data have been supplied to a number of firms to help them in studies of special problems (e.g. Hawker-Siddeley - automatic landing equipment; Rolls-Royce - temperature at engine air intake). Some assistance has been given to the Concorde project by providing data on manoeuvre accelerations by flight phase, aircraft flight profiles in climb etc.

Requests have come from many countries for CAADRP Reports; they have been sent to NASA and other USA organizations throughout the programme; Commonwealth, South American and European countries are now regular recipients, the most recent added to the list being Eire, India and Pakistan.

Continued interest in CAADRP has been shown by the commercial organization, Technology Incorporated, which handles much of the USA military operational data recording work. Exchange of ideas is profitable to both research groups.

Techniques of recording and data interpretation developed by CAADRP have been adopted, suitably modified, for operational research on Hovercraft.

Some manufacturers of airborne recorders and ancillary equipment have developed improved products (e.g. the outside air temperature probe) as a result of CAADRP activities.

The Accident Investigation Branch of the Board of Trade has had direct assistance in record interpretation and data from CAADRP to support findings.

## 7 PROFITABILITY OF CAADRP

### 7.1 Direct profit

The profitability of such a programme as CAADRP cannot be assessed quantitively. No claim can be made that an accident was prevented because of knowledge derived from CAADRP, neither can a reduction in the frequency of accidents be attributed to CAADRP. Nevertheless it can be claimed that greater understanding of the nature of the hazards encountered and the way the aircraft behaves resulted in a number of improved handling techniques which reduce the hazard. More realistic operating limits and improved training methods make the pilot's task a little easier, and may increase the safe life of the aircraft (e.g. improved flap-operating instructions reduce the fatigue life consumed during the flaps extended condition). Some changes of technique (e.g. on entering turbulence or during a hard landing) increase passenger comfort.

Projection of the findings to future aircraft design and operation has always been part of the purpose of operational recording. CAADRP data has been applied to a number of problems associated with Concorde, including such items as rough runways, high altitude turbulence, climb-out procedures and essential manoeuvres.

Assistance has been given in accident investigations using both CAADRP data and expertise acquired by study of CAADRP records.

Areas requiring study, experimentation, design or development by other experts have been revealed by CAADRP. The study of ILS interference by Radio Department RAE is a case in point.

### 7.2 Indirect profit

The continual necessity during the programme for improvements in recording instrumentation, including transducers, has set a standard of accuracy and reliability for future airborne recording instrumentation and playback equipment. The choice of analogue continuous photographic trace recorders for Phases 1 and 2 has been amply justified by the expertise in record interpretation acquired, and by knowledge which has enabled certain types of Special Event and other areas of interest to be defined so that they can be sought, by suitable programming, from magnetic wire or tape recorder data, by a computer.

CAADRP has also been of use in the design and development of AIDS and accident recorders, principally by demonstrating the relative value of the various parameters which could be recorded; it also assisted materially in the choice of frequency of recording each parameter.

Processing and analysis techniques developed in Phases 1 and 2 of CAADRP can be applied to UV recorder or similar playback data. Understanding of areas of interest and in particular of Special Events provides the information needed to programme computers to extract only meaningful data.

The need to check recording equipment frequently has also been highlighted. Mandatory accident recorders can only repay the enormous cost to operators if they provide useful data in the event of an accident. Not only must the recorder be recoverable and shock- water- and fire-proof, but the records must not be distorted by unusual aircraft attitudes or high accelerations just prior to the accident. It is therefore necessary to do more than check that 'something' is being recorded; the records must be studied from time to time to ensure that they exist and are accurate in difficult flying conditions.

### 7.3 Summary of areas of profitability

CAADRP has provided information and/or expertise in the following fields:-

(i) Handling techniques and operating instructions
(ii) Pilot training
(iii) Atmospheric-turbulence and other meteorological phenomena
(iv) Aircraft design requirements, including undercarriages
(v) Aircraft instrumentation requirements
(vi) Accident investigation
(vii) Airport facilities
(viii) Air traffic control
(ix) Design requirements and testing recording equipment for operational aircraft
(x) Record interpretation and analytical techniques
(xi) Data processing equipment
(xii) Support of other research projects and suggestions for new projects.

This list does not imply that use of CAADRP data and expertise has solved problems in all these fields. In some cases it has merely provided evidence of the need to search for ways of improving facilities, techniques, requirements, etc. As stated in the BOAC paper (cf. section 5.2) 'CAADRP has posed more problems and questions than it has provided solutions or answers'.

## 8 THE FUTURE OF CAADRP

The general usefulness of CAADRP information indicates that there is a continuing need for this type of operational research. Recording in Phases 1 and 2 was confined to five types of aircraft and two airlines. Data from other aircraft types and other airlines are needed. Some potentially useful parameters are as yet unrecorded, a number of trend studies should be continued and more data are needed in fields where existing data are inadequate.

It is however no longer feasible to use continuous photographic trace recorders and specially installed recording systems for CAADRP for the following reasons:-

(i) all commercial jet aircraft over 12500 lb all up weight in UK are now required by law to carry recorders with a minimum of six parameters, all suited to airworthiness investigations; airline operators are understandably reluctant to direct some of their recording and analysis staff to running a completely separate recording system; they might, however, be prepared to incorporate a few additional parameters in a small number of aircraft installations;

(ii) the cost of retrospective fit of a complete non-standard recording system would be great (probably in excess of £25000 per aircraft); carriage costs are mounting; if one of the two or three aircraft equipped should be lost it materially affects the rate of data acquisition, and the cost per flying hour;

(iii) the need to choose continuous paper trace recorders for their known reliability is fast disappearing; CAADRP Phases 1 and 2 have materially assisted in developing and proving present airline recording systems, and have indicated many of the improvements which could be incorporated in second generation systems to be introduced in a few years time.

Phases 1 and 2 therefore comprise all the analogue continuous photographic trace records to be taken for CAADRP from operational civil aircraft in the UK. Analysis of the bank of data will continue for some years, but CAADRP Phase 3 is being based on digital data purchased from airline magnetic wire or tape digital recorders.

## 9 CONCLUDING REMARKS

The Civil Aircraft Airworthiness Data Recording Programme has been a worthwhile project to all concerned. Much has been learned of the potentially dangerous situations encountered by operational aircraft. Methods of reducing the risks have been recommended and some of those which could be implemented without further research have been adopted; in general these are in the field of operating techniques, training methods and operational instructions.

Lines of investigation in some special research projects have been initiated by information from CAADRP data; the Radio Department investigation of distortion of ILS signals and Structures Department research on undercarriage performance during taxying are good examples. Other research has been helped by CAADRP data.

Recording instrumentation for operational use has been greatly influenced by CAADRP. The need for reliability and accuracy of the complete recording system has been emphasised and ways of achieving this have been suggested. CAADRP data has also set a standard of comparison and has provided proof of the relative usefulness of various parameters. The two major airlines have gained knowledge of great use in setting up their comprehensive AIDS programmes. Requirements for future mandatory recording systems have been influenced by CAADRP, and the parallel military project owes much to the expertise gained by study of CAADRP records.

It is anticipated that accident investigators will need to rely to a great extent on CAADRP experts when records require interpretation; this has already occurred in several instances.

The CI Data Centre Ltd., which was started to deal with CAADRP data processing, is of great value to any project requiring the services of an independent data processing firm with special knowledge in the aircraft field.

There is a need to spread CAADRP to include independent airlines and different aircraft types. The only feasible method is to make use of the airlines' own recording systems, and this is the basis of CAADRP Phase 3. The use of digital recording will provide a greater bulk of data and enable more reliable statistical studies to be conducted. It may also result in the discovery of very rare hazards, and the way to avoid them.

The CAADRP activity has provided a warning that automatic analysis of operational flight data may destroy the most critical features of the hazardous situation. It will always be necessary to provide a group of experts, with widely diversified experience, to study the original data in hazardous flight conditions and to search for new phenomena which, when found, require reprogramming of the automatic analysis. Nevertheless, it is hoped that automatic analysis will provide data on known phenomena from a large sample of operational flying and reduce the workload of visual data inspection by employing automatic selection of extreme flight conditions.

CAADRP has also shown that data extracted for general objectives is usually inadequate for the study of a new problem when it arises. It is essential to build up a library of data in such a form that data for a special study can be extracted with the minimum of delay; continuous additions to the library and the ability to acquire particularised data directly from the airlines are needed for trend analyses.

The success of CAADRP has depended on the unstinted co-operation of all who took part. The individuals forming the Technical Panel have changed, but the co-operation has remained. It is essential that the same spirit is maintained throughout the time work of this nature is needed.

# Appendix A

## RECORDING EQUIPMENT AND RECORDS TAKEN CAADRP PHASES 1 AND 2

### A.1 Recording equipment

1962-1965 SFIM A211 and A261 photographic paper trace recorders: 60 and 88 mm wide 15 m long

1965-1969 CID Century recorders, photographic paper trace: 90 mm wide 60 m long

### A.2 Parameters

**Phase 1 1962-1965**

A211 and A261
Indicated airspeed
Normal acceleration
Barometric height
Outside air temperature
Aileron movement
Elevator movement
Flaps in or out

A261 only
Rudder movement
Aircraft magnetic heading
Cockpit acceleration*
Autopilot in or out

*One aircraft only

**Phase 2 1965-1969**

Indicated airspeed
Normal acceleration
Barometric height
Outside air temperature
Aileron movement
Elevator movement
Rudder movement
Aircraft magnetic heading
Autopilot mode
Flap operation
Pitch
Roll
Thrust
Mach number
ILS glide slope
ILS localiser
Radio height
Airfield marker beacons

NOT ALL AT THE SAME TIME

### A.3 Recording speeds

SFIM A211 ran at 5 mm per minute of flight time; suitable for analysis of in-flight data.

SFIM A261 at 2½ mm per minute in flight and 37.5 mm per minute during take-off and landing: suitable for analysis of take-off and landing data.

CID Century ran at 10 mm per minute in flight and 40 mm per minute during take-off and landing: suitable for all phases of flight for data analysis.

All records scrutinised for unusual occurrences or 'Special Events'.

A.4 Aircraft types, recorders and recorded flying hours

| | Aircraft | Recorders | Recorded flying hours |
|---|---|---|---|
| Phase 1 (1962-1965) | 3 Comet 4 | 2 × SFIM A211 | 11200 |
| | | 1 × SFIM A261 | 5600 |
| | 3 Boeing 707 | 2 × SFIM A211 | 10500 |
| | | 1 × SFIM A261 | 7500 |
| | 2 Comet 4b | 1 × SFIM A211 | 3000 |
| | | 1 × SFIM A261 | 4400 |
| Phase 2 (1965-1969) | 1 Boeing 707 | SFIM A261 | 1300 |
| | 2 Super VC 10 | CID Century | 14400 |
| | 2 Trident | CID Century | 7300 |

## Appendix B

## METHODS OF EXTRACTING DATA FOR SPECIAL STUDIES

### B.1 Time slice method

When CAADRP first started it was recognised that one of the most time consuming and arduous tasks was extraction of data from the continuous trace records in a form suitable for special studies. It was obvious that many different studies called for the same basic data plus data from one or more other parameters. An attempt was made to extract data which would satisfy all likely special studies and thus avoid numerous passes of the rolls of photographic paper traces through the reading equipment.

For climb, cruise and descent the method used was to read all parameters at 5 or 10 minute intervals*; the readings were automatically punched on cards, calibrated in a computer and the resulting cards were stored for use. A computer or other automatic data selection equipment was used to extract data for a special study from the stored cards.

Special studies had to await the accumulation of an adequate supply of data and when the data bank was eventually used it was frequently necessary to refer to the original traces for further information or to recheck the validity of the readings. It was found that the time taken to read, calibrate and check the data used a disproportionately large amount of the available effort at the Data Centre, and towards the end of Phase 1 such reading was discontinued on two aircraft types which had already provided a large amount of stored data.

The data bank acquired so laboriously has provided much valuable information and is particularly useful when a large amount of data is needed urgently. Although from the start of Phase 2 a different method was employed it was later found that a data bank of limited size was needed for urgent request, and a few hundred flights of each type of Phase 2 aircraft were read, confining the reading to the most popular parameters.

### B.2 Flight index sheets

In the absence of time slice readings from all rolls of data it was considered necessary to scan all rolls at least once at the Data Centre, and to

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* Readings were taken of the most extreme upward and downward acceleration in each 'time-slice'; all other parameters were read at the beginning of the 'time-slice'. Ten minute 'time-slices' were used for cruise data, five-minute for climb and descent.

extract data which would describe the flight and pinpoint areas of interest. A number of questions, mostly requiring yes, maybe, or no as the answer, were posed in the five flight phases take-off, climb, cruise, descent and landing; a few questions, such as turbulence level, required more direct answers. The occurrence of a Special Event was noted and further Special Events discovered. All answers were punched on an 80 column card together with numbers identifying the flight and aircraft type and details of date, time, airfield, runway, windspeeds and all up weight at take-off and landing; as much of this data as is available is provided by the airlines for every flight. Fig.2 shows a set of automatically tabulated results, and Fig.3 identifies the locations on the index card of the punched data, and hence decodes Fig.2.

Using either the cards or the tabulated data direct answers to single questions can be answered quickly, e.g. on what proportion of flights was 0.8 g exceeded? Is the proportion of successful automatic landings increasing with experience?

More detailed, but still simple, questions can be answered using sorting methods on the cards, e.g. does 0.8 g occur more frequently on the North Atlantic or the European routes? At which airfields do hard landings occur most frequently?

The use of the Flight Index for Special Studies is best described by an example. Suppose a study of flap speed exceedences in climb is proposed:

(i) the frequency of occurrence of flap speed exceedences in climb is found from the cards or tabulations;

(ii) if they occur frequently (say once in 5 or 6 flights on average) a random sample of 200 or 300 flights should provide enough data for the study. If infrequently (say once in 100 flights on average) data from a random sample of about 200 flights would provide enough data for a pilot study; this would be followed by a larger random sample and detailed study would be confined to flights when the question on flap speed exceedence is answered 'maybe' or 'yes' thus avoiding reinspection of all flights. If it does not occur at all the study is unlikely to be useful.

(iii) If the study reveals a disturbing fact, study can be made of further occurrences of flap speed exceedences as they occur, watching for trends.

Another use of the Flight Index is the indication of areas where Special Studies are needed. A glance at Fig.2 shows that, in the fortythree flights indexed, flap speed is not exceeded in climb, but $V_{mo}$ is exceeded sixteen times in cruise and five times in descent; a study of $V_{mo}$ exceedences could be worthwhile.

## B.3 Take-off and landing data

In Phase 1 elaborate readings were made of take-off and landing data, and a bank of data accumulated. As with the time-slice readings, the labour of reading was disproportionately time-consuming, and was probably less useful because it lacked the universality of application of some parameters of the time-slice readings. The flight index includes information on all phases of flight.

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## Appendix C

## SPECIAL EVENT INDEX SYSTEMS

### C.1 Introduction

From the start of CAADRP every member of the Special Events Working Party received, through the Data Centre, a photographic copy of the trace record of every Special Event; each searcher obtained all available relevant information, such as meteorological and crew reports from the airline concerned, and added his own comments, which sometimes included a request to the Data Centre for particular readings from the trace; all this information was also passed to Working Party members. The resulting documents were used at discussions about the nature and probable cause of the events and the original traces were always available for more detailed examination if necessary.

At first it was not difficult to find a particular type of event by searching through files of information and for some time a simple index in chronological order was sufficient. Later an attempt was made to index the events by cause; this was not entirely successful as many events had multiple contributory causes; it did, however, serve as a guide to categorization and it highlighted the need for some form of quick access storage.

Two complementary systems were adopted in 1968. The first system uses a computer disc file at the Data Centre, and the second edge-hole cards which supplant the sheets of paper previously used to convey information to the Working Party. Descriptions of both systems are presented.

### C.2 Computer disc file

The computer disc file system entails numeric coding of all information relevant to the event, including detailed type classification and agreed basic cause; this provides a comprehensive description which is punched on one 80 column card per event. The cards form the input for compiling and updating a computer disc file of Special Events. Tables corresponding to the numeric coding system are also computer-stored for decoding purposes.

A data retrieval programme executes such instructions as sorting, type classification and printed output of decoded information in a variety of formats. Two major output facilities are: (i) an updated index of events classified and listed in alphabetical order with brief descriptive details of each event; (ii) text printout of the full description of any specified type of event.

Figs.4 and 5 give examples of extracts from printouts in these two categories; aircraft names and letters, airfields (other than Heathrow) and names of the searchers who reported the incidents have been obliterated to preserve anonymity in this Report.

Updating the disc file is simple; subject only to computer availability, access to the file is virtually immediate. Printed output is in a form suitable for direct despatch to the originator of any request for information from the index file.

C.3 Edge-hole cards

The type of card used for the edge-hole card indexing system is shown in Figs.6 and 7. The face of the primary card (Fig.6) is pre-printed to enable coded or direct information to be punched round the edge of the card. The data at the top and bottom of the card is punched at the Data Centre, who also print a photographic copy of the trace and information on the reverse of the card (Fig.7). Supplementary information, such as meteorological and crew reports, are printed on one or more additional cards identical in size and hole-layout to the primary card, but of a different colour and without pre-printing. A gang - punch is used by the Data Centre to punch all sets of cards for one event simultaneously. Every member of the Working Party receives a set of cards in place of the data previously supplied on sheets of paper. The sides of the cards are available to the holder of a set of cards to punch such information as he considers important, and the centre of the face of the primary card can be used for comments, such as the findings of the Working Party.

The purpose of the system is to provide a rapid means of finding information on a particular event or type of event. A sorting needle is used to extract the relevant card(s) which may be identified by Special Event Number, aircraft type, event characteristics, geographic location or other particulars according to the question asked.

The late implementation of this system left a considerable back-log of Special Event data to be printed on cards from the original sheets of paper. As yet this work is incomplete and consequently the full potential of the system cannot be realised.

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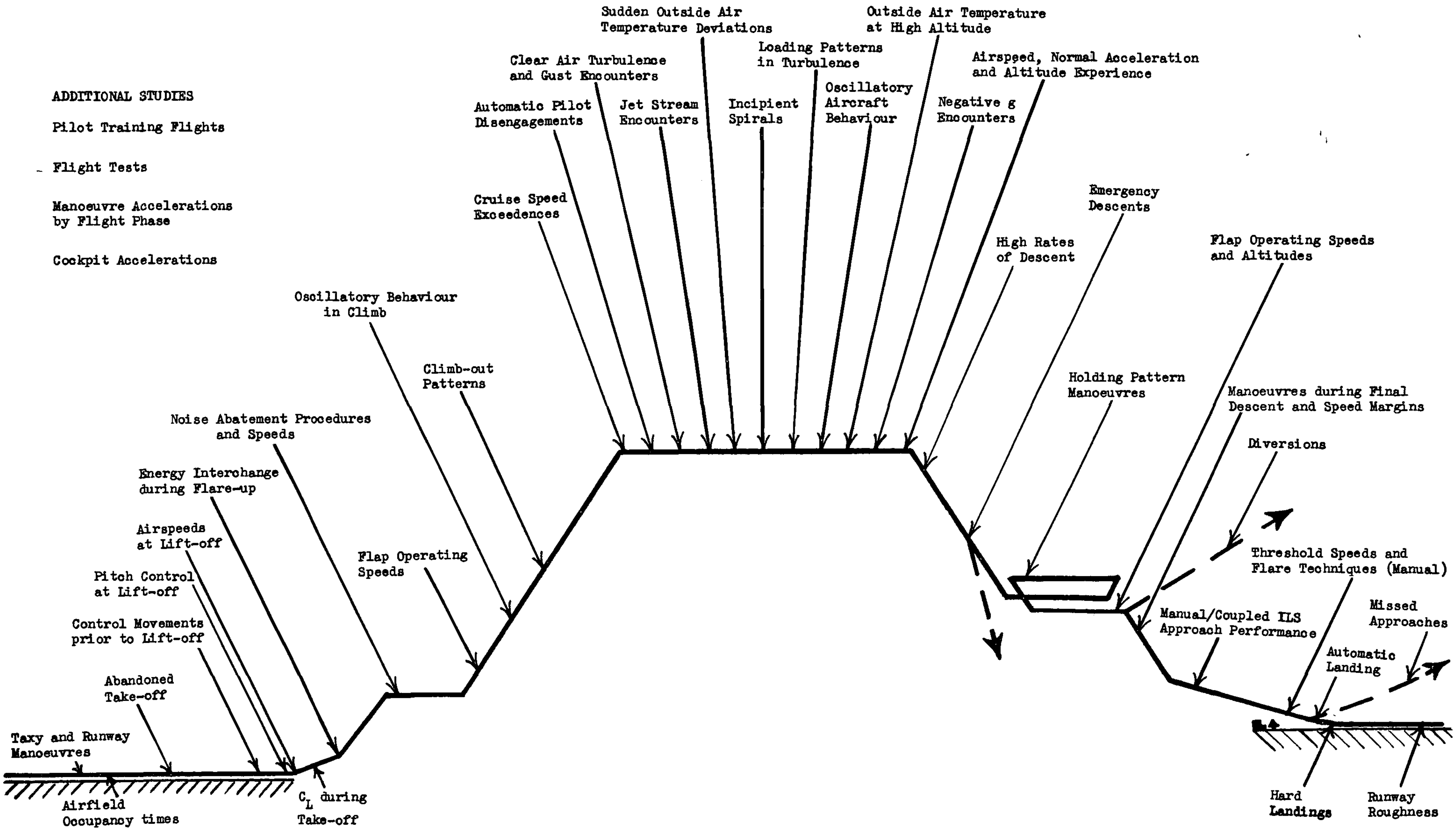


Fig.1. Normal and extreme behaviour of civil jet transport aircraft Examples of studies based on CAADRP analogue continuous trace records

| AC FLT | DATE | GMT | AF | RW | W | V | AU W | TAKE OFF 12345 | CLIMB 123456 | CRUISE 123456 | DESCENT 1234567 | GMT | AF | RW | W | V | WT | LANDING 1234567890 | MISC 12345 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41628 | 07097 | 1320 | 001 | 28 | -- | -- | 51 | 05000 | 0 0000 | 0 2000 | 2 00000 | 1446 | 134 | 07 | -- | -- | 45 | 000004 11- | 00 20 |
| 41629 | 07097 | 1555 | 134 | 07 | -- | -- | 49 | 05000 | 0 0000 | 0 2000 | 0 00000 | 1737 | 001 | 28 | -- | -- | 42 | 000004 210 | 20 20 |
| 41630 | 07097 | 1910 | 001 | 78 | -- | -- | 44 | 04000 | 0 0000 | 2 2000 | 2 00000 | 1943 | 063 | 25 | -- | -- | 42 | 000003 11- | 00 20 |
| 41631 | 07097 | 2059 | 063 | 03 | -- | -- | 48 | 04000 | 0 0000 | 2 1000 | 2 00000 | 2131 | 001 | 28 | -- | -- | 46 | 000003 11- | 00 20 |
| 41632 | 08097 | ---- | 001 | 78 | -- | -- | 48 | 05000 | 0 0000 | 0 2000 | 0 20000 | ---- | 002 | 24 | -- | -- | 45 | 000004 11- | 20 20 |
| 41633 | 08097 | 1018 | 002 | 24 | -- | -- | 48 | 05000 | 0 0000 | 0 2000 | 0 20000 | 1109 | 001 | 78 | -- | -- | 44 | 000004 210 | 00 20 |
| 41634 | 08097 | 1209 | 001 | 28 | -- | -- | 47 | 05000 | 0 0000 | 2 2000 | 0 00200 | 1248 | 063 | 03 | -- | -- | 44 | 000003 11- | 00 20 |
| 41635 | 08097 | 1331 | 063 | 03 | -- | -- | 45 | 04000 | 0 0000 | 2 1000 | 0 00000 | 1407 | 001 | 78 | -- | -- | 43 | 000003 210 | 00 20 |
| 41636 | 08097 | 1544 | 001 | 78 | -- | -- | 49 | 05000 | 0 0000 | 0 2004 | 0 00000 | 1649 | 073 | 27 | -- | -- | 45 | 011005 11- | 00 20 |
| 41637 | 08097 | 1337 | 073 | 27 | -- | -- | 46 | 04000 | 0 0000 | 0 2000 | 0 00000 | 1435 | 001 | 28 | -- | -- | 43 | 000003 210 | 20 20 |
| 41638 | 09097 | 0712 | 001 | 78 | -- | -- | 49 | 05000 | 0 0020 | 2 1000 | 0 20002 | 0744 | 063 | 21 | -- | -- | 47 | 000003 11- | 00 20 |
| 41639 | 09097 | 0838 | 063 | 25 | -- | -- | 44 | 04000 | 0 0000 | 2 1000 | 0 00000 | 0913 | 001 | 28 | -- | -- | 42 | 000003 11- | 20 20 |
| 41640 | 09087 | 1028 | 001 | 78 | -- | -- | 47 | 04000 | 0 0000 | 2 2000 | 0 00000 | 1101 | 063 | 25 | -- | -- | 44 | 000004 11- | 20 20 |
| 41641 | 09097 | ---- | 063 | 03 | -- | -- | 41 | 05000 | 0 0020 | 2 1000 | 0 00000 | ---- | 001 | 78 | -- | -- | 39 | 000003 210 | 20 20 |
| 41642 | 09097 | 1313 | 001 | 28 | -- | -- | 51 | 05000 | 0 0020 | 0 2000 | 0 20210 | 1452 | 083 | 22 | -- | -- | 45 | 000004 11- | 20 20 |
| 41643 | 09097 | 1543 | 083 | 22 | -- | -- | 51 | 05000 | 0 0000 | 0 2000 | 0 20000 | 1721 | 001 | 28 | -- | -- | 45 | 000003 11- | 20 20 |
| 41644 | 09097 | 1813 | 001 | 78 | -- | -- | 48 | 04000 | 0 0000 | 0 2000 | 0 20000 | 1903 | 002 | 24 | -- | -- | 44 | 000005 11- | 00 20 |
| 41645 | 09097 | 1852 | 002 | 24 | -- | -- | 44 | 04000 | 2 0000 | 2 2000 | 0 00000 | 2042 | 001 | 28 | -- | -- | 41 | 000003 11- | 00 20 |
| 41646 | 09097 | 2214 | 001 | 78 | -- | -- | 51 | 05000 | 0 0000 | 0 2000 | 0 00000 | 2357 | 106 | 30 | -- | -- | 44 | 000003 11- | 00 20 |
| 41647 | 10097 | 0507 | 106 | 30 | -- | -- | 52 | 05000 | 0 0000 | 0 2000 | 0 00000 | 0701 | 001 | 28 | -- | -- | 44 | 000004 11- | 00 20 |
| 41648 | 11097 | 0735 | 001 | 78 | -- | -- | 48 | 04000 | 0 0000 | 2 1000 | 0 20000 | 0808 | 063 | 21 | -- | -- | 40 | 000003 210 | 00 20 |
| 41649 | 11097 | 0912 | 063 | 25 | -- | -- | 47 | 05000 | 0 0000 | 2 1000 | 2 20000 | 0947 | 001 | 78 | -- | -- | 44 | 000003 210 | 00 20 |
| 41650 | 11097 | ---- | 001 | 28 | -- | -- | 45 | 04000 | 0 0000 | 2 1000 | 0 20000 | ---- | 062 | 24 | -- | -- | 43 | 000004 210 | 00 20 |
| 41651 | 11097 | 1214 | 062 | 24 | -- | -- | 45 | 04000 | 0 0000 | 0 1000 | 0 00000 | 1240 | 001 | 78 | -- | -- | 43 | 000004 210 | 00 20 |
| 41652 | 11097 | 1414 | 001 | 28 | -- | -- | 47 | 05000 | 0 0000 | 2 2000 | 0 20000 | 1448 | 063 | -- | -- | -- | 45 | 000003 210 | 00 20 |
| 41653 | 11097 | 1547 | 063 | -- | -- | -- | 48 | 04000 | 0 0000 | 0 1000 | 0 00200 | 1612 | 001 | -- | -- | -- | 45 | 000003 11- | 00 20 |
| 41654 | 11097 | 1710 | 001 | -- | -- | -- | 49 | 05000 | 0 0000 | 0 2000 | 0 00000 | 1757 | 002 | -- | -- | -- | 46 | 000004 11- | 00 20 |
| 41655 | 11097 | 1906 | 002 | 24 | -- | -- | 44 | 04000 | 0 0000 | 0 2000 | 0 00000 | 1956 | 001 | 28 | -- | -- | 41 | 000003 11- | 00 20 |
| 41656 | 12097 | 0905 | 001 | 60 | -- | -- | 50 | 05000 | 0 0020 | 0 2002 | 0 20000 | 1029 | 072 | 36 | -- | -- | 44 | 000004 210 | 00 20 |
| 41657 | 12097 | 1119 | 072 | 36 | -- | -- | 50 | 05000 | 0 0000 | 0 3000 | 0 00000 | 1254 | 001 | -- | -- | -- | 44 | 000004 210 | 20 20 |
| 41658 | 12097 | 1350 | 001 | -- | -- | -- | 49 | 05000 | 0 0000 | 0 2000 | 0 00200 | 1536 | 043 | 01 | -- | -- | 42 | 000003 11- | 00 20 |
| 41659 | 12097 | 1622 | 043 | 28 | -- | -- | 48 | 05000 | 0 0000 | 0 3000 | 0 20000 | 1805 | 001 | 10 | -- | -- | 42 | 000003 210 | 00 20 |
| 41660 | 12097 | 1857 | 001 | 60 | -- | -- | 48 | 05000 | 0 0000 | 2 2000 | 0 00000 | 1943 | 186 | 06 | -- | -- | 44 | 000005 11- | 00 20 |
| 41661 | 12097 | 2026 | 186 | 06 | -- | -- | 43 | 04000 | 0 0020 | 0 2002 | 0 00000 | 2111 | 001 | 60 | -- | -- | 40 | 000003 210 | 00 20 |
| 41662 | 13097 | 0640 | 001 | 60 | -- | -- | 47 | 05000 | 0 0000 | 2 2000 | 0 00000 | 0717 | 070 | 06 | -- | -- | 45 | 000004 210 | 00 20 |
| 41663 | 13097 | 0813 | 070 | 01 | -- | -- | 46 | 04000 | 0 0000 | 2 2000 | 2 00000 | 1858 | 001 | 10 | -- | -- | 43 | 000003 11- | 20 20 |
| 41664 | 13097 | 0913 | 001 | 60 | -- | -- | 51 | 05000 | 0 0000 | 0 2020 | 0 00000 | 1111 | 015 | 10 | -- | -- | 43 | 000003 210 | 20 20 |
| 41665 | 13097 | 1313 | 015 | 25 | -- | -- | 52 | 05000 | 0 0000 | 0 2000 | 0 00200 | 1455 | 067 | 15 | -- | -- | 46 | 000004 11- | 00 20 |
| 41666 | 13097 | 1551 | 067 | 15 | -- | -- | 48 | 04000 | 0 0020 | 0 2006 | 0 00000 | 1722 | 003 | 18 | -- | -- | 41 | 000004 210 | 20 20 |
| 41667 | 14097 | 0751 | 003 | 21 | -- | -- | 47 | 04000 | 0 0000 | 0 2004 | 0 00000 | 0921 | 067 | 33 | -- | -- | 41 | 000004 210 | 20 20 |
| 41668 | 14097 | 1035 | 067 | 15 | -- | -- | 51 | 05000 | 0 0020 | 0 2000 | 0 00000 | 1205 | 015 | 25 | -- | -- | 46 | 000004 11- | 20 20 |
| 41669 | 14097 | 1254 | 015 | 25 | -- | -- | 52 | 05000 | 0 0020 | 0 3000 | 0 20000 | 1444 | 001 | 78 | -- | -- | 45 | 000004 210 | 20 20 |
| 41670 | 14097 | 1604 | 001 | 28 | -- | -- | 50 | 05000 | 0 0000 | - ---- | - ----- | ---- | 073 | -- | -- | -- | 46 | ------ --- | -0 20 |

**Fig.2. Flight index sheet**

## NOTES

**Annotation:** Identification and take-off data - Cols 1 to 24; landing data - Cols 52 to 65.

**Runway Code:** for RIGHT runways 50 is added to direction (given in $10^{o}$)

**Answers to questions:** 0 = No, 1 = maybe, 2 = yes.

**Rotation Speed** is given by one number which is the tens part of the speed, i.e. 144 knots given as "4". If T.O. is abandoned Y is printed here.

**Turbulence levels:**

If 0.8 Δg exceeded, 8 printed
0.5 Δg exceeded, 5 printed
below 0.5 Δg, 0 to 4 printed

**Autopilot Disengage question:**

is Autopilot disengaged > 5 minutes? (0,1,2)

**Max. Altitude:**

0-9k' = 0
10-19k' = 1
20-29k' = 2
30-39k' = 3 etc.

**Landing/Approach Code:**

Type of Approach: (Flight down to 200 feet) — Manual = 1, Autocoupled = 2, Autoland = 3

Type of Landing: (From 200 feet to touch) — Manual = 1, Autoflare = 2, Autoland = 3 (inc. roll auto)

Landing Success: (Automatics reliability) — Pilot disconnect = 0, Auto " = 1, Duplex = 2, Triplex = 3

**Special Events Code:**

1. A/S & Handling
2. Meteorological
3. Airworthiness
4. Operational
5. AORB
6. Spare
7. Unknown
8. > 1 S.E.

**TAKE OFF**

1. Runway Δg level
2. Rotation Speed
3. Extreme pitch Att?
4. Extreme flare up?
5. Extreme Roll Att?

**CLIMB**

1. VMO exc?
2. MMO exc?
3. Flap Speed exc?
4. Extreme Pitch att?
5. Autopilot Disengaged?
6. Turbulence

**CRUISE**

1. VMO exc?
2. MMO exc?
3. Max Alt?
4. Autopilot Disengaged?
5. Turbulence

**DESC.**

1. VMO exc?
2. MMO exc?
3. Flap Speed exc?
4. Extreme Pitch Att?
5. Autopilot Disengaged?
6. Turbulence
7. Rate of Descent

**LANDING**

1. Extreme pitch att?
2. Extreme flare?
3. Landing Δg
4. Runway Δg level
5. Extreme Roll Att?
6. Touchdown Speed
7. RVR
8. Type of Approach
9. Type of Landing
10. Landing Success

**MISC.**

1. Autopilot Malfn.
2. Special Event Code
3. Log Entry
4. Recorder Fault
5. Fifth Engine Pod carried.

Fig.3. CAADRP index sheets printout identification

—CLEAR AIR TURBULENCE
—730— [redacted] —CRUISE-PHASE—PUBLISH—AUTHOR—DECISION— [redacted]

—CLOUD,FLIGHT—IN
—755— [redacted] —CLIMB PHASE—REJECTED— [redacted]
—788— [redacted] —DESCENT—PHASE—PUBLISH—AUTHOR—DECISION— [redacted]

—CROSSWIND LANDINGS,TAKE-OFFS
—746— [redacted] —APPROACH—PHASE—REJECTED— [redacted]
—749— [redacted] —LANDING/GROUND—PHASE—REJECTED— [redacted]

—'D'

—DELAYED—CLIMB,SEE—OPERATIONAL—EVENTS

—DIVERSIONS,SEE OPERATIONAL—EVENTS

—DESCENT—RATE—HIGH
—629— [redacted] —APPROACH—PHASE—REJECTED— [redacted]
—635— [redacted] —DESCENT—PHASE—REJECTED— [redacted]
—644— [redacted] —DESCENT PHASE—FILE—FOR—REFERENCE— [redacted]
—694— [redacted] —DESCENT—PHASE—REJECTED— [redacted]
—709— [redacted] —DESCENT—PHASE—PUBLISH—PANEL—DECISION— [redacted]
—724— [redacted] —APPROACH—PHASE—PUBLISH—PANEL—DECISION— [redacted]
—734— [redacted] —DESCENT—PHASE—PUBLISH—PANEL—DECISION— [redacted]
—787— [redacted] —APPROACH—PHASE—PUBLISH—AUTHOR—DECISION— [redacted]
—820— [redacted] —APPROACH—PHASE—PUBLISH—AUTHOR—DECISION— [redacted]
—821— [redacted] —APPROACH—PHASE—UNDER—DISCUSSION— [redacted]
—822— [redacted] —APPROACH—PHASE—FILE—FOR—REFERENCE— [redacted]
—823— [redacted] —APPROACH—PHASE—UNDER—DISCUSSION— [redacted]

—'E'

—EXCEEDENCES,AIRSPEED,SEE—AIRSPEED

—ENGINE FAILURE,SEE—OPERATIONAL—EVENTS

—ELEVATOR—GEAR—CHANGE—FAULT,SEE—MISCELLANEOUS

—ELEVATOR—OSCILLATIONS,SEE—OSCILLATIONS

—ELEVATOR—USAGE,MANUAL,SEE—CONTROL—USAGE

—'F'

—FAILURES

—- ELECTRICAL
—623— [redacted] —CLIMB—PHASE—REJECTED— [redacted]

—-MECHANICAL
—753— [redacted] —LANDING/GROUND—PHASE—REJECTED— [redacted]

Fig.4. Extract from classified index of special events

SE 821. DATE 28. 8.68. GMT 9999. [redacted]. LONDON HEATHROW TO [redacted].

CONTROL/HANDLING,HIGH RATE OF DESCENT - APPROACH PHASE,4000 TO 1000 FEET. PRESSURE HEIGHT -2400 FT PER MIN. HEADING AND IAS BEHAVIOUR ALSO NOTABLE. NO SUPPORTING MET,NO SUPPORTING LOG ENTRY,ACTION AWAITED,NO DATA ANALYSIS AND NO OTHER SUPPORTING DATA. AGREED RESPONSIBILITY - OPERATIONAL, ENVIRONMENT.
RESPONSIBILITY FOR REPORTING - [redacted]. STATUS - UNDER DISCUSSION.

SE 822. DATE 15. 8.68. GMT 0057. [redacted].

CONTROL/HANDLING,HIGH RATE OF DESCENT - APPROACH PHASE,4000 TO 1000 FEET. PRESSURE HEIGHT -2070 FT PER MIN. PITCH AND HEADING BEHAVIOUR ALSO NOTABLE NO SUPPORTING MET,NO SUPPORTING LOG ENTRY,CREW NOT APPROACHED,NO DATA ANALYSIS AND NO OTHER SUPPORTING DATA. AGREED RESPONSIBILITY - OPERATIONAL, ENVIRONMENT.
RESPONSIBILITY FOR REPORTING - [redacted]. STATUS - FILE FOR REFERENCE.

SE 823. DATE 15. 8.68. GMT 0804. [redacted] TO LONDON HEATHROW.

CONTROL/HANDLING,HIGH RATE OF DESCENT - APPROACH PHASE,4000 TO 1000 FEET. PRESSURE HEIGHT -2130 FT PER MIN,PITCH -10 DEGREES. NO SUPPORTING MET,NO SUPPORTING LOG ENTRY,ACTION AWAITED,NO DATA ANALYSIS AND NO OTHER SUPPORTING DATA. AGREED RESPONSIBILITY - OPERATIONAL,ENVIRONMENT.
RESPONSIBILITY FOR REPORTING - [redacted]. STATUS - UNDER DISCUSSION.

Fig.5. Extract from set of descriptions of one type of special event

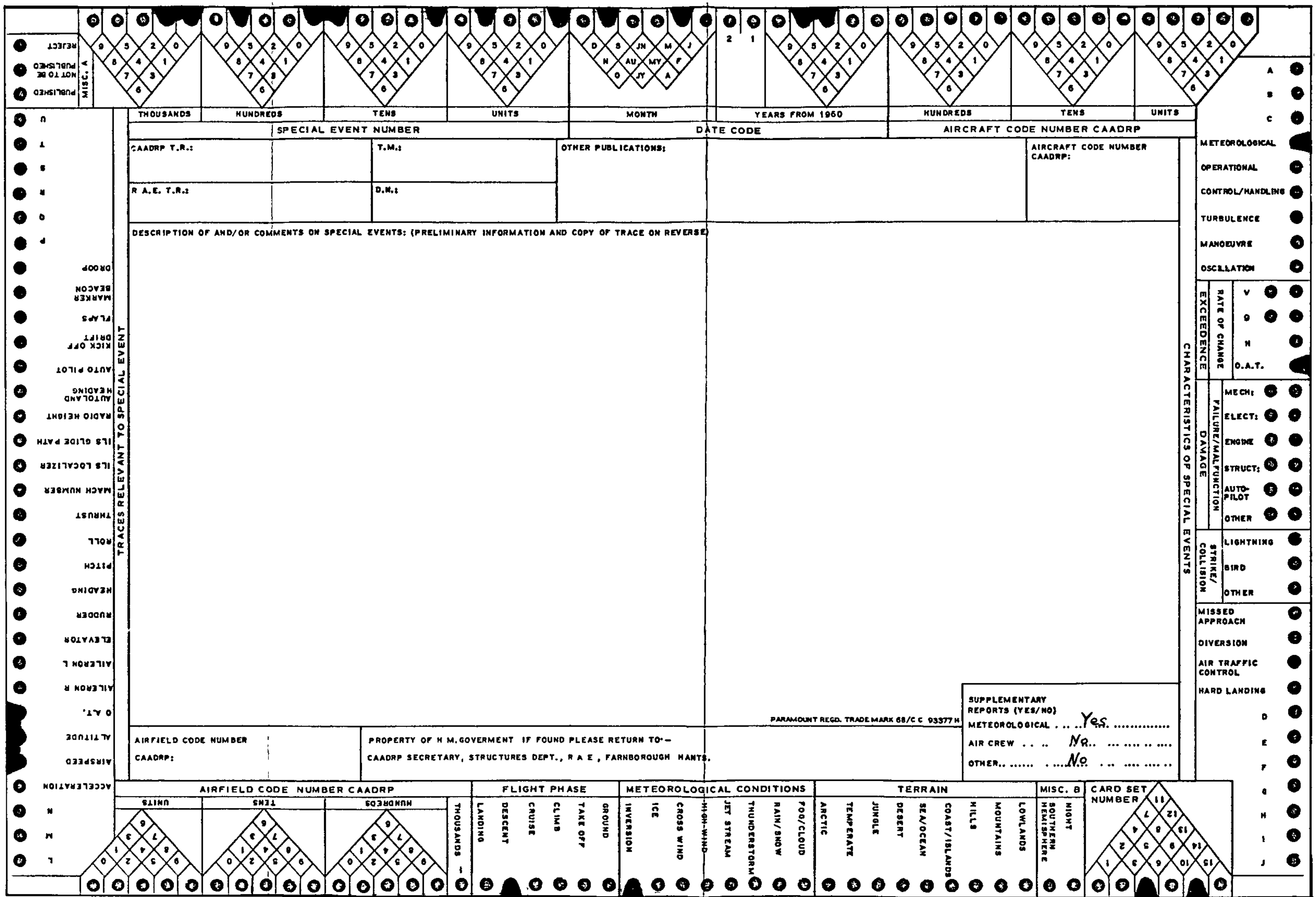


Fig.6. Example of pre-printed face of edge-hole card, actual size

SPECIAL EVENT No. 363

PRELIMINARY:- C.A.A.D.R.P. Analysis Panel Members Only.

Aircraft Roll 140. 790/460. Flight No. 15268 dated 2.7.65. 21.15 - 21.30.

Unusual O.A.T. fluctuation.

ACTION:- met. data.

Data Centre: Calibrate O.A.T., Height, Speed. (Time: 21.18 O.A.T. 6°/2° C. Time: 21.27 O.A.T. 33°/18° C)

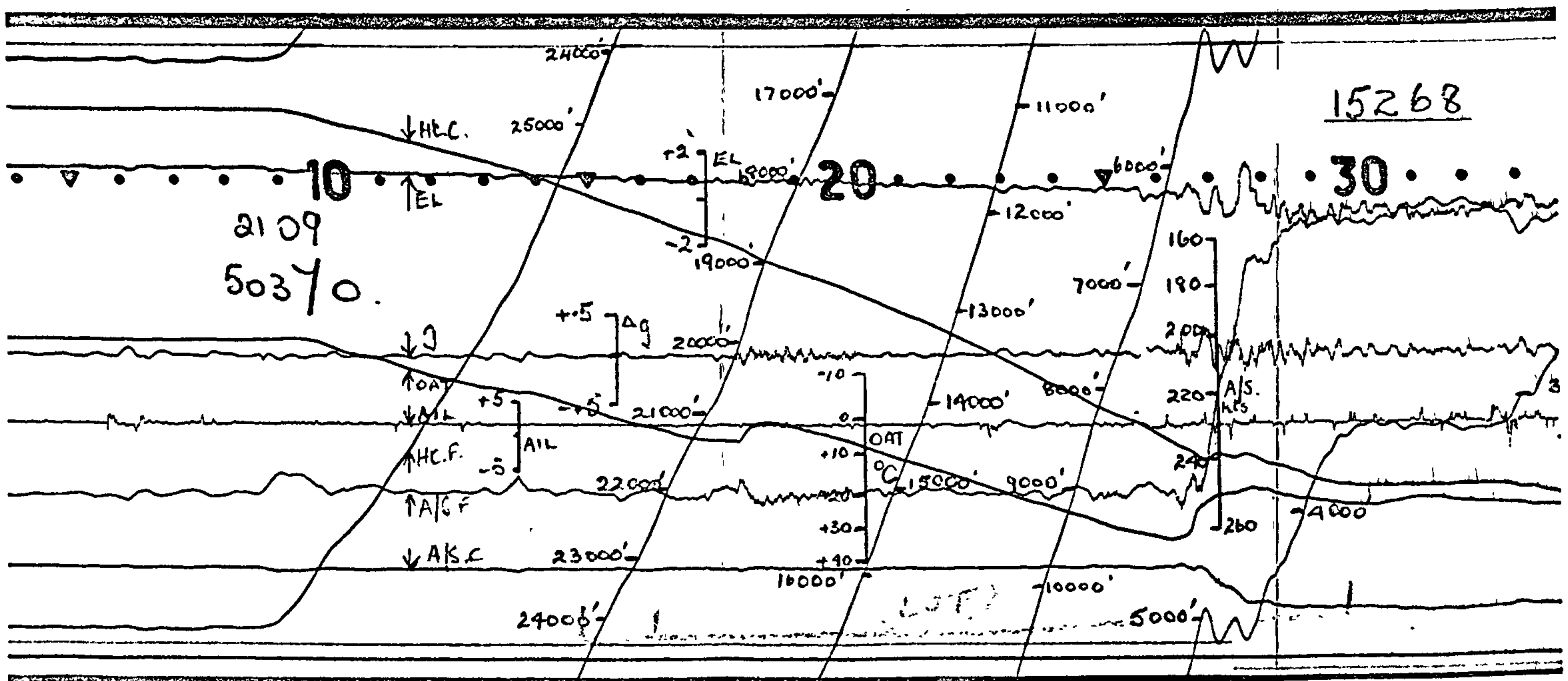


Fig.7. Example of reverse of edge-hole card

*Printed in England for Her Majesty's Stationery Office by the Royal Aircraft Establishment, Farnborough. Dd.502109. K.4.*

# DETACHABLE ABSTRACT CARD

A.R.C. C.P. No.1181 629.13.053.3 :
February 1971 629.13.07

Owen, E. Marjorie

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The success of the programme depended on close co-operation between representatives of ARB, BOAC, BEA, CI Data Centre Ltd , RAE and a number of other organizations. This Report describes briefly the work undertaken and the benefits derived by each organization, and by others using CAADRP data.

(Over)

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(Over)

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