Acoustics Bulletin

October 1989 Volume 14 Number 4

Special Feature

NOISE IN THE AEROSPACE INDUSTRY

INSTITUTE OF ACOUSTICS

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The Institute of Acoustics was formed in 1974 by the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is now the largest organisation in the United Kingdom concerned with acoustics. The present membership is in excess of one thousand and since the beginning of 1977 it is a fully professional Institute.

The Institute has representation in practically all the major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental acoustics, architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration.

DEGREES AND AWARDS IN ACOUSTICS AND RELATED SUBJECTS

ISVR Graduates July 1989

D = Distinction; M = Merit

PhD Sound and Vibration Studies

A R D Curtis
R C Drew
P G Eastwood
N S Ferguson
T Hodges
Ms S P Hough
Mrs H V C Howarth
A Lawther
J-S Lee
Mrs H R Lo
Mrs S M Moss
A M Raper
Miss C Wilcox

MPhil Sound and Vibration Studies

P Peruzzetto

MSc Audiology

E J Brown
Miss V R Hart
Miss C R Horn
Miss C E Mason
N D Partington (*D*)
Mrs J S Samant
M J Walley

MSc Automotive Engine and Vehicle Design Technology

I Fragoulidis
T S Jasper (*D*)
J R Nkondokaya
K Robinson (*D*)
K Sadr-Salek

MSc Sound and Vibration Studies

C A A Nassar
J-B D Carpentier
W W-P Fong
Miss P M Joplin (*D*)
K K Li
D I Oeters
H S Sparkes
T J Sutton (*D*)
J M Terry (*D*)

Diploma of the University of Southampton

Zulfian

MEng (Hons) Engineering Acoustics and Vibration

R I Adnitt (*M*)
D C Anderson (*M*)
K G Hamson (*M*)

BEng (Hons) Engineering Acoustics and Vibration

First Class	N Hogwood
Second Class (Upper)	Miss S P Boyle
	D P Clarke
	D M Greaves
	M H D Santer
	M C M Wright
Second Class (Lower)	Miss C E Herbert
	M R Herzig
	S J Marvin
	D R Moore
	B J O'Neill
Third Class	S R Hancock
	M S Pascall
	Miss S C Thomas

Prizes 1988/89

MSc

Wessex Audiology Prize	Miss L S Bradley-Smith
Sir Harry Ricardo Prize	S N Roberts
E J Richards Prize	Y K Koh

BEng

Institute of Acoustics Prize Part I	A D L Phelps
Institute of Acoustics Prize Part II	M T Beeston
	S M Okotie
Institute of Acoustics Prize Part III	N Hogwood
	M H D Santer

MEng

Richard Newitt Prize	K G Hamson
R M Douglas Construction Ltd Prize	D C Anderson

University of Salford Graduates June 1989

Department of Applied Acoustics

BEng (Hons) in Electroacoustics

AEOF 3

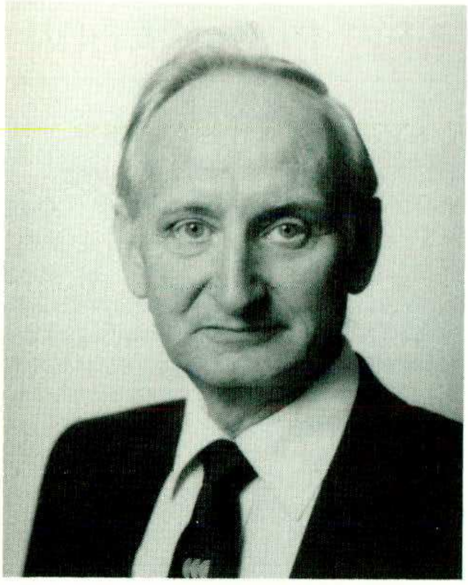
S L Ash	2nd Class (Div. two)
G W Crooks	3rd Class
C W Dilworth	1st Class
I E Etchells	2nd Class (Div. two)
W P Francis	2nd Class (Div. one)
R M Howe	1st Class
C R Kimberley	3rd Class
T P Levi	3rd Class
D M Redgrave	3rd Class
S J Shilton	2nd Class (Div. two)
P A Taylor	2nd Class (Div. one)
N J Watson	2nd Class (Div. two)

AEOF 4

S G Angliss	2nd Class (Div. one)
A H Duncan	1st Class
P Hanes	2nd Class (Div. one)
R A McNab	2nd Class (Div. one)
A E Nicol	2nd Class (Div. one)
D R Philip	2nd Class (Div. one)
A Shadbolt	1st Class
S A Watkins	2nd Class (Div. one)
B A Wilkins	1st Class
R M Windle	1st Class
P Wright	1st Class

Final Year Prize

A Shadbolt



President's Letter

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Dear Fellow Member,

As you will all by now have noticed, the Institute has severed its longstanding connection with Chambers Street in Edinburgh. No longer do we climb the numerous stairs and walk the resonant corridors which led us to our Headquarters.

When the lease of our premises finally expired in June, Cathy Mackenzie moved the IOA to St Albans where, after a period of reorganization and change, she has re-established business as usual. We are all hoping that the move south will prove beneficial to all our activities, and on your behalf I would like to thank Cathy for all the efforts she went to in effecting the move. Change, however, always has its sad moments and I cannot let this opportunity pass without also thanking the loyal Edinburgh staff who served Cathy and the Institute so well for so long; we are all sorry to have to part company with them. Let us wish the new Headquarters every success and give our backing, not only to Cathy but also to Roy Lawrence who, often without due thanks and appreciation, also devotes so much of his time to running our affairs.

There is still time to send in nominations for the 1989 Simon Alport Prize. The Prize of £250 is awarded annually by Cirrus Research Ltd to the young person or persons who, in the opinion of the judges, has published the best paper describing work involving the use of computers in acoustics. The sponsors have recently agreed that the age of recipients shall be changed to 30 years and under. Submissions should be sent to Cathy Mackenzie at St Albans.

May I remind you that we are just starting a new series of Meetings, including the Windermere Conferences. Meetings Committee has arranged a varied programme which should appeal to most of our members. Please try and attend at least one meeting before Christmas, and in addition help to publicize our activities by encouraging your colleagues and staff to attend. The revenue obtained from meetings is vital for our financial survival.

Chris Rice

Book Review

Verminderung des Verkehrslarms (Reduction of Traffic Noise)
Bela Buna and S Ullrich
Published by Springer-Verlag, 1988; £27.50, ISBN 3-540-16867-2

This book by Dr Bela Buna, Head of the Environment Department of the Transport Research Institute in Budapest, is published in collaboration with Dr S Ullrich, of the Environment Department in the German Federal Institute for Highways. Dr Buna's Institute carries out research on reducing noise and pollution not only from vehicles produced in eastern Europe, but also under contract for West Germany. This is reflected in the scope of the book, the greater part of which deals with the theory and practice of reducing noise at source. By avoiding non-essential mathematical presentations and concentrating instead on very clear explanatory diagrams and figures, the authors enable the sources of noise and methods of reduction to be more easily appreciated by the non-specialist in this field. Although most of the book deals with lorries and cars, there is also a useful section on railway noise covering both propulsion units and track generated noise, and a rather less comprehensive section on aircraft and helicopters. The propagation of noise from highways, and methods of reducing transportation noise by road design, noise barriers and planting are covered and again are well and clearly illustrated.

The book provides a very useful and up to date survey of causes and cures for traffic noise but is perhaps too ambitious in including aircraft noise which is really a separate subject requiring different treatment. The space saved could have been used to expand the sections on legislation as well as on emission and environmental standards and guidelines in different countries. One apparent disadvantage of the book from the British point of view is that at present it is only available either in German or in Hungarian. However with even a limited knowledge of German (or Hungarian!) the tables, figures and diagrams would provide useful reference material as well as giving an overview of current work on transportation noise in Europe.

G H Vulkan

NEW PUBLICATION

BRE INFORMATION PAPER

IP12/89 The insulation of dwellings against external noise

W A Utley and J W Sargent

This paper provides data on the noise reduction achieved in dwellings exposed to road traffic noise. The dwellings were fitted with a range of types of window, including single casements, replacement thermal double glazing, and double windows formed by adding a secondary inner pane. It also considers methods of meeting ventilation requirements.

Engineering Division

The forms etc for those who wish to proceed to Chartered Engineer status through the Institute's route are now available. The Chairman of the Engineering Division, Professor Peter Lord, is currently circulating information to all members who have requested details. Any other members interested should contact Cathy Mackenzie initially, at The Institute of Acoustics, PO Box 320, St Albans, Herts AL1 1PZ. Tel: 0727 48195.

Noise in the Aerospace Industry

The following papers were presented at a meeting of the London Branch of the Institute of Acoustics held at British Aerospace Dynamics Group at Hatfield in May 1988. The aim is to present an overview of the acoustic activities carried out over the various divisions of the company. It is not possible, within these few papers, to give complete coverage to the diverse acoustic activities within the company and those covered are perhaps the more obvious or unusual ones.

For example, aircraft noise is possibly the most obvious acoustic topic associated with aerospace and this is covered first with a description of the overflight noise certification procedures adopted for new aircraft types. Still with civil aircraft, the research programmes examining cabin noise resulting from the use of prop-fan propulsion are reviewed and the new cabin noise transmission loss rig and modelling techniques are described.

The large, relatively flimsy, constructions required for operation in outer space must necessarily endure a harsh launch environment for a short period. These structures must be examined and proved satisfactory under simulated launch conditions on the ground. The third paper then examines two particular problems that have arisen and subsequently been overcome by design modifications.

Also associated with the simulation of the operational environment, the last paper here looks at the reproduction of boundary layer induced vibration on high performance aircraft by the use of high intensity noise. This method, combined with temperature and mechanical vibration, is now commonly used to apply flight sortie conditions to aircraft carried weapons. In the particular application discussed, this provides an economical method of establishing the equipment performance and reliability under service conditions.

In addition to the specific acoustic activities mentioned there are a number of other fields covered within the group of companies. These range from the measurement of sound power generated by equipments, through underwater acoustics to research into the acoustic fatigue of advanced materials under various temperature conditions. It is hoped that the meeting provided a short insight into some of these activities.

Derek Sims
British Aerospace (Dynamics) Ltd

Noise Certification of the BAe 146 and ATP

A K Mortlock
Civil Aircraft Division

Introduction

The most recent civil aircraft produced by British Aerospace include the following:

(a) 146–200 – an 85 to 100 seat jet feeder aircraft;
(b) 125–800 – a 6 to 8 seat business jet;
(c) ATP – a 64 to 72 seat heavy propeller-driven regional aircraft;
(d) Jetstream 31 – a 17 to 19 seat light propeller-driven commuter aircraft.

The above aircraft have had to comply with the most stringent noise regulations of British Civil Airworthiness Requirements BCAR Section N (equivalent to ICAO Annex 16) and Federal Aviation Regulations FAR Part 36.

This paper gives an insight into the planning, test conduction, data acquisition and subsequent analysis of the noise data to demonstrate compliance of the BAe 146 and ATP with the above noise regulations.

Finally the noise levels demonstrated by the BAe 146 and ATP are compared with the noise requirement levels and the noise levels of other aircraft in their respective categories.

Noise certification requirements

Noise certification requirements evolved in the late 1960s to provide a method whereby the acoustic technology standard for an aircraft configuration could be evaluated from flyover noise measurements corrected to specific reference conditions. The noise certification test does not necessarily produce a measure of airport noise performance, as the certification measurement points are specified whereas individual airports have unique requirements for noise abatement in the surrounding communities. However the noise certification regulations provide 'bench marks' against which the relative performance of each aircraft type can be assessed.

The noise certification requirements for civil aircraft are given in FAR Part 36[1] and ICAO Annex 16.[2] The United Kingdom noise regulations BCAR Section N[3] is generally accepted as equivalent to ICAO Annex 16. Since 1977 a more stringent noise certification requirement has been in force applicable to new aircraft designs. Up to 1977 the noise regulations differed in the USA compared with ICAO. However, the latest requirements are now basically the same and are referred to as Stage 3 noise requirements in the USA and Chapter 3 noise requirements within ICAO.

The noise limits required to be met by an individual aircraft type are based on the maximum certificated take-off weight and in the case of take-off (flyover) the number of engines are also taken into account. The increase in the noise limits with maximum take-off weight represents the major difference between regulatory and airport noise acceptance as the noise perceived around an airport is purely based on noise level. Examples of determining the noise limits for the BAe 146-200 and ATP are given in Figures 1, 2 and 3 for the three noise certification measurement points of sideline, take-off and approach.

The metric used for noise certification is the effective perceived noise level (EPNL) which is measured in EPNdB. EPNL is weighted for the following aspects:

- annoyance perceived by the ear;
- tonal content in the flyover noise spectra;
- duration for the time the aircraft remains within 10 dB of the peak noise at the microphone.

The EPNdB term can be written as follows:

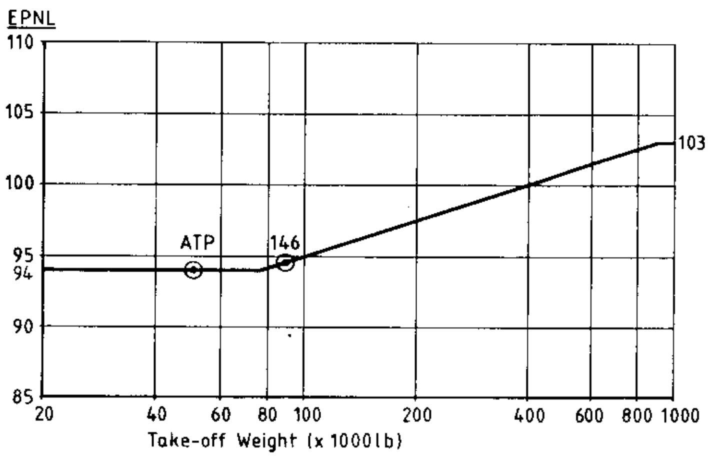

Fig. 1. Stage 3/Chapter 3, Noise certification limits: Sideline (lateral)

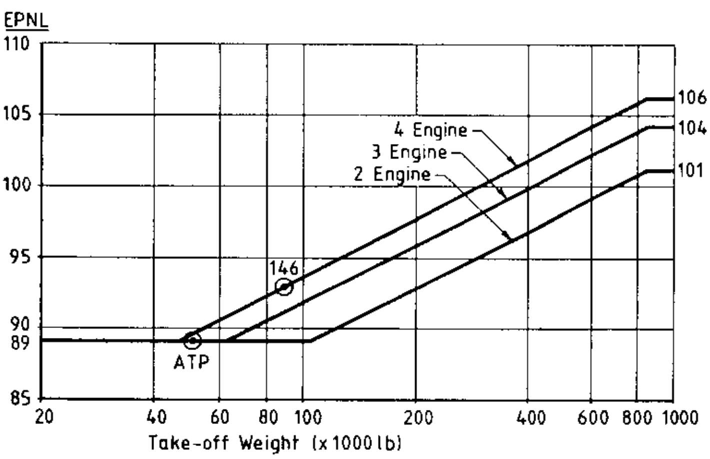

Fig. 2. Stage 3/Chapter 3, Noise certification limits: Take-off (flyover)

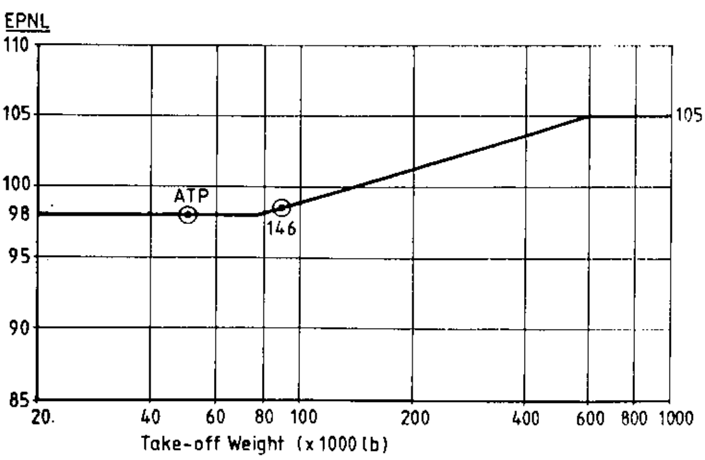

Fig. 3. Stage 3/Chapter 3, Noise certification limits: Approach

$$\text{EPNdB} = \text{peak PNdB} + \text{Tone correction} + \text{Duration correction}$$

The constituent parts of calculating EPNdB are illustrated in Figure 4.

There is also a trade-off rule allowed in the regulations such that a noise limit can be exceeded by up to 2 EPNdB at any given point with a total of 3 EPNdB exceedance, provided the exceedances are offset by corresponding reductions at the other point or points.

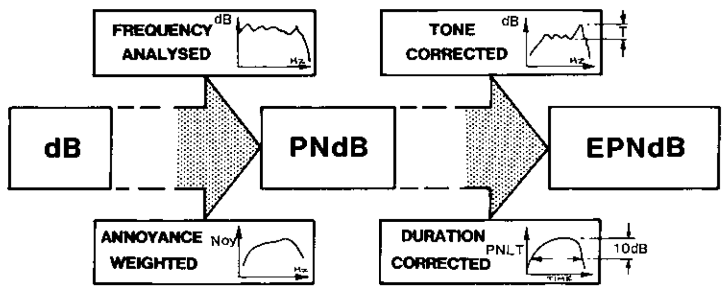

Fig. 4. Noise certification units

Reference noise measurement positions

The reference noise certification measurement points for the BAe 146 and ATP aircraft address three phases of operation namely:

(a) *Sideline*
The determination, during take-off, of the peak noise received at a point along a line parallel to and 450 m (1476 ft) from the extended runway centreline;

(b) *Take-off*
The noise received at a point directly beneath the aircraft take-off flight path and positioned 6.5 km (21325 ft) from brakes release; and

(c) *Approach*
The noise received at a point directly beneath a 3 degree glideslope and positioned 2000 m (6562 ft) from the runway threshold.

The above reference noise measurement points are shown in Figure 5.

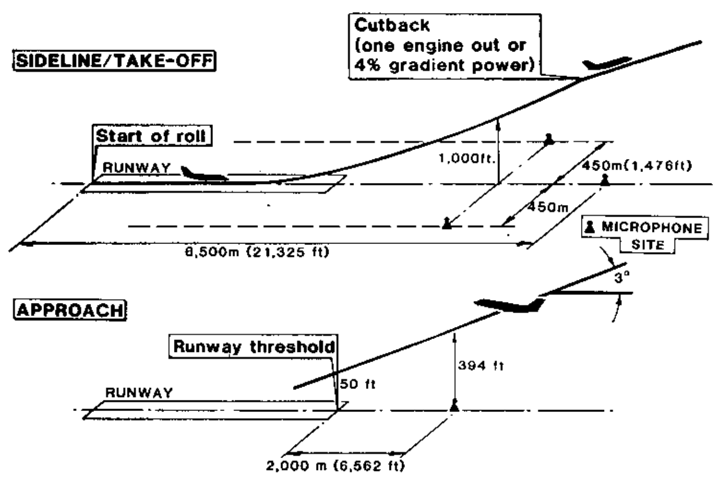

Fig. 5. Reference noise certification positions

Test environment

There are many factors that affect the choice of a noise site so that the test programme can be completed in a timely manner. The following meteorological, topographical and environmental considerations have to be addressed:

Meteorological

- Temperature test window between 2 °C and 35 °C from the microphone to aircraft.
- Relative humidity test window between 20% and 95% from the microphone to aircraft.
- Sound attenuation rates in air not exceeding 14 dB/100 m in 8 kHz one-third octave band.
- No precipitation.
- Average wind speed no greater than 12 kt and crosswind not greater than 7 kt measured at 10 m above ground level.

Topographical

- Flat terrain required having no excessive sound absorption characteristics (e.g. tall grass, shrubs, woods etc.)
- No obstructions which could significantly influence the sound field from the aircraft to the microphone (e.g. buildings, earth banks, pylons and posts etc.)
- Avoid close proximity to rivers and ditches etc.

Environmental

- No excessive ambient noise from highways, other aircraft, agricultural machinery etc.
- Community noise problems associated with low flying test aircraft.

As mentioned above, there are many factors which can inhibit a test run. Therefore in general due to the inclement English weather a test site is chosen abroad (e.g. Granada, Spain and Casablanca, Morocco).

Test aircraft

The BAe 146 Series 200 test aircraft was powered by four AVCO-Lycoming ALF 502-3 turbo-fan engines (Figure 6). The BAe ATP test aircraft was powered by two Pratt and Whitney Canada PW126 turbo-prop engines (Figure 7). Each PW126 engine drove a BAe/Hamilton Standard six-bladed propeller.

Test programme

Over the past 20 years the noise certification flight demonstration method has been developed by using equivalent procedures which maintain the intent of the test without degrading data quality or accuracy. The BAe 146, certificated 5 years ago, mainly used the older conventional flight demonstration method. The method involved performing at least 6 runs at near reference conditions (e.g. maximum weight, achieving reference height, speed and engine power conditions), which is often referred to as the 'clustered run' method.

The BAe ATP flight demonstration method, completed last year, adopted a method whereby a matrix of noise data was recorded from a sufficient number of test flyovers to form noise–power–distance (NPD) curves.

Fig. 6. BAe 146-200

Fig. 7. BAe ATP

In both of the above methods the test aircraft used the flight path intercept method which enabled the aircraft to continue in a circuit (race track) without requiring to land. Whether performing take-offs or approaches the aircraft was targeted to achieve a certain height above the prime noise site (Figure 8).

In the BAe 146 case the take-off test runs were maintained at high weights (hence some were performed on separate days) in order to demonstrate the reference condition as closely as possible. Take-off weight was less of a concern during the ATP tests as the aircraft was targeted to achieve 1250 ft above the prime noise site for a range of operating conditions. This was achieved by varying the set-up height prior to applying the appropriate power at a specific time forward of the microphone array (Figure 8).

Sideline noise measurement sites

There are two basic methods of demonstrating the position of peak sideline noise. The original method used an array of peak sideline sites positioned parallel to the extended runway

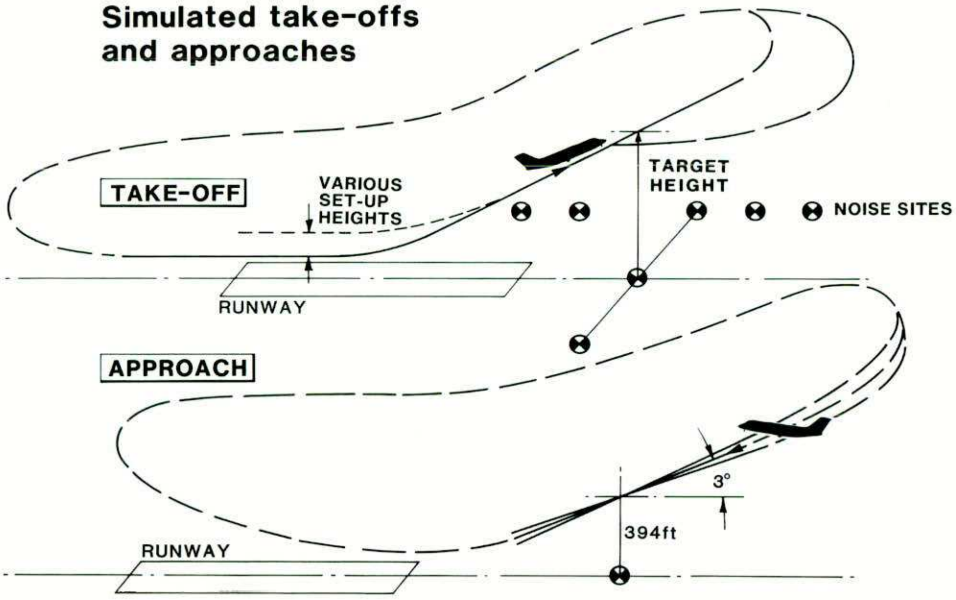

Fig. 8. Aircraft test procedures

centreline and at a normal distance of 1476 ft from the centreline. A further noise site was positioned symmetrically opposite one of the sites in the array as shown in Figure 9. A sufficient number of runs were conducted to determine approximately the position of peak noise from on-site preliminary analysis. Subsequently, at least a further 6 runs were conducted such that the aircraft passed through the symmetrical sideline sites at the aircraft height producing peak sideline noise.

The 146 and ATP peak sideline noise demonstration used only two symmetrical sites positioned 1476 ft from the runway extended centreline and therefore minimized the problem of using an airfield with suitable terrain for multiple sideline sites. This method subsequently reduced manpower costs. Approximately 50 runs at maximum take-off power were conducted on the 146 (20 runs on the ATP) passing the aircraft between the noise sites at various heights (Figure 9). The ATP method reduced the number of test runs required compared with the 146 test during which the regulatory authorities required at least 6 runs at each height. This was eventually shown to be an unnecessary requirement. The noise data base also tends to be more consistent when using the two-site method as site to site effects on noise propagation are minimized.

In both of the above methods the measured noise data were corrected to specific reference conditions and the peak noise levels determined. The correction procedures are described in the section on data correction procedures.

Take-off and approach measurement sites

The take-off and approach sites used during the ATP tests were made common whereas the 146 used the older demonstration method whereby two separate sites were used. One site was positioned under the 3 degree glideslope and another site positioned under the take-off flight path approximately 21,000 ft from the aircraft start of roll position on the runway (Figure 10).

Test data

During each test run for both sideline, take-off and approach, the aircraft instrumentation, tracking and noise recording equipment were synchronized twice, by initial and final countdowns transmitted from the aircraft to the ground tracking and noise sites. Typically data were recorded from the following sources:

- Aircraft height and lateral position measurements based on a photographic scaling technique using three ground based cameras located under the aircraft flight path as shown in Figure 10.
- Ground (10 m) meteorological station recording dry/wet bulb temperatures and wind speed/direction.
- Upper air met. measurements on the test aircraft recording dry bulb and dew point temperatures.
- Aircraft and powerplant performance data including radio height, speed, incidence and engine/propeller source noise parameters.

Noise measurement

The ambient noise and the noise produced by the aircraft were recorded in permanent form at each noise measuring site using the equipment and methods prescribed in References 1 and 2 (see Figure 11 for the ATP noise measurement set-up). At each noise measuring site the microphone was tripod-mounted with the centre of the diaphragm 1.2 m (4 ft) above the local ground surface. Each microphone was oriented so that the diaphragm was approximately at grazing incidence, i.e. was substantially in the plane defined by the flight path of the aircraft and the measuring site.

A ground microphone installation was also used during the ATP tests to check ground reflection effects on noise received at the 1.2 m microphone. A dual channel tape recorder was used so that both microphones could be simultaneously recorded and hence analysed as a function of time.

At each noise measuring site the noise sensing system and recording system were calibrated each day before and after testing. The aircraft noise was recorded throughout each take-off and approach run for a period including both the initial and the final synchronization count-downs transmitted from the test aircraft.

Measured noise data

Each test run was monitored in the field during the noise certification test. The aircraft radio height was used in the field to monitor the achievement of the target heights above the prime site. The CAA witness was consulted after each run to assess the validity of the run regarding the meteorological data, the aircraft/engine performance data, aircraft flight path data and the noise data. A CAA observer was also on board the test aircraft during the test runs to monitor the aircraft/powerplant performance data.

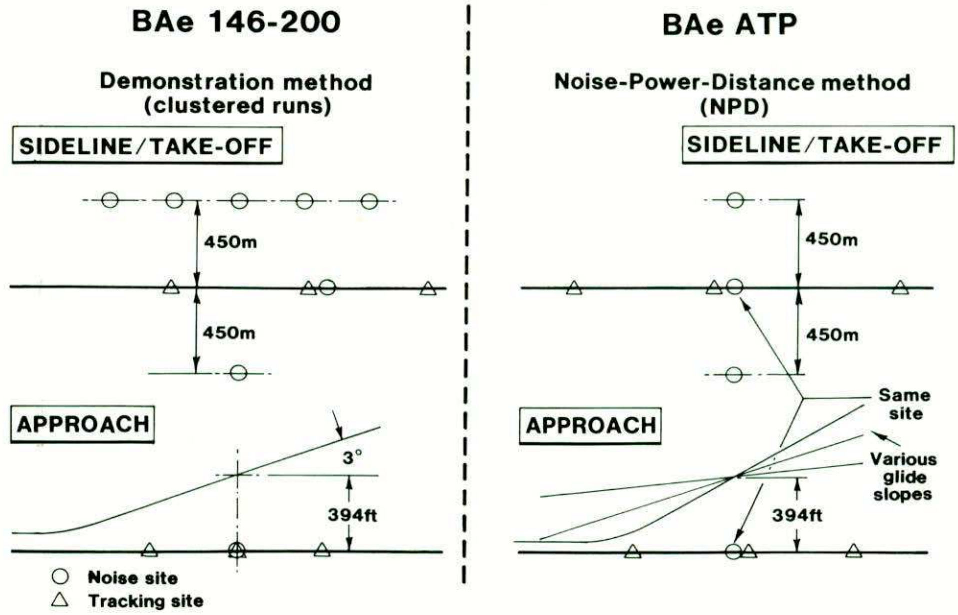

Fig. 10. Typical noise site under flight path

Fig. 9. Noise measurement and tracking sites

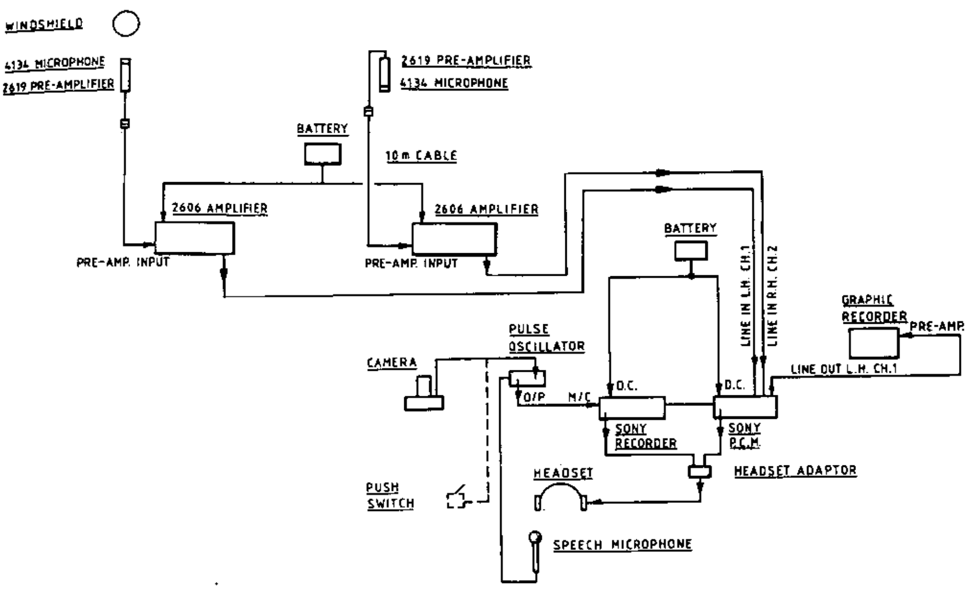

Fig. 11. BAe ATP noise measurement setup

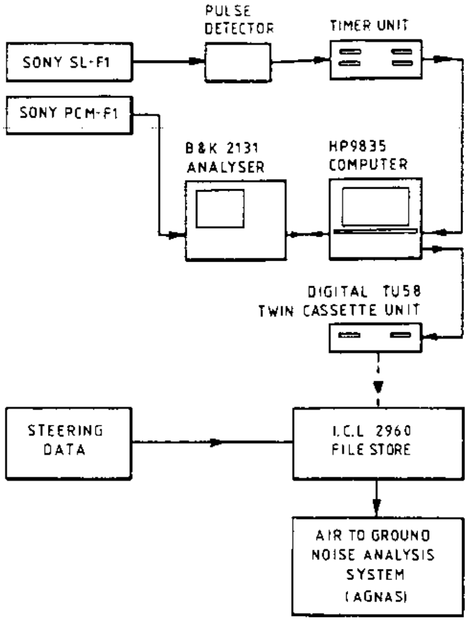

Fig. 12. Noise analysis system

Typical causes of invalid runs included the following:

- Above wind limits
- Large aircraft speed variation (above 6 kt)
- Ambient noise event affecting noise recording
- Failure to record noise event
- Camera failure at prime site
- Target aircraft speed error
- Atmospheric absorption above 14 dB/100 m
- Pilot requested repeat; run conditions unstable
- Aircraft offtrack

For each valid test run, the recorded noise was analysed at 0.5 s intervals into 24 one-third octave band levels, with centre frequencies from 50 Hz to 10,000 Hz, using the prescribed procedures of References 1 and 3 (Figure 12). The digital magnetic tape produced from the noise analyser contained the spectral levels for each noise measurement together with those of the appropriate pink noise calibration and background noise. The spectral data contained on each magnetic tape were input to the computer filestore to be subsequently operated on by the Air-to-Ground Noise Analysis System (AGNAS).

Using the AGNAS, corrections were applied for the total analysis system frequency response, for background noise and for microphone free-field response characteristics. The measured effective perceived noise level, EPNL, for each run was then evaluated using the methods of References 1 and 3.

Data correction procedures

The valid test runs were conducted in atmospheric conditions which, although within the limits defined in References 1 and 3, were not equal to the noise certification reference conditions. Also the test aircraft height and speed were not generally equal to the reference conditions.

The measured effective perceived noise levels (EPNLs) determined by AGNAS were corrected for the differences between test and reference conditions. All of the runs were corrected to sea level, and to a still homogeneous atmosphere having a temperature of 25 °C (77 °F) and a relative humidity of 70%. In general the test atmosphere had higher atmospheric absorption rates than the reference day and therefore the test noise levels were usually increased. Corrections were also made for the difference between measured and reference distances and for the difference between the measured and reference powerplant performance (source noise correction) as follows:

Take-off profile

A certification reference take-off profile was derived for the aircraft operating at its maximum take-off weight in the reference acoustic day conditions, with an appropriate flap setting, maintained constant throughout the climb-out. The aircraft climb speed of V2 + 10 kt was also maintained during the climb-out. The take-off and initial climb were performed using take-off power on all engines and in the case of the ATP a propeller speed of 1200 r.p.m. A cutback manoeuvre was used from a point defined by the spool-down characteristics of the engine (and propeller for the ATP), together with the associated noise history. The engine power and propeller speed were reduced to those required to maintain level flight with one engine inoperative or a 4% gradient whichever was the higher.

Approach profile

The reference approach profile consisted of a 3 degree glideslope passing vertically above the noise measuring site on the extended centreline of the runway, the aircraft being in the final landing configuration of selected landing flap and undercarriage extended. A constant aircraft speed of 1.3 Vs + 10 kt appropriate to the maximum landing weight was used.

Noise level corrections

Each valid test run was corrected to the aircraft operating reference conditions and day conditions described above. The corrected noise level EPNL*, was calculated as follows:

$$EPNL^* = EPNLmeas + \Delta 1 + \Delta 2 + \Delta 3 + \Delta SNC$$

where $\Delta 1$ = a correction for spherical spreading (inverse square law) and for a change in atmospheric absorption rate between the test and reference day conditions over the test to reference acoustic minimum distances or NPD distances.

$\Delta 2$ = a correction to the duration of the noise to account for the change in aircraft minimum distance (or NPD distance) between the test and reference (or NPD) flight paths.

$\Delta 3$ = a correction to the duration of noise to account for the difference between the measured and reference (or NPD) track speed. A further small correction was applied when using the NPD method for the difference between the NPD and reference aircraft track speeds.

ΔSNC = a powerplant source noise correction for the difference between the test and reference powerplant conditions (used only for the 146 method). For the ATP method the corrected noise levels were obtained directly from the NPD curves at the appropriate powerplant conditions.

Noise results

The presentation of the noise results for the 146 and ATP differed due to the methodology adopted in the test and analysis procedures. The development of the peak sideline, take-off and approach noise level is described below.

Sideline noise data

The average of the corrected sideline noise data (determined from the port and starboard noise sites) for each test run was plotted against the aircraft opposite height (Figure 13). In the case of the 146 test at least 6 runs were performed at various heights, including 8 runs from the take-off demonstration test. These 8 runs were subsequently corrected and checked with the peak noise determined from the curve of sideline noise versus aircraft height. A total of 50 runs were finally used, which ended up as an overkill situation.

The ATP method simply plotted the corrected average noise levels from the symmetrical sites against aircraft opposite height (Figure 13) and determined the peak noise from the equation of the average line. Only 20 runs were found necessary to define the sideline noise curve.

Of particular interest: the noise propagation of a single stage propeller driven aircraft is not symmetrical about the flight track. The simple rule to determine which side is noisier is to consider the propeller as a corkscrew i.e. 'right hand screw peaks to port and left hand screw peaks to starboard'.

Take-off noise data

The take-off noise certification level was determined for the 146 by the average of 12 fully corrected demonstration runs clustered close to the take-off reference conditions (Figure 14). The corrected noise levels from additional runs at various engine powers were also plotted to determine the source noise slope.

In the ATP noise analysis the corrected noise data were plotted in the form of a NPD carpet for three fixed ranges (Figure 14). The two noise correlation parameters Mh and SHP/delta were plotted against EPNL* for distances of 1200 ft, 1500 ft and 1800 ft.

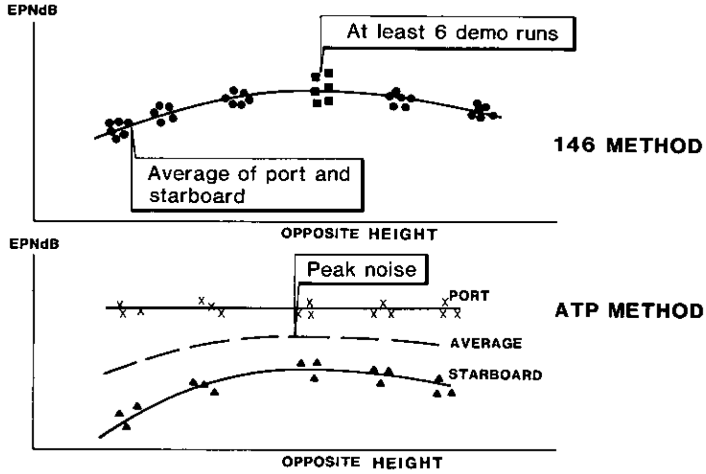

Fig. 13. Sideline noise data at maximum take-off power

The take-off noise certification level was determined from the plots, by interpolation, at the reference distance for the maximum take-off weight condition and applying an adjustment for any difference between the NPD and reference aircraft track speed $\Delta EPNL = 10\log \frac{Vnpd}{Vref}$

Approach noise data

The 146 and ATP corrected approach noise data were plotted in a similar manner as described for the take-off condition above. In both methods shown in Figure 15 the noise data were corrected to an overhead distance of 394 ft and the approach noise certification level was determined from the plot by interpolation at the reference SHP/delta and Mh and applying a small adjustment for the differences between the NPD and reference aircraft track speeds as above.

Presentation of noise certification levels

An example of determining the final noise certification levels and 90 per cent confidence intervals for the ATP (using the NPD method) is shown in Figure 16. In the case of the 146 the 90 per cent confidence intervals were determined for the average of the clustered demonstration runs whereas the ATP 90 per cent confidence intervals were determined about a mean line at the appropriate powerplant condition. The 90 per cent confidence intervals were calculated to show compliance with a ±1.5 EPNdB tolerance required by the noise certification rules.

The 146 and ATP noise certification levels for sideline, take-off and approach are compared with the noise limits in

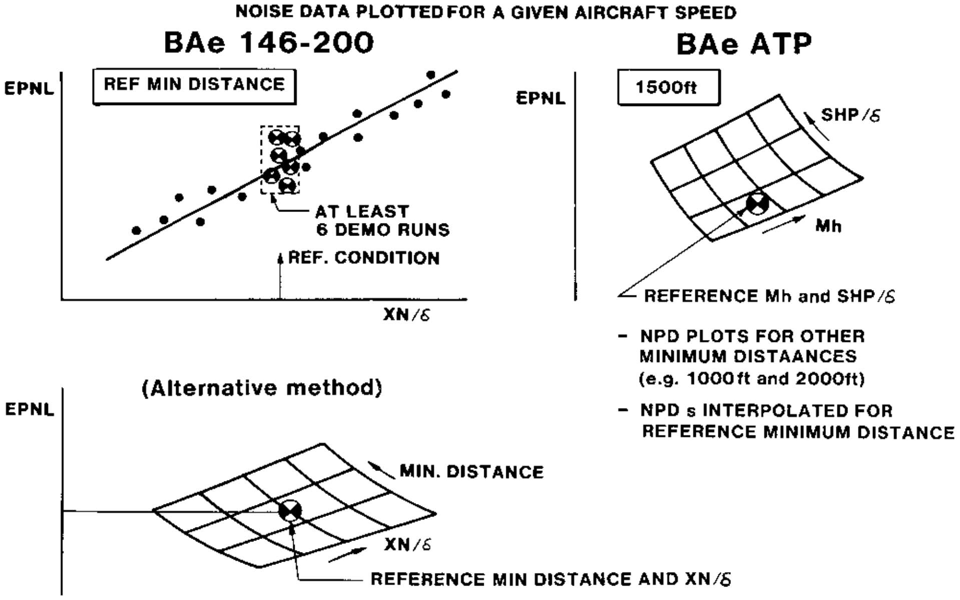

Fig. 14. Take-off noise data

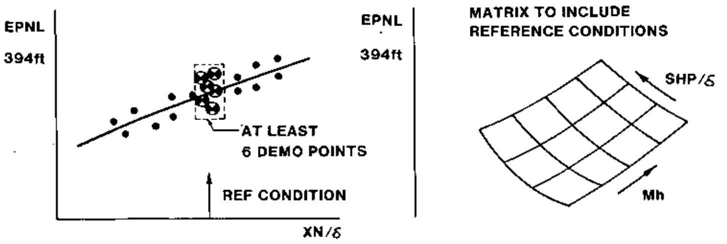

Fig. 15. Approach noise data (plotted for a given flap setting and aircraft speed)

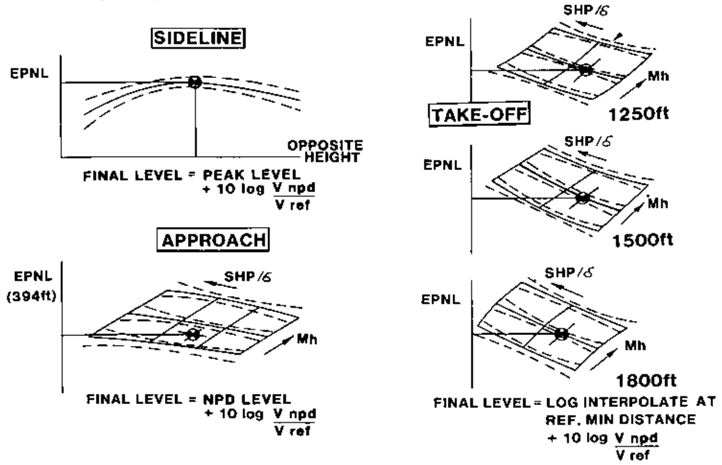

Fig. 16. BAe ATP: final noise certification levels and 90 per cent confidence intervals

Figures 17, 18 and 19. Both aircraft better the noise limits by handsome margins. The 146 surpassed the limits by a total of 17.9 EPNdB and the ATP by 25.9 EPNdB.

Noise comparison with other aircraft

To demonstrate the low noise characteristics of the 146 and ATP a comparison is made with other aircraft in the same category at sideline, take-off and approach (Figures 20 and 21 for the 146 and ATP respectively). The other aircraft include current and older technology types.

As indicated the current aircraft are significantly quieter than their predecessors and the BAe 146 and ATP are favourably placed to be considered as 'super quiet' in their aircraft category.

References

1 *Federal Aviation Regulations (FAR)* Part 36, Noise Standards: Aircraft Type and Airworthiness Certification – Amendment 13, 11 August 1981.
2 *International Standards and Recommended Practices* – Environmental Protection Annex 16 to the Convention on International Civil Aviation Volume 1 – *Aircraft Noise*, First Edition, 1981.
3 *British Civil Airworthiness Requirements (BCAR)* CAP 469, Section N, Noise, Issue 4 – 1 January 1988.

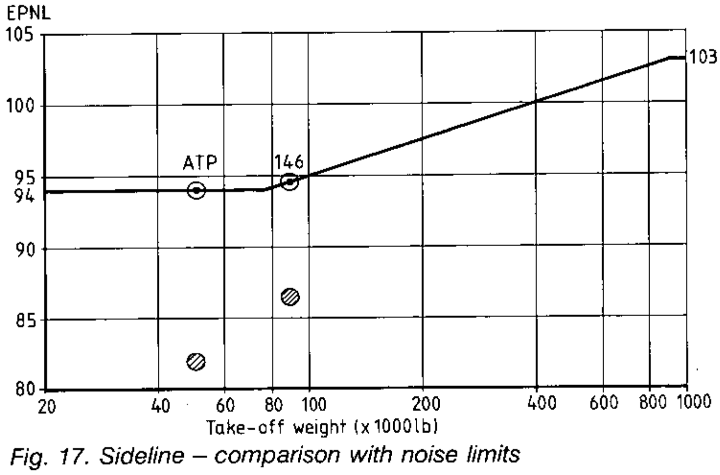

Fig. 17. Sideline – comparison with noise limits

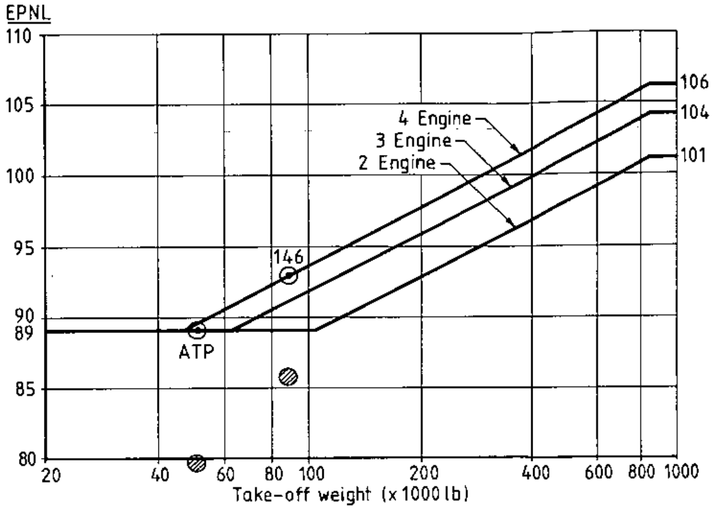

Fig. 18. Take-off – comparison with noise limits

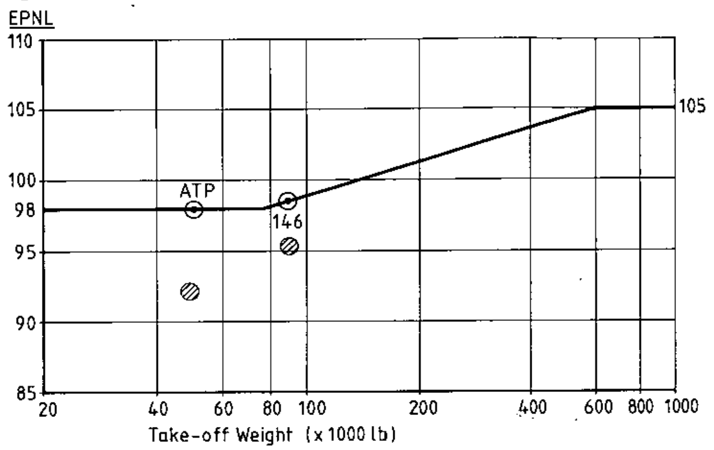

Fig. 19. Approach – comparison with noise limits

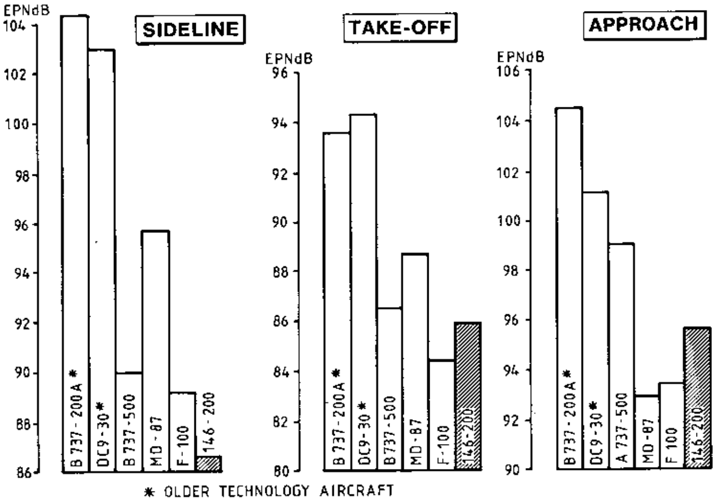

Fig. 20. BAe 146-200: noise comparison with other aircraft

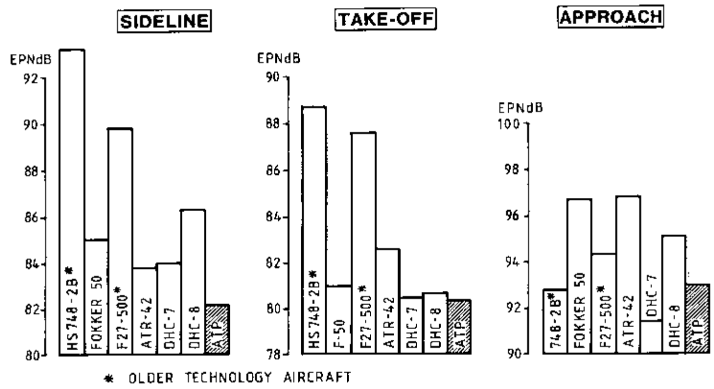

Fig. 21. ATP: noise comparison with other aircraft

Open Rotor Noise Research for Civil Aircraft

S Rogers
Civil Aircraft Division

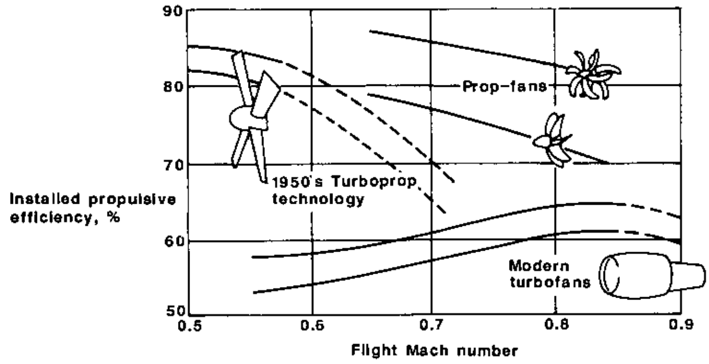

Fig. 1. Evolution of powerplant efficiency

Introduction

The current resurgence of interest in propellers can be traced to the constant search for lower operating costs coupled with the increasing cost of fuel. It was in the late 1950s that the first jet airliners entered service. Compared with the then current turboprops, they offered the great advantage of higher speeds and increased passenger comfort; as the cost of fuel was low, the lower propulsive efficiencies (Figure 1) were accepted. Since then, improvements in aircraft and engine design, including the adoption of high bypass ratio engines, has resulted in large increases in fuel efficiency (Figure 2). It was the fuel crisis of the late 1970s (Figure 3) which spurred the pace of research and encouraged the development of advanced open rotors (or propfans). These offer the potential for maintaining the high propulsive efficiencies at the flight speeds necessary if they are to be considered as replacements for current turbofan power. Among the propulsion options (Figure 4) are wing mounted tractor propellers and rear fuselage mounted pushers. Unlike the early propellers which generally had no more than 4 straight blades, the new designs have a large number of blades (up to 12) which, certainly for the higher aircraft speeds (above M = 0.7), will be swept. Many of the designs embody contra rotation, which results in improved efficiency (relative to single rotation).

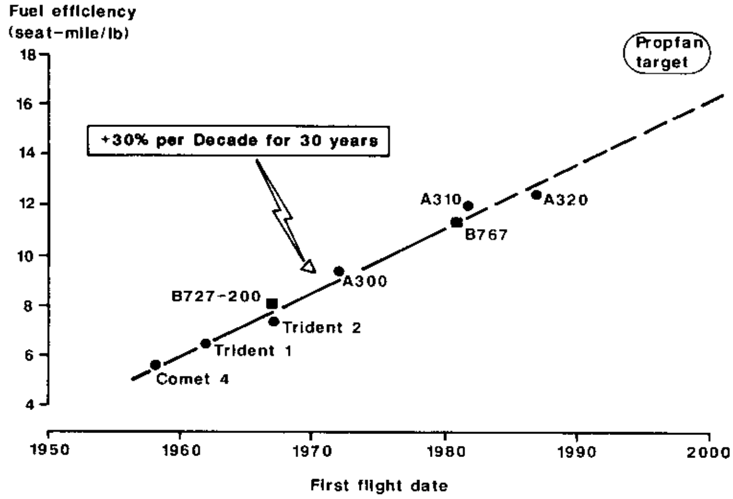

Fig. 2. Trends in fuel efficiency with time for medium range airliners

The need for noise research

Propellers have remained dominant on the short range aircraft where their operating economics are attractive and the higher cabin noise levels (Figure 5) are acceptable because of the short sector lengths. If the advanced propellers are to replace turbofans then the passengers will expect interior noise and vibration levels to be as low as those in present-day jets. In jet powered aircraft, except at the rear of rear-engined aircraft, the major cabin noise source is the external turbulent boundary layer. This high frequency broadband source is well attenuated by the existing sidewall treatment. A typical sidewall cross section is shown in Figure 6. Propellers produce intense low frequency noise at the blade passage frequency (rpm × number of blades) and its harmonics. There has been considerable deliberation about the best way of relating equivalent comfort levels between these two very different noise sources. Traditionally, cabin noise has been expressed in one or more of the following – Overall sound pressure level (OASPL), Speech interference level (SIL) or A weighted overall level (dBA). OASPL tends to be dominated by the lower

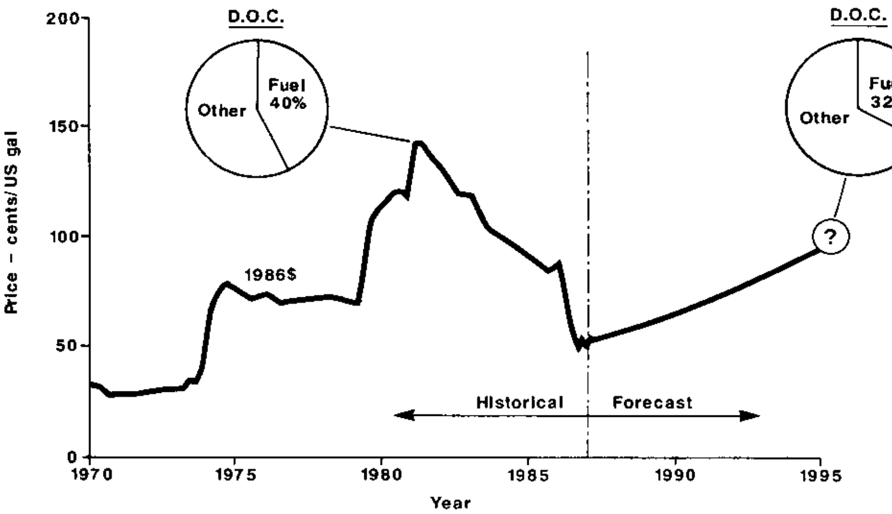

Fig. 3. Jet fuel price

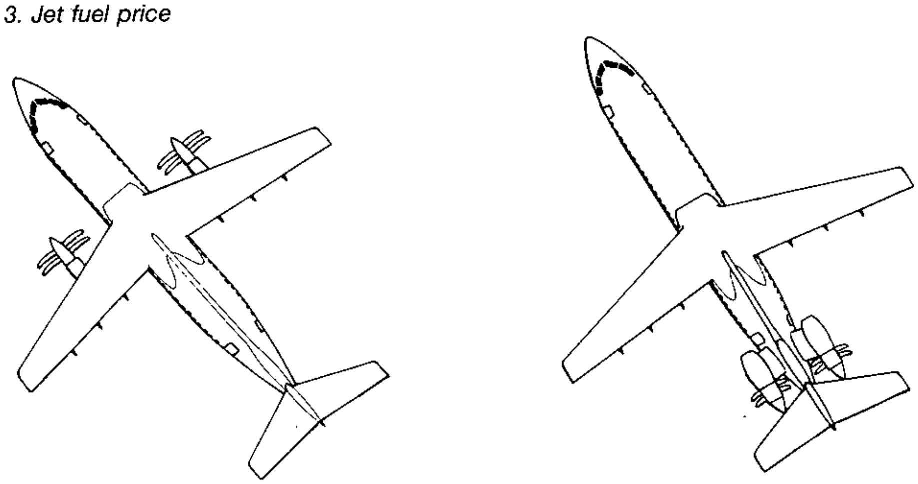

Fig. 4. New propulsion options for mid-1990s: left, wing-mounted geared tractor contra-rotating propellers; right, fuselage-mounted unducted fan

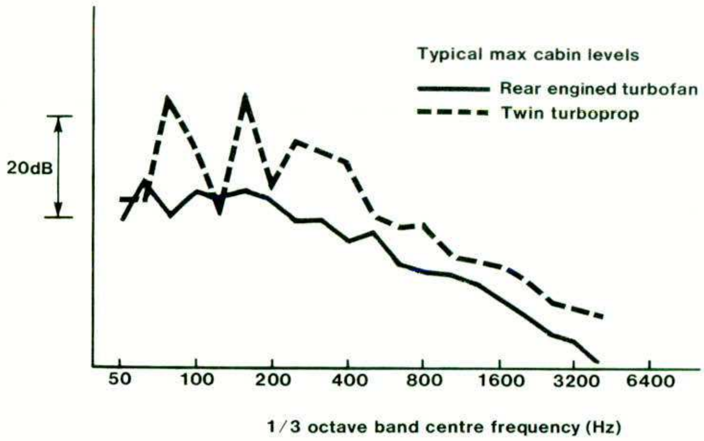

Fig. 5. Comparison of turbofan and turboprop interior noise levels: ———, rear engined turbofan; - - - - -, twin turboprop

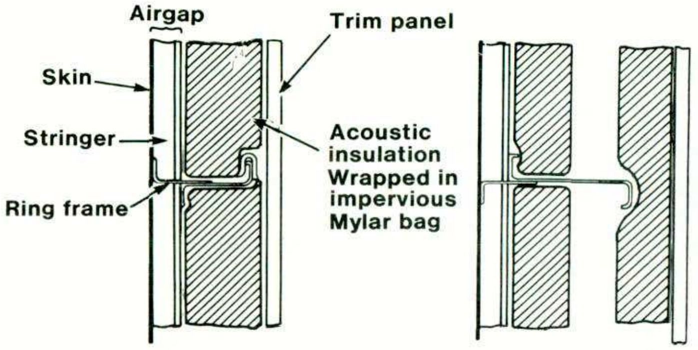

Fig. 6. Typical sidewall installations: left, between-frame blanket system; right, between-frame/overframe system

frequencies while SIL describes high frequency noise. The general consensus is to use dBA to relate the comfort levels although there is some evidence that because of the weighting, dBA underestimates the annoyance of intense low frequency tones.

Figure 7 shows the relationship between cabin noise in conventional propeller aircraft and those with advanced propellers. Higher flight speeds and greater blade loadings increase source noise, whereas careful propeller and airframe design can redress the balance. On an aircraft designed to cruise at M 0.65–M 0.7 additional noise reductions of about 12 dBA will be needed compared with existing designs, if acceptable comfort levels are to be achieved. Because of the low frequency nature of propeller noise, such gains are not easily achievable and so account for the large amount of noise research which is currently under way. It is generally accepted that maximum cabin noise levels of 75–80 dBA will be necessary.

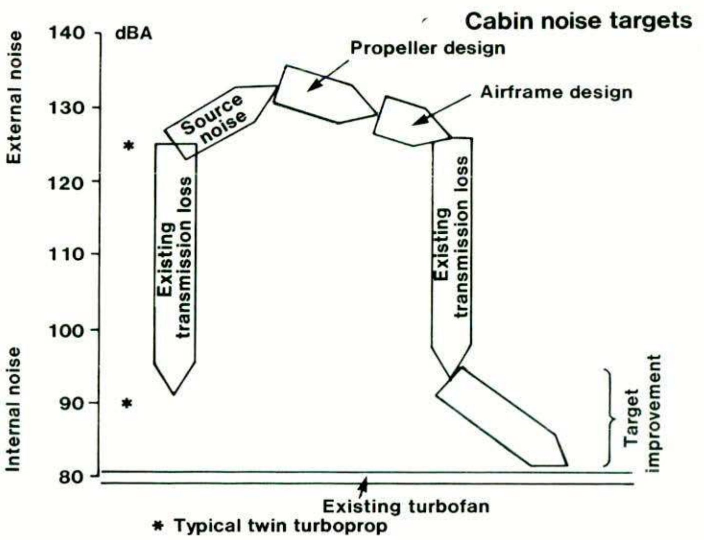

Fig. 7. Joint open rotor technology demonstrator programme. Noise reduction parameters: tip speed and clearance; blade loading and number; sweep; synchrophasing

As flight speeds increase, the problem is magnified. For aircraft with design cruise speeds between M 0.75 and M 0.80, it is acknowledged that it will be very difficult to achieve acceptable cabin noise using wing mounted propellers and most designs in this speed range have concentrated on rear mounted engines, thus taking the propellers away from the passenger cabin.

Although the major issue with advanced propellers is related to cabin noise, the certification requirements covering take off and landing noise must be met.

The American Federal Aviation Administration (FAA) have raised the question of 'en-route noise'. This is noise experienced on the ground during cruising flight. Initial indications from the demonstrator aircraft are that levels are within the range of turbofan noise and should not present a problem.

Research in the United States

The majority of the current advanced propeller research is being carried out in the United States and all the major airframe and engine manufacturers as well as NASA and other research organizations have large research programmes.

The noise research falls into two separate areas: firstly the design of the powerplant with noise as a prime design criterion, and secondly, engine installation and the design of fuselage treatments in order to produce acceptable cabin noise levels.

Currently there are three powerplants undergoing flight testing (Figure 8). The first into the air was the General Electric Unducted Fan (UDF). The UDF employs contra-rotating rotors driven directly by the engine turbines, with no gearbox involved. Initial flight tests[1] were carried out with a propulsor with 8 blades in each row; a modified version with 10 blades in the front row and 8 in the rear has also flown. The 10 + 8 is 2–3 dB quieter than the 8 + 8. On community noise, the production UDF is expected to be 5 dB quieter than the 10 + 8 bladed prototype. The design of the UDF means that it is best suited to aft fuselage mounting.

The second major engine is the Pratt and Whitney–Allison 578DX. This engine also has two rows of Hamilton Standard contra-rotating blades but they are driven by a gearbox from the core engine. This pusher engine will also be flying, in demonstrator form later this year [1988].

The third flight test powerplant is the only tractor installation. It consists of an Allison engine driving a Hamilton Standard 8-blade single rotation propeller. It is currently [1988] being tested on the NASA Gulfstream aircraft.

All these propeller designs employ considerable sweep to the blades. This sweep confers aerodynamic and acoustic advantages. Figure 9 shows the effect of blade sweep.[2] It can be seen that for this particular cruise condition, peak efficiency occurs for tip sweep of about 30–40 deg. Increasing tip sweep will reduce the noise but efficiency also reduces and the rotor weight will tend to increase. Similar trends apply at other flight conditions.

As with the powerplants, there are three major aircraft flight test programmes under way (Figure 10). The first test was the Boeing 727 with the General Electric UDF tested in 1987. This engine was then installed on an MD80 in its 8 + 8 form. Results from these tests[1] claim that cabin noise is as good as or better than on a standard MD80 with a maximum noise level of 80 dBA. The fuselage treatment weight required to achieve these levels is not available but is believed to be substantial. Douglas plan to remove the UDF and install the PW Allison engine for flight tests later this year.

The third flight test programme is the NASA test using the Hamilton Standard tractor propeller with Allison engine on a modified Gulfstream 2. Tests in 1987 addressed community and en-route noise studies as well as fuselage exterior noise but cabin noise was not included. Limited cabin noise tests this year included the effect of Helmholtz resonators tuned to the propeller fundamental of 225 Hz.[3]

In addition to these major flight test programmes, a great deal of supporting research is going on including propeller noise prediction development at NASA, and the effect of techniques such as synchrophasing. Work on the development of improved fuselage treatments is being carried out by many researchers, in industry, in the universities and in NASA itself.

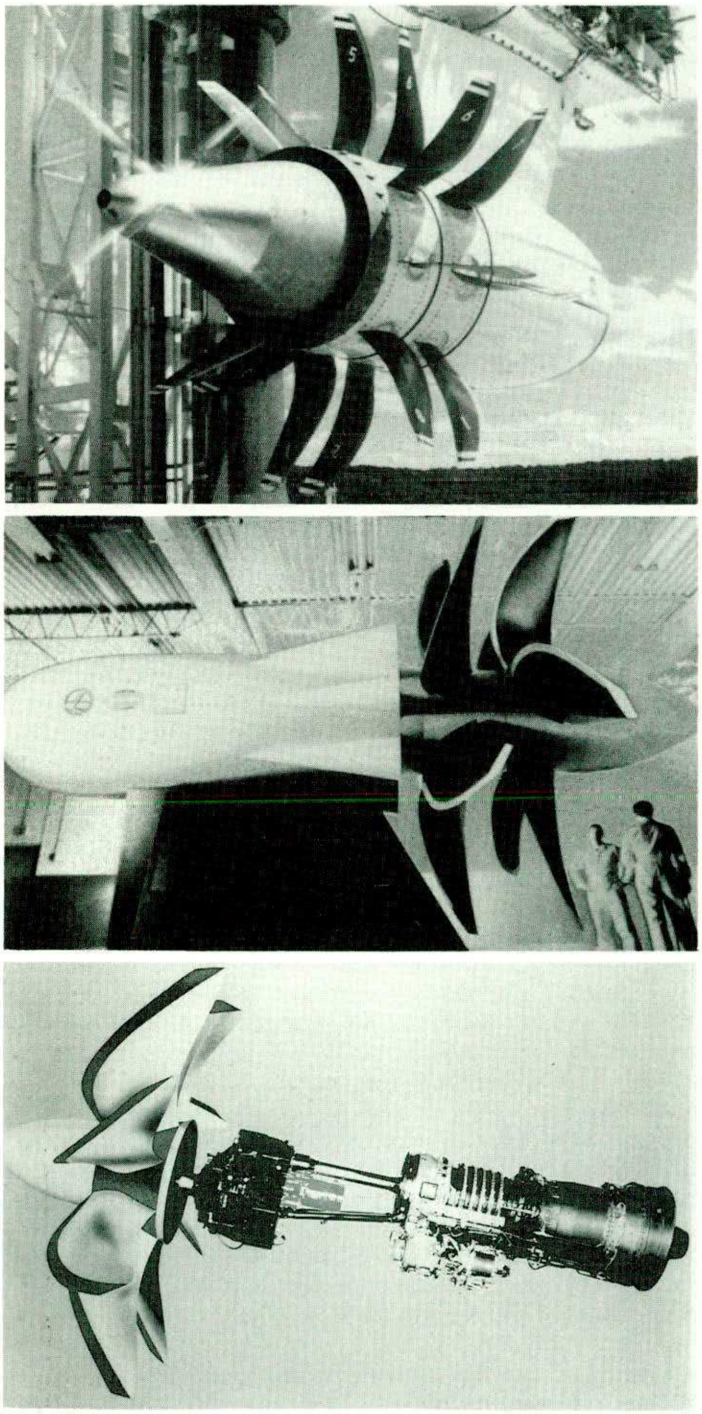

Fig. 8. US propfan engine options: top, General Electric UDF; middle, Pratt and Whitney/Allison contra propeller; bottom, Allison/HS single rotation tractor

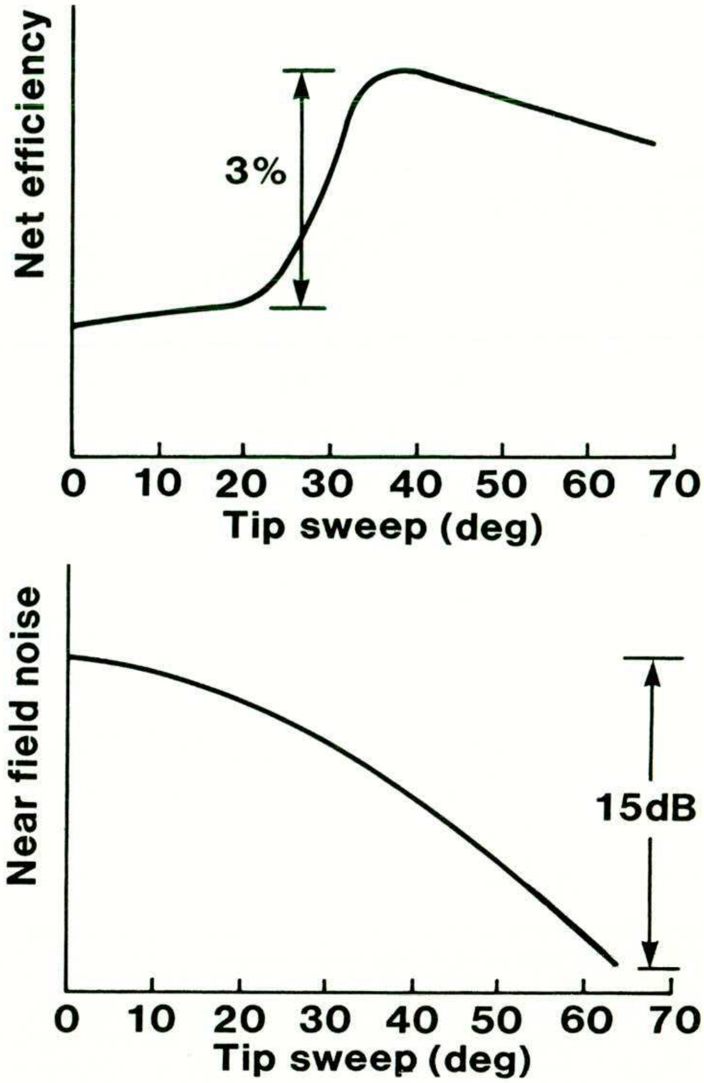

Fig. 9. Effects of blade sweep

Research in the United Kingdom

Open Rotor research in the UK is not as advanced as in the US because UK companies generally see the market development coming much later than indicated by some US companies. However, in addition to British Aerospace (BAe), Dowty Rotol (DR) and Rolls Royce (RR) both have active research programmes involving propeller and powerplant development. Relevant research is also under way in the universities and the research establishments.

The increased efficiency of contraprop powerplants and the lack of adequate acoustic data led to flight tests on a Fairey Gannet (Figure 11) undertaken as a joint venture by BAe, DR, RR and General Electric during 1983/4. This aircraft was modified by the addition of a wing mounted microphone boom in order to measure near field noise in the vicinity of the propeller planes. The Gannet's Double Mamba engine drives contra-rotating propellers and has the great advantage that each propeller can be driven independently and the relative crossing point varied. In addition to these near field tests the Gannet was also used to assess air to ground noise. Hamilton Standard in the US also used a similarly modified Gannet for noise evaluation.

During open rotor development work it is necessary to undertake wind tunnel research using isolated and installed model rotors. The only acoustically treated wind tunnels in the UK were the 24 ft and 1.5 m tunnels at RAE Farnborough which are limited to very low forward speeds (M < 0.25). In order to be able to evaluate propeller cruise noise at representative forward speeds a high speed (M 0.8) acoustic facility was needed. A joint programme between BAe, RR and the Aeronautical Research Association (ARA) is under way to produce an acceptable acoustic liner for the ARA Transonic wind tunnel (TWT) (Figure 12). The liner consists of 6 in thick foam installed behind perforated sheeting. It is intended that the acoustic liner should be commissioned this year [1988].

At the RAE, work continues on the development of statistical energy methods for noise prediction, on understanding the acoustic performance of fuselage panel structures and on path identification techniques. An important step in the most efficient application of noise treatments is the ability to separate structureborne and airborne noise (Figure 13).

The universities have evaluated many concepts to reduce propeller noise and increase fuselage noise reduction; one of the most novel techniques suggested is the use of active noise control as applied to aircraft cabins. The ISVR at Southampton[4] have predicted that the average level at the blade passage frequency on a BAe 748 aircraft might be reduced by 8 dB; smaller reductions are predicted at the higher frequencies.

Fig. 10. US propfan flight test aircraft: top, NASA propfan flight test programme; middle, MD UHB demonstrator; bottom, General Electric UDF flight test on Boeing 727

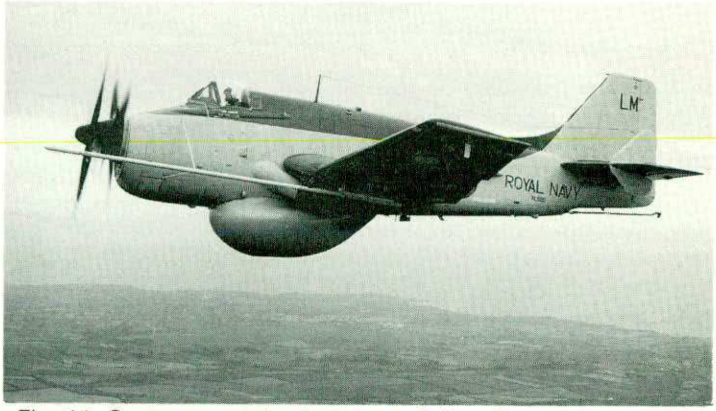

Fig. 11. Contraprop noise tests on a Fairey Gannet

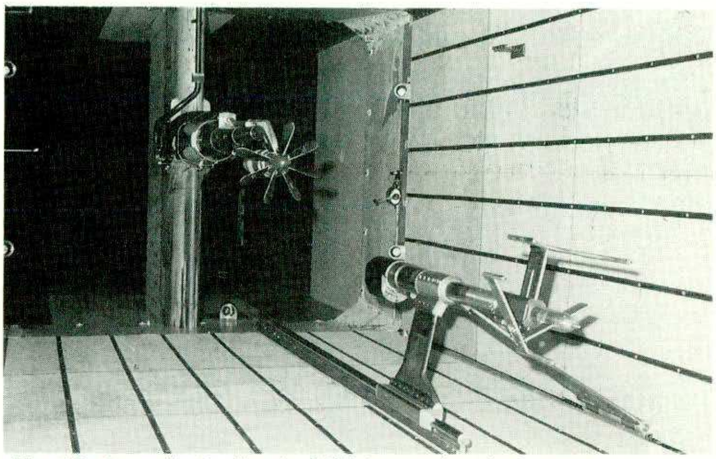

Fig. 12. Acoustic testing in ARA transonic wind tunnel

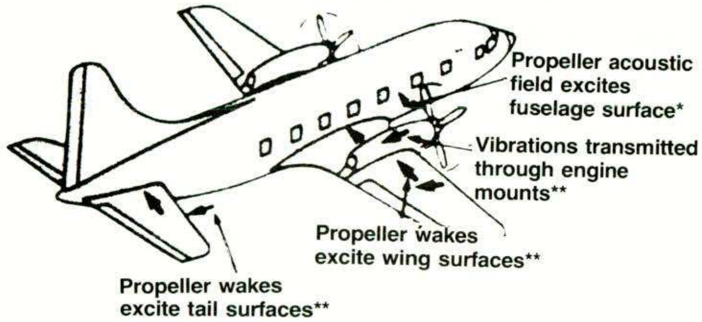

*Fig. 13. Passenger cabin noise levels: transmission paths. *, airborne noise; **, structureborne noise*

British Aerospace research programme

British Aerospace recognizes the potential importance of the advanced propeller and has instituted an open rotor research programme designed to produce technology readiness. The research work includes aerodynamics of the powerplant installation as well as acoustics. The acoustic programme has three main parts; flight research on current aircraft, the ground transmission loss rig and the development of a cabin noise prediction model.

Current flight research

Flight research is being conducted mainly on a BAe 748 (Figure 14) although a Vickers Vanguard has also been used to evaluate the effects of four engines and higher flight speeds. The initial 748 tests provided data to validate the cabin noise prediction model and in support of other research work. The data acquired included measurements of the external pressure field, made using miniature transducers installed in drilled-out rivet holes, structural vibration and cabin noise levels. In addition RAE carried out tests to assist in their work on path identification. A further phase of test flying is currently under way [1988].

Cabin noise transmission loss rig
The cabin noise transmission loss rig is a major new ground test facility which is being developed at BAe Hatfield for testing from the middle of the year [1988] and has two major objectives. The rig will be used to develop and assess advanced sidewall treatments and data from the rig will also be used to evaluate and develop the prediction model. Ultimately it should be possible to design noise treatments using the prediction model and demonstrate on the rig prior to a flight demonstration.

The basic rig (Figure 15) consists of a full scale section of BAe 146 fuselage alongside a Double Mamba engine driving contra-rotating propellers. The 146 fuselage specimen is about 45 ft long, includes the wing box and is complete with floor. The relative positions of propeller and fuselage can be altered by moving the fuselage which stands on a dummy undercarriage.

Because of the difficulty of simulating a propeller field it was decided to use a real propeller. The Double Mamba powerplant is similar to that which powered the Gannet described earlier.

The noise characteristics of a propeller change significantly between static and flight, due mainly to ingested turbulence in the static case, with an associated increase in unsteady loading

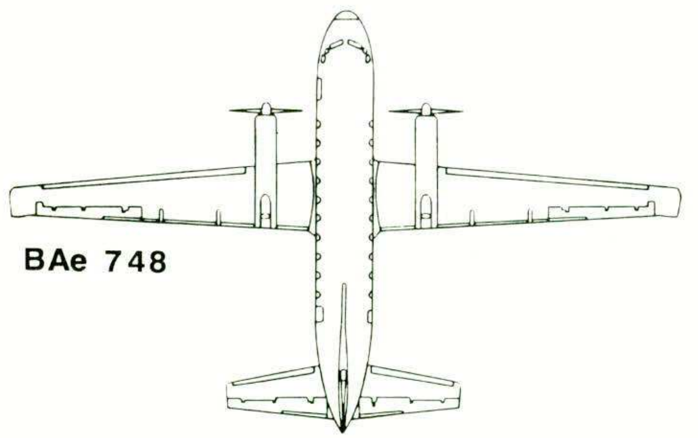

Fig. 14. Current flight research:
propeller source noise · *fuselage structural vibration* · *cabin noise distribution* → *calibration of theory* · *development of measurement techniques*

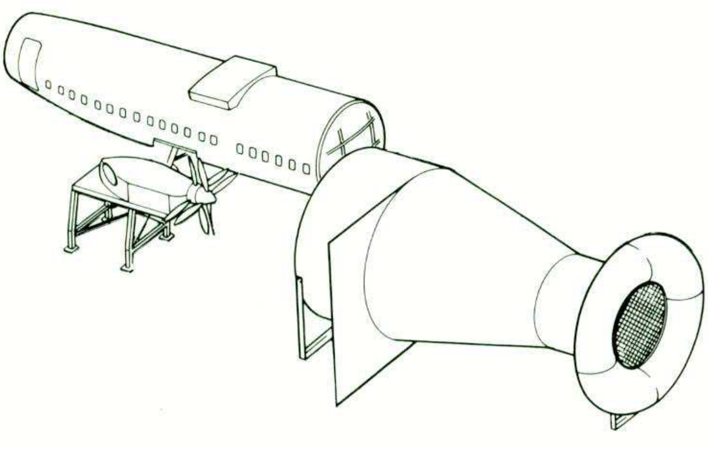

Fig 15. Cabin noise transmission loss rig

noise. In order to obtain a representative noise distribution on the fuselage, it is necessary to provide some forward speed simulation. The fan system will provide about 40 fps over a 20 ft diameter, which should comfortably enclose the 10½ ft diameter propeller.

As well as the airborne noise path we intend to investigate the significance of the structureborne noise transmitted through the wing. This excitation will be simulated by using vibration input to the wing roots from electrodynamic shakers. Using a shaker as opposed to coupling the engine to the wing will enable the two paths to be separated more easily.

In addition to the propeller noise source, tests will also be conducted using electro-pneumatic noise generators to give a more controllable noise distribution and spectrum shape.

Among the measurements to be made are the external surface pressure distribution, the vibration of cabin wall and trim and the distribution of noise in the cabin. The rig has the capability of being pressurized up to 4 p.s.i. and the effect of pressurization on noise transmission is to be investigated.

In order to cope with the large quantities of data to be generated on the rig, a new 32 channel analysis system based on a DEC microVAX computer is to be installed together with a 32 channel tape recorder.

Initially tests will be performed on the bare fuselage to investigate external pressure distribution, vibration of the basic fuselage structure and cabin noise. After this initial programme the test section, covering a length of about 27 ft from the front bulkhead, will be furnished using a standard BAe 146 trim. Luggage bins, trim mounts, insulation and trim panels will all be included. Aft of the test section a mockup standard will be used to ensure a representative cabin geometry and to eliminate flanking transmission. These tests will provide the opportunity to learn the transmission and propagation mechanisms involved and so design treatments to increase the noise reduction.

When the datum tests are complete a series of tests on advanced noise reduction treatments will be carried out (Figure 16).

The site chosen for the rig is a remote one on the north west

Advanced noise reduction concepts

— Dynamic absorbers

— Double wall /isolated inner cabin

— Acoustic resonators

— Structural changes

- Increased Mass

" Stiffness

" Damping

— Active noise control

Fig. 16. Cabin noise transmission loss rig

side of the airfield, giving improved safety and minimum noise disturbance. The need for free field propeller noise means that the rig has to be an open air one. The Company is well aware of the importance of being seen to be a good neighbour and that an open air propeller rig would not be universally popular. In order to assess noise levels accurately in communities around the site we carried out a community survey and also used a mobile propeller unit (Figure 17) to assess the propagation effects from the rig. The rig orientation and the fuselage position were chosen to minimize the impact on the local community.

Fig. 17. Cabin noise transmission loss rig; mobile propeller unit for noise propagation tests

Cabin noise prediction model

The third major element of the research programme is the development of a theoretical cabin noise prediction model. Before development began, a study was carried out into the most appropriate model to be used. It was concluded that the only model which would be adequate to assess the effect of discrete parts of the structure on noise and vibration propagation was one using finite element techniques (Figure 18). Models have been developed to represent a BAe 146 and a BAe 748. The BAe 146 model will be used for prediction of advanced open rotor powerplants and ground rig correlation. The BAe 748 model is being used in conjunction with the data from flight experiments to validate the model parameters. The figures which follow depict the BAe 748 but similar data exist for the BAe 146. Separate finite element models are produced for the structure and cabin space. These models are solved assuming a modal solution and the coupling of the cavity and structure calculated. The cabin noise is predicted by calculating the response of each mode at each node for a prescribed force on the external fuselage nodes. For the structure a quarter of the aircraft fuselage was modelled as shown in Figure 19. Ring frames, floor and windows are all faithfully modelled. The stringers are smeared into the skin and pressurization effects are included as incremental terms in the stringer and frame bending stiffness. The current model standard is of a green, or untrimmed, aircraft but the luggage bins have been modelled as lumped masses attached to the structure. The acoustic cavity is modelled as a 2-dimensional section. The 2D modal solutions were expanded to the full 3D cavity modes by assuming a cosine solution. It was assumed that the underfloor cavity could be ignored.

For project studies the external fuselage pressure distribution in amplitude and phase (Figure 20) would be supplied by the powerplant manufacturers. For the 748 evaluation experimental data exist and a propeller noise prediction module is also available. The *in vacuo* structural response (Figure 21) due to the given pressure loading is then calculated. It is normal to predict acoustic response of a set of nodes describing a plane. Figure 22 shows the predicted noise distribution in the plane at seated head height on the 748.

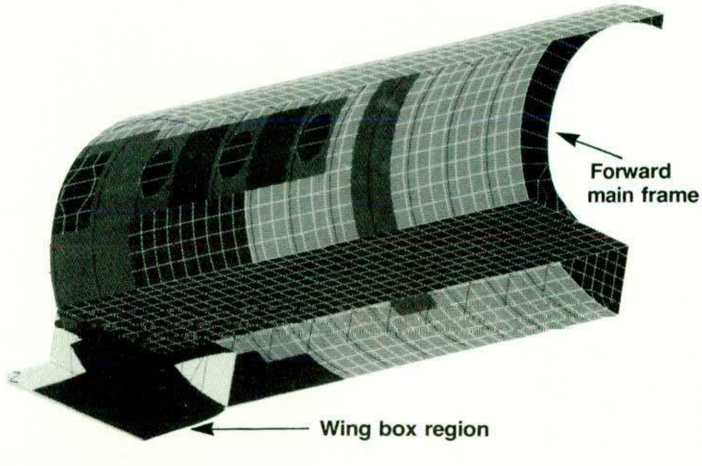

Fig. 19. Cabin noise prediction: passenger cabin finite element model

Using the experimental data from the 748 flight trials and the ground rig, the assumptions in the model will be verified and adjusted as necessary. The next development will be to incorporate the sidewall trim.

Conclusions

Open rotor powerplants offer the potential of considerable fuel saving compared to existing turbofans. These open rotors produce high levels of cabin noise which if left untreated would be unacceptable. Major noise research programmes are under way in both the United States and Great Britain to produce the technology to ensure that acceptable noise levels can be achieved on aircraft using these open rotors.

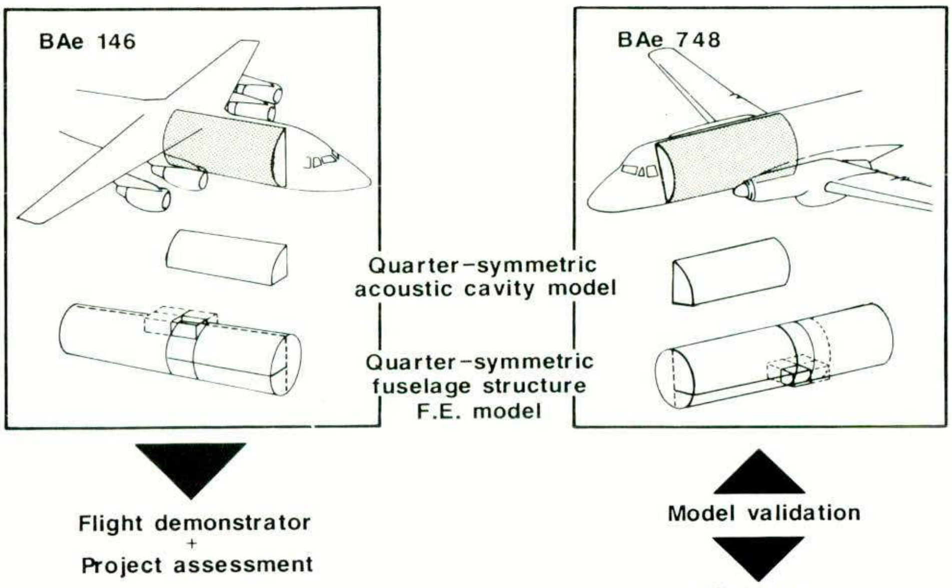

Fig. 18. Cabin noise prediction

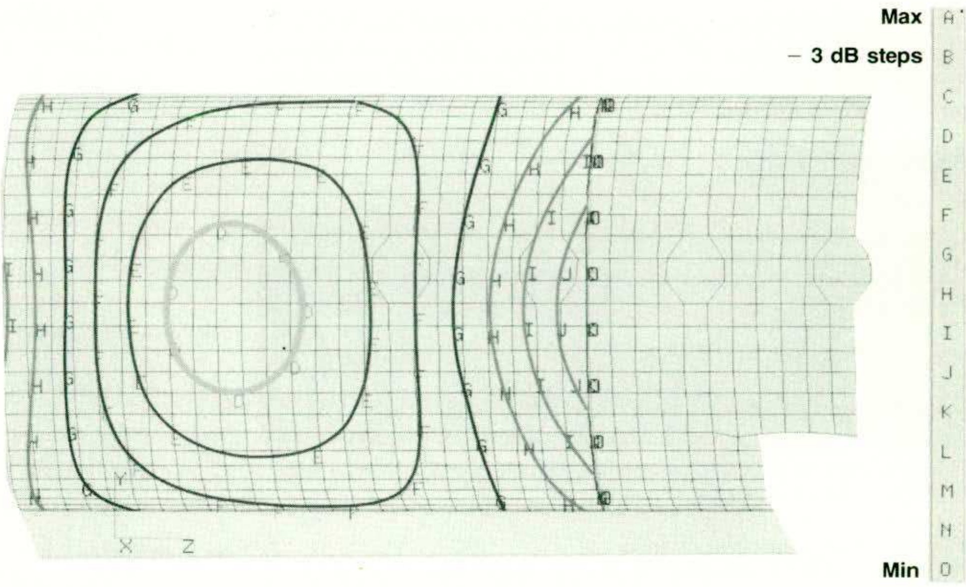

Fig. 20. Cabin noise prediction: typical amplitude distribution

Acknowledgements

I would like to thank my colleagues. Paul Brereton has been responsible for the development of the cabin noise prediction model, and Bernard Chidley and John Evers at Woodford were responsible for the 748 flight tests. I would also like to thank British Aerospace for their permission to present this paper.

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2 Gatzen, B S. *Advanced Turboprop Propulsion Technology*. SP03A82, 1982.

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Fig. 21. Cabin noise prediction: typical structural response

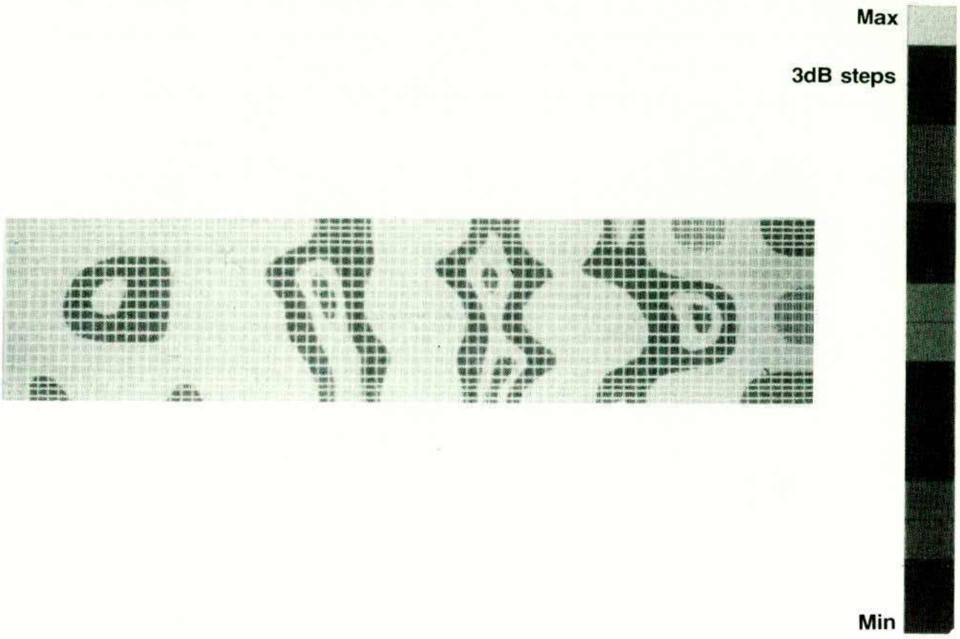

Fig. 22. Cabin noise prediction: typical noise distribution at seated ear plane

Acoustic Effects on Spacecraft

J Bennett
Space and Communications Division

Introduction

Spacecraft are launched by large rocket-engined vehicles which develop high levels of acoustic noise. This gives rise to two classes of problem for the spacecraft engineer:

High stress levels are induced in light weight plate and shell structures causing fatigue or high peak stress failure.

High levels of random vibration are transmitted to mechanisms and electronic boxes causing failure of PCBs or their component leads.

This article gives details of the sound pressure levels (SPL) applicable to spacecraft launched by various vehicles and discusses an example of each of the two types of problem.

Sound pressure level comparison

A comparison of SPL for spacecraft launched by various vehicles is given in Table 1. The spacecraft is normally carried high above the engines and the levels are also attenuated by a fairing or, in the case of shuttle, by the fuselage structure and cargo bay doors. An indication of the levels close to the engines is given in the right hand column for the release gear of *ARIANE*.

On some vehicles the spectrum is specified in ⅓ octave bands but all have been translated to octave bands for comparison. It can be seen that there is considerable variation in overall level as well as frequency distribution.

Most launch vehicle authorities require a spacecraft to be qualified by test usually at 4 dB above the flight levels quoted. For complete spacecraft and even for some of the larger panels which require development testing there can be problems in locating a suitable chamber which combines physical size and the ability to achieve the full SPL spectrum.

Structural problem example

Description of problem

Spacecraft are generally constructed of lightweight sandwich panels which are both stiff and strong. They respond to acoustic noise excitation with high accelerations but relatively low stresses and strength is therefore not usually a problem. One example where strength was a problem was a large lightweight antenna shown in Figure 1.

The dish is 3.2 m in diameter with only slight curvature. It is of sandwich construction, the core being 6.2 mm thick Kevlar honeycomb and the facings one layer of Kevlar cloth and one layer of carbon cloth reinforced plastic.

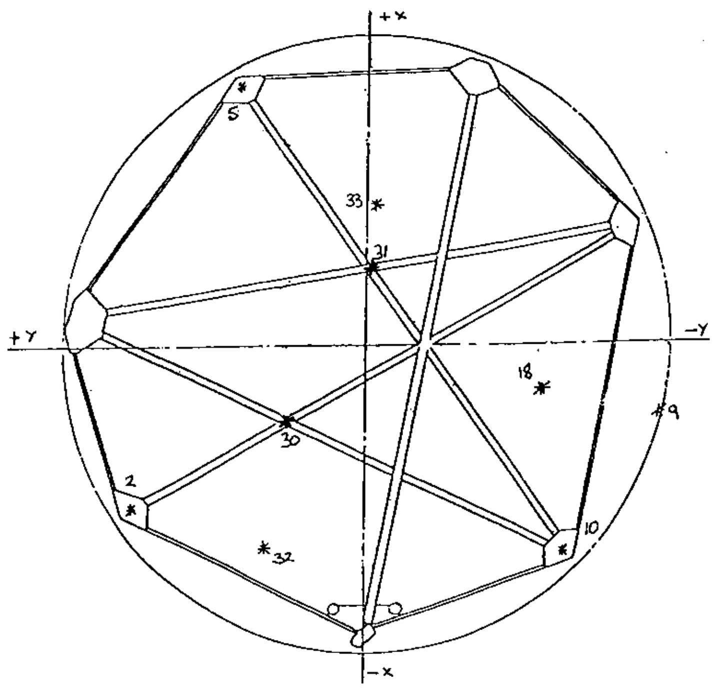

Fig. 1. Layout of antenna reinforcing beams: original design (★ = accelerometer)

Stiffening consists of I section beams of CFRP bonded to the back face of the dish. The whole is supported at three points on the periphery during the launch phase.

Considerable analytical work had been carried out on the reinforcing beams in order to minimize mass and satisfy the overall stiffness, strength and thermal distortion requirements, but the basic shell had been used before without problems and the qualification acoustic noise test was expected to be a formality. However, post test inspection showed cracks in the rear face of the shell in three of the larger panels. These cracks were quite long (tenths of a metre) but appeared to be in the carbon only and had not led to total structural collapse. The carbon is, of course, very brittle compared with Kevlar.

The situation was quite unacceptable since the effect on thermal distortion would be large and hence a modification to prevent the failure was required. The schedule requirements of the project meant that the modification had to be established very quickly without a full analysis to understand the reason for the failure and it was decided to add light stiffeners to break up the larger panels as shown in Figure 2.

Whilst the modified antenna was being built some analysis was performed and also a test on a spare piece of sandwich

Table 1. Spacecraft acoustic noise levels: various launch vehicles (dB Ref. 20×10^{-6} N/m²)

(Hz)	*Atlas*	*Titan III*	*Shuttle*	*LM2E*	*Proton*	*Ariane 4*	*Ariane release gear*
31.5	114		126	113	126	114	158
63	125	129	132	131	129	127	162
125	133	134	134	131	135	132	166
250	132	135	132	139	137	136	169
500	128	135	128	138	136	137	168
1000	123	132	123	126	133	134	165
2000	117	126	117	123	126	128	163
4000	113			121	119	122	157
8000				110		120	
Overall	137	141	138	142	142	142	174

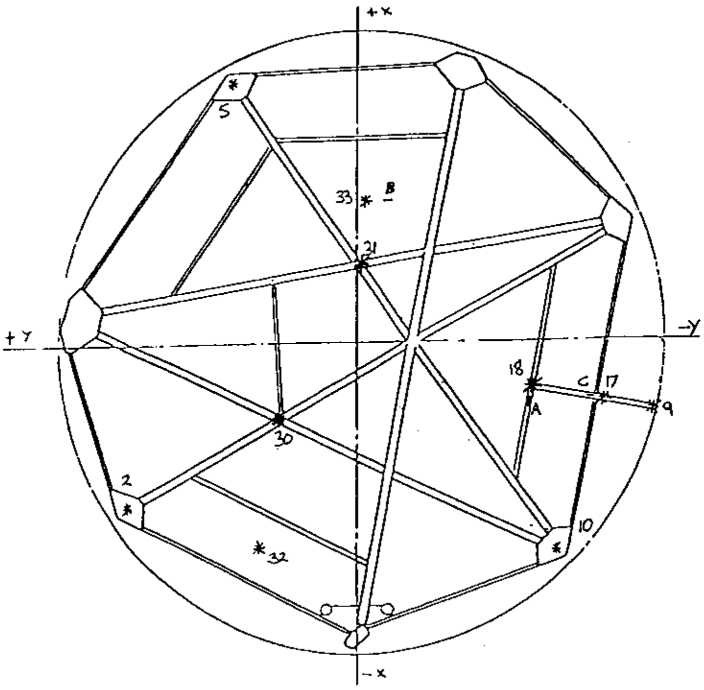

Fig. 2. Layout of antenna reinforcing beams: modified design (— = strain gauge; ★ = accelerometer)

which was approximately the same size and shape as the large triangular panel.

Analysis

A simplified analysis of the triangular panel was performed based on the response of the first mode only. Using a finite element analysis and assuming simply supported edges, a natural frequency of 69 Hz was predicted and an r.m.s. stress of 38 MN/m^2 for a structural dampening factor of 0.04.

There had been little instrumentation on the antenna test but accelerometer No. 18 was approximately in the middle of this panel near the theoretical position of maximum response. This showed a natural frequency of about 80 Hz with a spectral density of 160 g^2/Hz. The acceleration spectral density corresponding to the 38 MN/m^2 stress at 69 Hz was calculated to be 9600 g^2/Hz showing that the analysis was slightly underestimating the stiffness but seriously overestimating the response levels. The main reason for this was probably the linearity assumption in the analysis. The r.m.s. deflection corresponding to the analytical stress of 38 MN/m^2 is 11.5 mm i.e. nearly twice the thickness of the plate. At this level the small deflection, plate bending theory is inaccurate as significant membrane stresses are induced providing a stiffening spring. An analysis of this more complex problem was not considered to be justified in the circumstances.

A 'design allowable' quasi static stress of 90 MN/m^2 had been derived from a limited number of test specimens of the face skin material. The mean value was 127 MN/m^2. Thus if the analytical r.m.s. stress of 38 MN/m^2 was correct a first excursion failure would not be unlikely. However, scaling this stress by the square root of the ratio of measured to theoretical acceleration spectral densities, the r.m.s. stress reduces to about 5 MN/m^2. The probability of first excursion failure is then virtually zero.

No specific data were available on the fatigue properties of the material but in general, CFRP has good fatigue resistance and a failure would not be expected in a short test of this nature. Two minutes with a natural frequency of 80 Hz is only 10^4 cycles.

The antenna had previously been tested for 30 s at 4 dB below the qualification level with no evidence of cracking; hence it was considered that the modification would be successful if it reduced the stress level in the facing to 63 per cent, i.e. from 38 to 24 MN/m^2. A re-analysis of the panel with the stiffener showed an increase in natural frequency to 112 Hz and a decrease in r.m.s. stress to 25 MN/m^2. This result did not convince the writer that the modification solved the problem since the large deflection non-linearity which apparently made the analysis of the original design very pessimistic was not nearly so significant in the modified design. However, by this time a new antenna to the modified design had been built and it was decided to go ahead with a retest. This proved to be satisfactory.

Panel test

A piece of sandwich which had been used for manufacturing development existed which was suitable for a specimen representing the large triangular panel which had been analysed. It was mounted in a wooden frame instrumented according to Figure 3 and tested in the chamber to nominally the same spectrum as had the failed antenna.

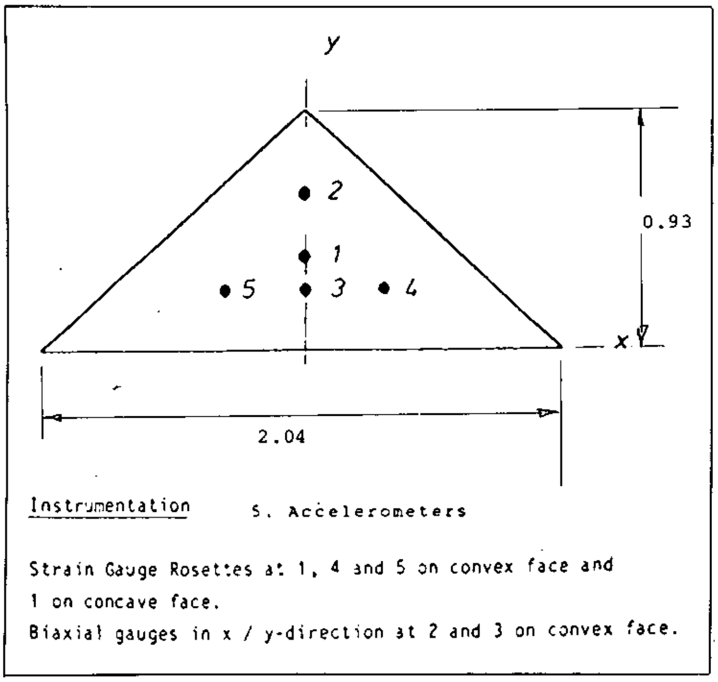

Fig. 3. Panel test specimen

A comparison of the response measured by accelerometer No. 1 with that of accelerometer No. 18 on the failed antenna is shown on Figure 4. This shows quite reasonable agreement

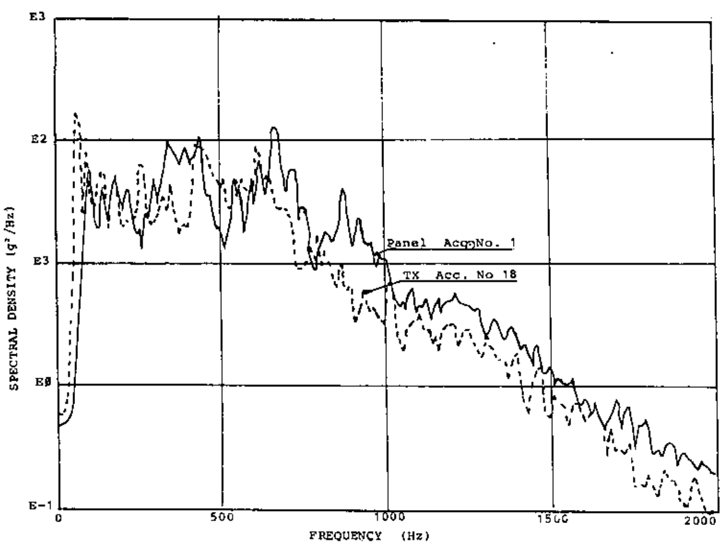

Fig. 4. Comparison of antenna and test panel response

although the first mode frequency is somewhat higher and the response lower than on the antenna. Overall the r.m.s. accelerations were 195 and 180 g respectively.

The maximum overall strain was measured at position 1 at 111$\mu\epsilon$ r.m.s. This corresponds to a stress of 8 MN/m^2 which is somewhat higher than that deduced for the antenna but still well below that which might lead to failure, and in fact no failure occurred.

The remaining instrumentation gave results which have no particular interest; they were consistent with the above and gave no indication as to the reason for the failure of the antenna.

Conclusions

- The reason for the failure is not understood.
- The modified design survived the qualification test.
- This antenna provides a good example of the inaccuracy of using small deflection theory when deflections are large.

Unit random vibration problem

Description of problem

Figure 5 shows an exploded view of a large communications spacecraft. It can be seen that a large number of units (electronic boxes) are mounted on honeycomb sandwich panels. These panels respond to acoustic excitation and transmit a random vibration into the units. The units are designed and developed in parallel with the spacecraft, and early estimates of the random vibration environment are needed, long before the first structural model of the spacecraft is tested under acoustic noise. Even when that test has been performed it is difficult to translate the measurement into accurate shaker test specifications.

An example of a case where at first sight we had severely underestimated the input to the unit was a Battery Discharge Regulator (BDR) mounted on the lower X wall of the spacecraft.

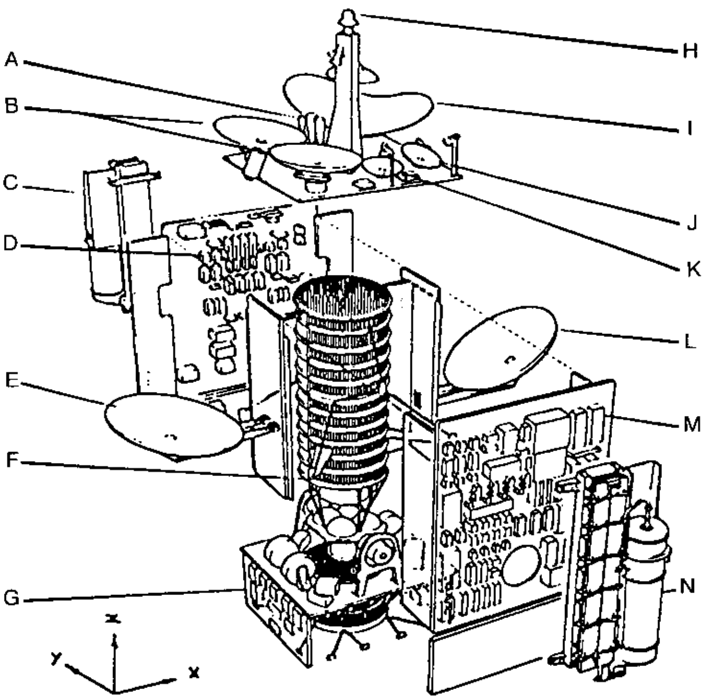

Fig. 5. Spacecraft layout: A, 12/20/30 GHz beacons; B, 20/30 GHz antenna; C, solar array; D, communications equipment panel; E, TVB steerable transmit antenna; F, propulsion module; G, service module; H, 'S' band TT&C antenna; I, 12 GHz Italian beam; J, specialized service VHM beam antenna; K, TVB receive antenna; L, specialized beam multi-beam antenna; M, communications equipment panels; N, solar array.

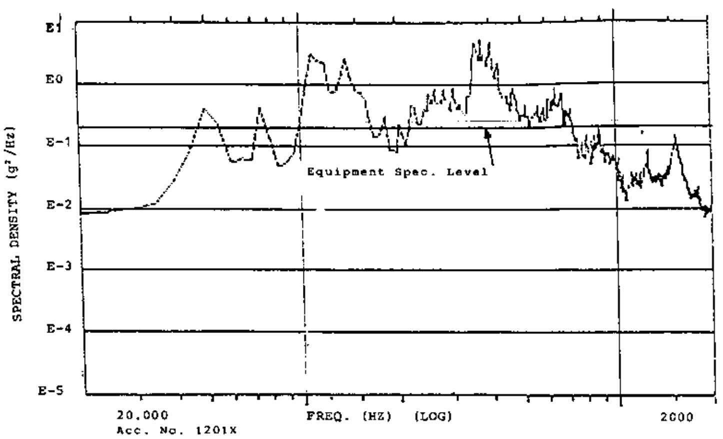

Fig. 6. Structural model spacecraft acoustic noise test response at BDR interface

Figure 6 shows the acceleration spectral density measured on the panel adjacent to a mass dummy of the BDR during the structural model spacecraft acoustic test at qualification level. Also shown is the spectrum which had been specified for the unit and to which it had been designed and tested. It can be seen that over most of the frequency band from 100 to 700 Hz the measured level is significantly greater than specified.

It is quite common during spacecraft acoustic noise testing to find cases where measured PSDs exceed unit specification levels but these are usually narrow resonant spikes which can be accepted on the basis that they are resonances of the panel/unit combination at frequencies which will not be resonant for the unit alone when tested fixed base on the shaker. In this case such an argument was not obviously valid and further investigation was necessary.

Panel tests

It was not possible to perform more extensive testing at spacecraft level with a real unit installed but it was considered that some useful testing could be done with a panel representative of the spacecraft lower X wall supported as one face of a box to simulate the right boundary conditions. An outline of the panel is shown in Figure 7 with the various dummy units mounted and the accelerometer positions identified. A number of different tests were performed but this article only deals with those concerned with the BDR on the +Y side of the panel. All testing was performed at 'Flight Acceptance' level to reduce fatigue damage.

Initially all dummy units were mounted and the box 'tuned' to reproduce the same response characteristics as on the structure model spacecraft. Figure 8 shows a comparison of the response measured by accelerometer No. 1201 on panel test and spacecraft test, and the agreement is seen to be quite reasonable for this type of testing.

It should be noted that test records from different facilities cannot be directly overlaid due to different plot formats and the heavy line representing the panel test has been put in by hand and smoothed to some extent.

Having achieved a reasonable comparison between panel and spacecraft response the dummy BDR was replaced by a real unit. It was not fully flight standard but adequately representative from a structural dynamic point of view. A drawing of the unit is reproduced on Figure 9. It can be seen that there is little room for instrumentation but two accelerometers were installed on PCB No. 1 at the top of the stack, No. 1 at the centre of the PCB and No. 2 near the edge between support pillars.

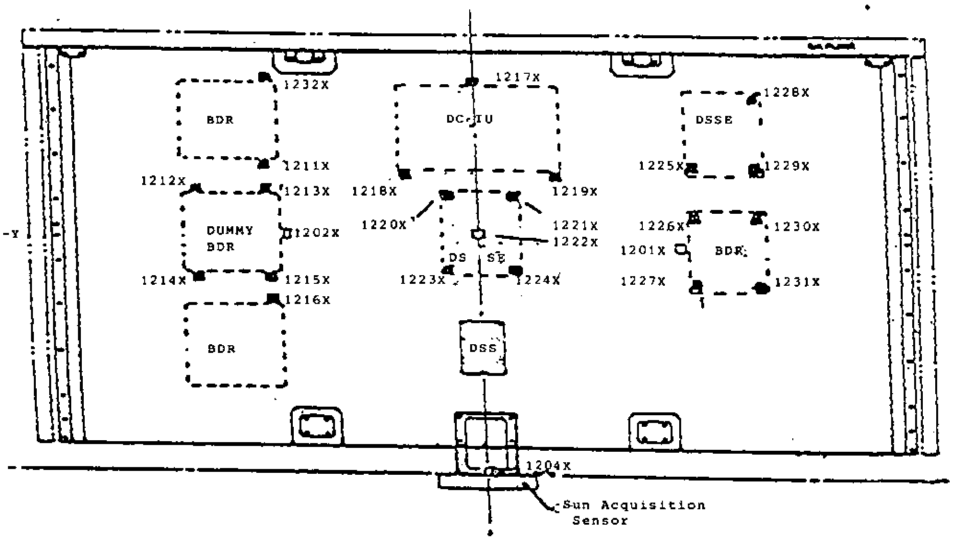

Fig. 7. Layout of test panel

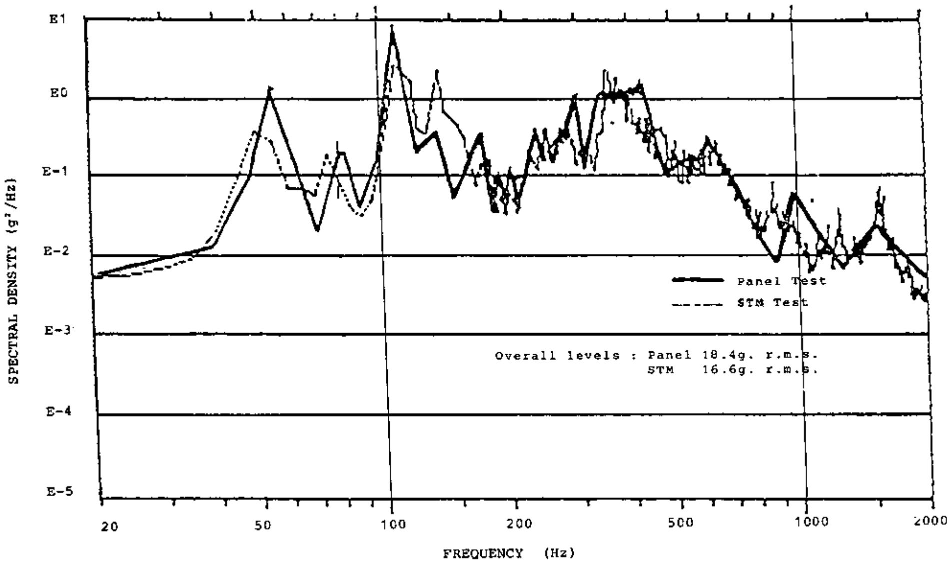

Fig. 8. Comparison of STM and panel test responses – acc 1201

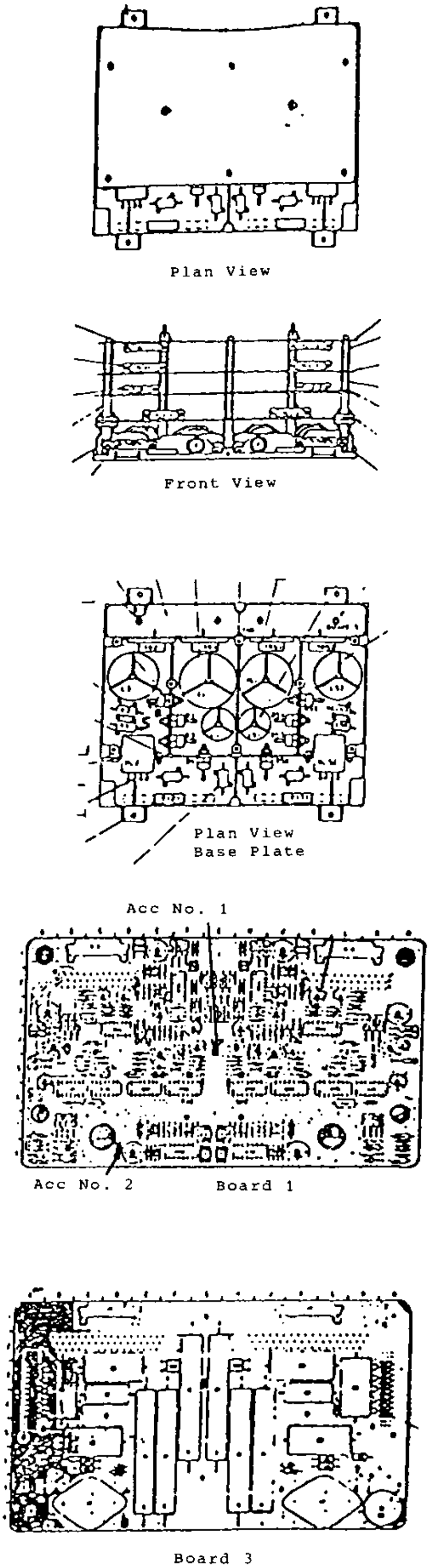

Fig. 9. Layout of BDR

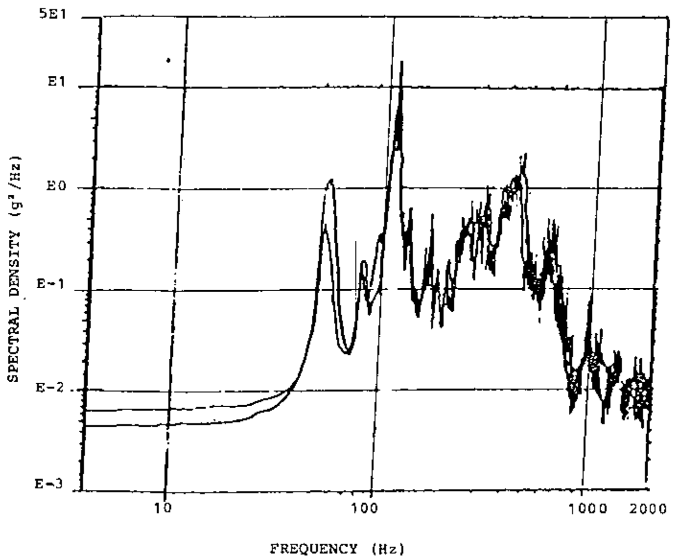

Fig. 10. Acc 1201 response: dummy and real BDR

Tests with real BDR

Figure 10 shows a comparison of the measured response at acc. No. 1201 with the real BDR and dummy. The natural frequencies of the main modes are unchanged but there is some effect on response level at the 50 Hz and 110 Hz modes. It is not clear whether this is a real effect of changing the unit or random test to test variability.

The response at the actual feet of the unit is shown for accs

1226 and 1227 on Figures 11 and 12. It can be seen that these are very similar to each other and to acc 1201 except that 1227 has a higher level around 250 Hz.

The response at the PCB inside the unit is shown for accs 1 and 2 on Figures 13 and 14. Also shown on these figures is the response measured during a shaker test at flight acceptance levels. It can be seen that in general the shaker test still provides the critical environment for the PCBs inside the unit in spite of the apparent underspecification of the unit test spectrum. The peak at 50 Hz is a rigid body response of the unit to the main panel mode and is covered by a sine shaker test on the unit.

The peak at 110 Hz is also apparently a rigid body response and will have negligible effect on the stress levels and deflections of the boards compared with the rest of the spectrum.

Conclusions

The structural model spacecraft acoustic noise test suggested a significant underspecification of the random vibration environment for the BDR.

Further testing at panel level with a real unit demonstrated that the original specification was adequate. However, at present [1988] we have no suitable analytical tools to deal with this situation whilst testing is expensive and time-consuming.

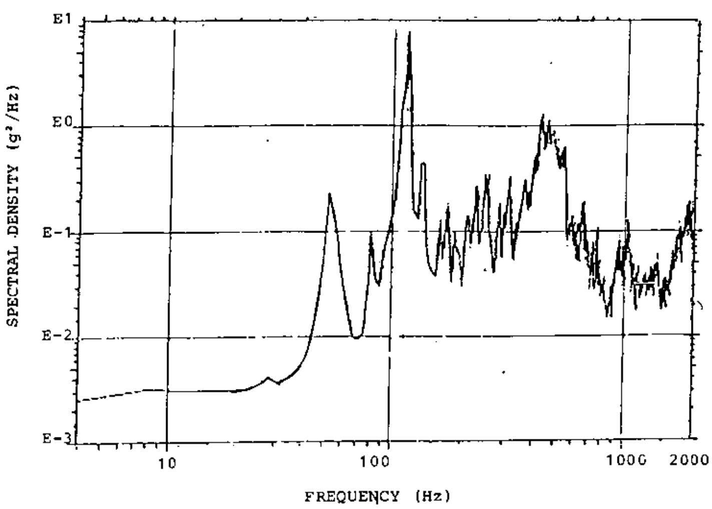

Fig. 11. Acc 1226 response

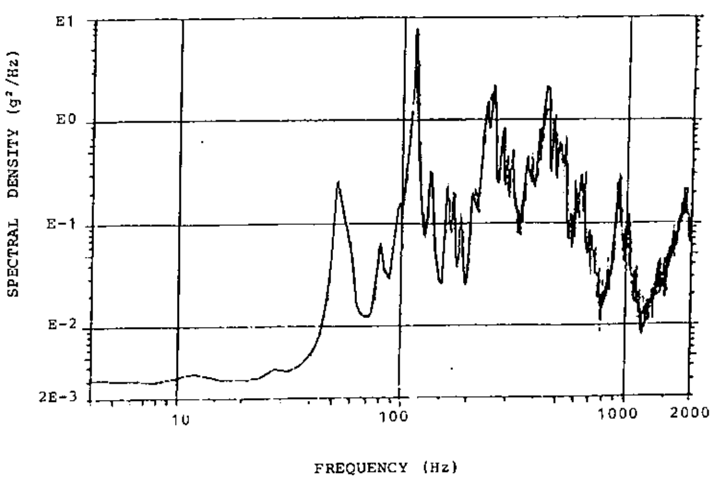

Fig. 12. Acc 1227 response

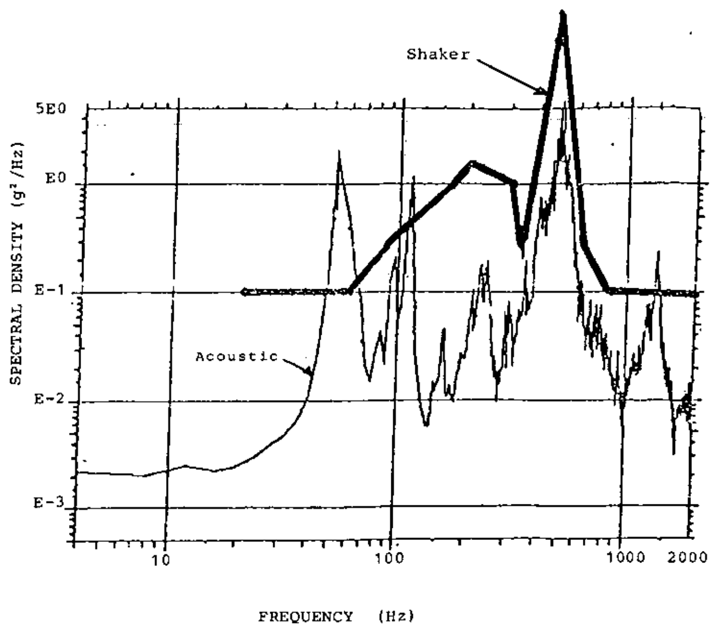

Fig. 13. Comparison of acoustic – shaker response (BDR, acc no. 1)

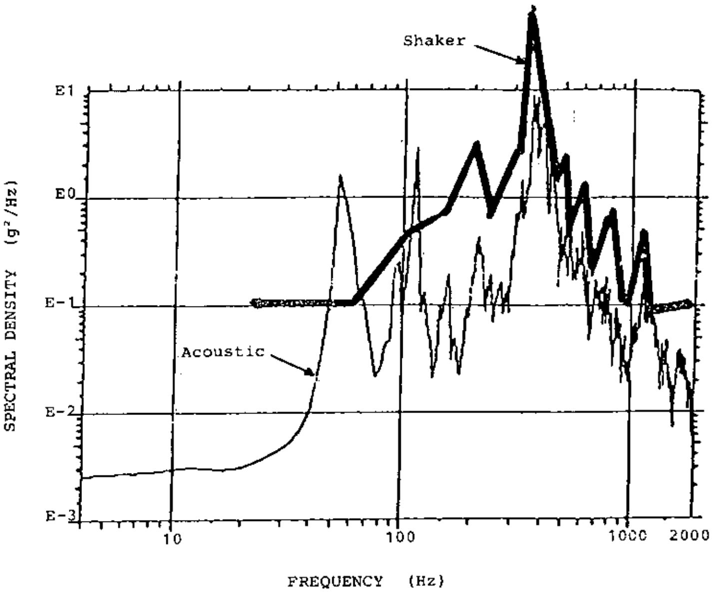

Fig. 14. Comparison of acoustic – shaker response (BDR, acc no. 2)

OCCUPATIONAL NOISE – LEGISLATION GUIDELINE BOOKLET

Following the series of one day seminars run by Accent Systems, formerly ICI Acoustics, on the forthcoming 1990 EC Occupational Noise Legislation, the company has produced a booklet on the subject, aimed at managers who do not have a detailed knowledge of acoustics, and so want an easy-to-read guide to the practical implications of the proposed regulations. The guide offers clear explanations of the terms used, and follows a question and answer format.

This booklet is the latest addition to Accent Systems' range of services designed to help industry implement the forthcoming regulations as cost-effectively as possible. The booklet is available free from Accent Systems upon request.

Further information from: Stephen Diston – Acoustic Engineering Consultant, Accent Systems. Tel: Biggleswade (0767) 318871.

The Acoustic Environment of the Aircraft-carried Store

D Sims
Dynamics Division

Introduction

An external store, when carried on a high performance military aircraft, may be affected by a number of acoustic sources. Obvious audible sources may be jet engine exhaust and afterburner noise or gunfire impulses.

Normally, stores are mounted well forward of jet engine exhausts and are thus not generally affected by this source. However a new generation of high performance aircraft is evolving, capable of both vertical take-off and landing and very high flight speeds. This requires the use of high-powered engines resulting in sustained high noise levels under the aircraft during the vertical landing mode. Under-fuselage and under-wing are, of course, the normal locations for carried stores and this area could well achieve significant noise levels that will influence store design in the future.

Guns are usually mounted within, or under, the fuselage and can be situated close to store locations. They are capable of high rates of fire, producing pressure impulses of high intensity at rates up to 100 impulses per second. These impulses can induce significant levels of vibration in the store but due to limited magazine capacity, present a correspondingly time limited problem.

Background

Vibration, of course, is the end result of any acoustic excitation. It has been established that the major source of vibration in high speed flight, in terms of accumulated energy, results from the turbulent boundary layer. Some additional low frequency energy is also transmitted across the aircraft/store interface and provides a 'coloured' spectrum that includes aircraft structural modes, e.g. wing and pylon bending and torsional frequencies in the case of a wing mounted store. Also, this low frequency band usually includes the store lower harmonic modes of vibration.

The boundary layer excitation, far from being mechanically transmitted through the attachment points, is applied to the store as a distributed input over the whole of its wetted surface. This provides for good transmission of high frequencies into the structure.

It is always necessary to simulate operational environments under controlled conditions in order to examine how the equipment will perform in service. For an aircraft-carried store this is required for:

(a) Flight clearance of stores for trials and aircraft integration purposes,
(b) Type test of the final design,
(c) Reliability growth and demonstration, and
(d) Production acceptance testing.

In order to obtain a realistic reproduction of service failure modes it is necessary to provide a realistic representation of the service environment.[1] It has been shown, by an extensive survey in the United States, that the causes of failures could be defined in terms of the equipment operating conditions and environment. The results of this survey are shown in Figure 1. Attempts to accelerate the failure rate by the application of higher stress levels can result in the generation of non-representative failures. Indeed it has often been found necessary to reproduce the various stresses of operational life in the correct combinations, sequences and levels. In fact it is normal to apply 'simulated sorties' in which the store is subjected to a sequence of applications of the relevant environments in combination to represent typical sortie conditions.

Having accepted that realistic conditions are required, the methods of applying these to operational stores require examination.

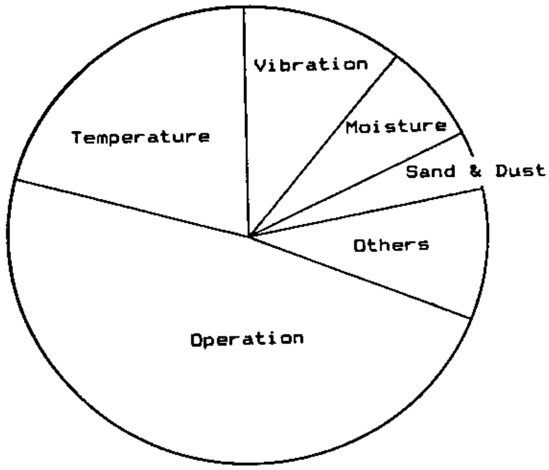

Fig. 1. Distribution of service failures

Related temperature conditions

Temperature conditions are normally applied to and controlled from the skin of the store. At this position it is possible to achieve the required extreme levels, spatial distribution and rates of change of temperature representative of the service operational environment. The internal components, which are the ultimate aim of the conditioning treatment, then respond as required by their thermal mass and temperature transfer coefficients. These masses and coefficients usually prevent the components from seeing any significant thermal shock from rapid changes on the skin (which can reach 20 °C per minute) but internal thermal shock conditions can result from the application of power to the electronic circuits.

External skin temperatures are usually related to the aircraft performance and knowing the flight parameters the recovery temperatures can be easily calculated for any given flight condition. Vibration, however, is not so easily derived and applied.

Vibration responses

Over many years of flight measurements of vibration responses of a wide range of weapons on many aircraft, a significant data bank has been built up. From this a number of relevant facts have been established.

First, the vibration excitation is broad band random over a frequency range extending from a few Hertz to several tens of kiloHertz.

Secondly, the acoustically induced vibrational energy supplied to the store is proportional to the dynamic pressure. By regression analysis of data from a wide range of store/aircraft combinations it has been established that, within defined occurrence and confidence levels, a value of rms acceleration can be attributed to any store of given construction for any known flight condition.[2] These regression data have been compared with similar data determined for other weapons and aircraft combinations in the USA with effectively the same result, as shown in Figure 2.

Thirdly, although the energy levels for a store associated with a particular aircraft performance are determinate, the characteristic frequency responses for each installation are unique. Thus it has been shown that a particular store will respond differently in similar installations on different aircraft for ostensibly the same flight conditions.

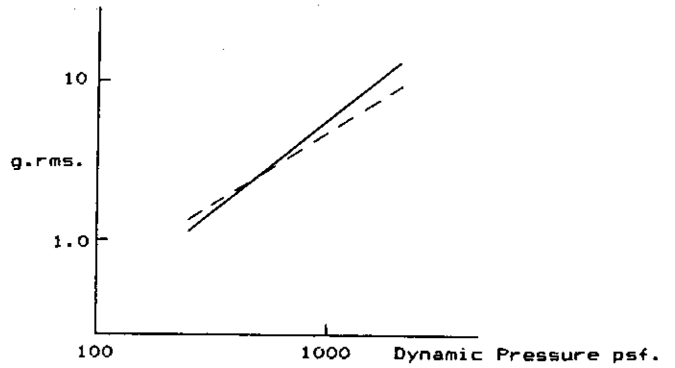

Fig. 2. Vibration/dynamic pressure relationship: ———, UK data 90 per cent occurrence, 95 per cent confidence; – – –, US data 95 per cent occurrence, 50 per cent confidence

Simulation

Having established the vibration levels and spectra on a store, by measurement or estimation, it is necessary to be able to reproduce this in the laboratory. The established method of doing this has been to couple the store to one or more mechanical vibrators and excite the structure by applying the required stimulus under closed loop control.

This is a perfectly acceptable method of vibrating structures in a number of applications but it has its limitations, especially when considering long thin structures typical of aircraft carried weapons. The major problems are:

(a) Attachment of the vibrator(s) provides added mass which changes the mass distribution of the structure and hence its dynamic modal response. It also restrains the motion of the store primarily to that of the axial motion of the vibrator.

(b) From what are effectively point inputs, the higher frequencies are attenuated as they progress along the structure and across the various structural interfaces. This results from dissipation and reflection of energy at the interfaces at the higher frequencies.[3]

(c) In turn the input power from the vibrator in this frequency range has to be increased to compensate for these losses. This results in local overstressing of the structure at the input points together with probable non-representative failure and possible overdriving of the vibrator and its amplifiers in a frequency range where an acceleration limitation applies. Additionally, due to the dispersive nature of bending waves in the structure, the distribution of energy becomes irregular, giving frequency dependent peaks and notches in the response that will probably require corresponding notching and peaking in the drive frequency spectrum.

In order to achieve maximum realism in the ground simulation of this environment it is possible to induce the vibration in a similar manner to that seen in service. By the application of high intensity noise to the outer skin it is possible to provide the required distributed input to the store's surface in all axes simultaneously. This then overcomes, to a great degree, the high frequency structural attenuation problem, by applying the excitation over the whole of the wetted surface of the structure.

The acoustic energy is then transmitted through the skin, with its normal frequency dependent attentuation, to attack the internal components of the store in the manner encountered in its operational life. These components are sensitive to the higher frequencies produced acoustically as their physical dimensions are more closely related to these wavelengths.

Development of acoustic techniques for vibrating aircraft-carried external stores, particularly guided weapons, was carried out concurrently in the USA and the UK in the decade ending in the mid-1970s.[4–6] The work in the USA was performed using both large and small missiles in reverberation chambers while that in the UK examined the progressive wave tube (PWT) as a method of vibration stimulation on a similar range of stores. Our work in the UK was extended to cover supersonic free flight conditions and also the methods of noise generation and coupling into the test facility.[7]

These development programmes all concluded that the acoustic method of testing gave superior results in representing the aircraft carriage flight vibration environment over the use of mechanical vibrators although the mechanical systems were still adequate for many purposes.

It is known that the transfer of acoustic energy into a structure from a progressive wave or diffuse field is different from that of an attached boundary layer. For this reason it was also concluded that acoustic tests on carried stores should be controlled from the vibration response of the structure. The acoustic excitation is then adjusted to give a structural response representative of the operational condition.

Progressive wave tubes and reverberation chambers each have differing characteristics that make them suitable for testing aircraft carried stores.[7]

The progressive wave tube has a working section suitable for the particular store. That is, the cross section is the same shape, usually circular, in order to keep a uniform annular clearance, and the length is at least that of the store itself. A noise generator is coupled to one end via a horn to give the required impedance match. The other end of the working section is coupled via another horn to an acoustically absorbent termination in which the majority of the injected energy will be absorbed. The efficiency of this termination will determine the degree of standing wave distribution along the store. When the noise is injected into the tube a progressive wave will pass over the exposed surface of the store.

In a reverberation chamber noise is again injected via a horn but in this case, due to the multiple random reflections from the walls, a diffuse noise field is set up. This diffusivity gives a uniform noise field over the major part of the room volume into which the store can be placed. An added advantage of this is that more than one store can be tested at any one time. This has advantages when conducting reliability tests as it is then possible to acquire data more rapidly. High power levels are required, however, if realistically high acoustic noise levels are to be achieved.

Both of the above methods are now in common use in this application. PWTs are limited to single stores but are more efficient in their use of acoustic energy. A system is in use which will achieve 165 dB re 20 micropascals around a store with only 4000 acoustic watts.

Reverberation chambers provide the added advantage of space around the store(s) which also allows for the provision of temperature conditioning equipment, target simulation, etc. Low frequency excitation is commonly provided by mechanical vibrators driving through a light coupling to a strong point on the structure. This is more economical than providing a larger chamber and, as has been previously noted, is more representative of the in-service condition.

If we examine the energy distribution under test conditions it is seen that the majority of the vibration response is acoustically induced. To achieve flight vibration responses a position at the forward end of a store will typically receive 90 per cent of its excitation acoustically. At the lower frequencies, where the modal density of the chamber is low, it is more difficult to generate high levels of acoustic energy. Typical responses are shown in Figure 3.

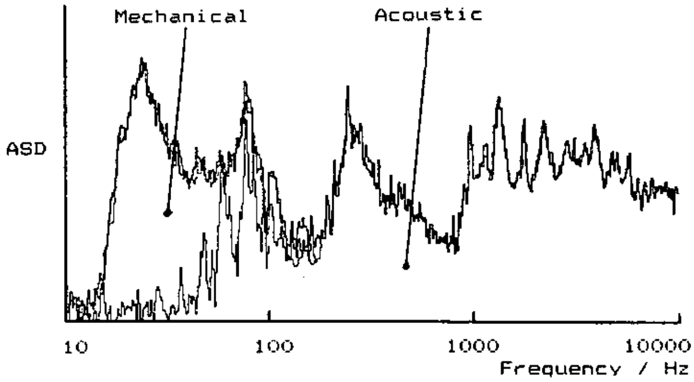

Fig. 3. Typical structural response to vibro-acoustic excitation

Currently we are operating a facility that is capable of applying acoustic noise excitation at levels up to 165 dB re 20 micropascals. This can be applied to 4 missiles at once in a reliability demonstration programme. In combination with mechanical vibration and varying temperatures an extensive range of equivalent flight sortie conditions can be applied in a relatively short time period and more economically than flying aircraft.

This realism in applying test simulations prevents the generation of non-representative failures and enables the development of a product that has a high reliability and is fit for service.

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3 Gaul, L. Wave transmission and energy dissipation at structural and machine joints. Trans. ASME, *J. Vibration, Acoustics, Stress and Reliability in Design*, Vol. 105, Oct 1983.
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5 Spandrio, A M and Burke, M E. Acoustics or shakers for simulation of captive flight vibration. *Shock and Vibration Bulletin*, Vol. 48, Pt. 4, 1978.
6 Sims, D. Acoustic simulation of the flight vibration environment. *J. Soc. Environmental Engineers*, March 1979.
7 Sims, D. Acoustic test methods for environmental simulation. *Proc. SEECO '85* and *J. Soc. Environmental Engineers*, June 1985.

NON-INSTITUTE MEETINGS

1989

23–27 October	ISVR-METRAVIB-TPD-Course, Noise Reduction of Machinery Installations by Vibration Isolation, Noordwijkerhout, The Netherlands.
24–26 October	*Sensors & Systems '89*. Test and Transducer Conference at Wembley Conference Centre. Details from: Norma Thewlis, Conference Secretary, Trident International Exhibitions Ltd, 21 Plymouth Road, Tavistock, Devon PL19 8AU. Tel: 0822 614671.
15 November	*R & D in Vibration Shock and Noise in Industry and Education,* Symposium to be held at Imperial College London. Contact: Secretary, Society of Environmental Engineers, Owles Hall, Buntingford, Herts. Tel: 0763-71209.
27 November–1 December	Meeting of Acoustical Society of America, St Louis, USA. Details: Murray Strasberg, 500, Sunnyside Blvd, Woodbury, NY 11797.
December	European Symposium on Transportation Noise, Braunschweig, FGR. Details from: Deutsche Gesellschaft für Luft- und Raumfahrt e.V., Godesberger Allee 70, D-5300 Bonn 2.
4–6 December	*Inter-Noise 89,* Newport Beach, CA, USA. Details from: Internoise '89, Institute of Noise Control Engineering, PO Box 3206, Poughkeepsie, NY 12603.
5–7 December	BMUS 21st Annual Scientific Meeting & Exhibition, The English Riviera Centre, Torquay. Contact: The General Secretary, British Medical Ultrasound Society, 36 Portland Place, London W1N 3DG. Tel: 01-636 3714.
11–12 December	Third International Noise Seminar, Rio de Janeiro, Brazil. Contact: Organizing Committee, Laboratoria de Acustica e Vibracoes, PEM-COPPE/UFRJ, C.P. 68503, 21.945, Rio de Janeiro, Brazil. Tel: (021) 280 8832 R/412.

1990

February	*Fourth Conference on Hydro- and Geophysical Acoustics,* Rostock, E. Germany.
6–8 March	International Congress on *Recent Developments in Air and Structure Borne Sound and Vibration,* organized by the Dept. of Mechanical Engineering, 201 Ross Hall, Auburn University, AL 36849-3541, USA.
20–22 March	IMechE International Conference on *Engineering – A Quieter Europe,* at the Centennial Centre, Birmingham. Details from IMechE on 01-222 7899.
10–13 April	First French Conference on Acoustics. Details from: Congrès Français d'Acoustique, I.C.P.I. Lyon, 25 rue du Plat (or 31 Place Bellecour) 69288 Lyon Cedex 02, France.
21–25 May	Meeting of the Acoustical Society of America, State College, Pennsylvania.
6–8 June	16th World Congress of the International Association against Noise, AICB, hosted by The National Society for Clean Air, at the Brighton Conference Centre. Details from: National Society for Clean Air, 136 North Street, Brighton, BN1 1RG. Tel: 02273 26313.
19–23 June	Symposium on *Physical Acoustics, Fundamental and Applications,* at the Catholic University Leuven Campus Kortrijk in Belgium. Details from: Prof. O. Leroy, Katholieke Universiteit Leuven Campus Kortrijk, E. Sabbelaan, B-8500 Kortrijk, Belgium. Tel: (056) 21 79 31.
8–10 August	International Tire/Road Noise Conference, Gothenburg, Sweden. Details from: U Sandberg, Swedish Road and Traffic Research Institute, S-581 01 Lønkoeping, Sweden. Tel: +46-13-115200.
13–15 August	*Internoise '90,* International Conference of Noise Control Engineering, Gothenburg, Sweden. Contact: Internoise 90, Chalmers University of Technology, Gothenburg, Sweden. Tel: INT+ 4631 72 22 11
27–31 August	*12th International Symposium on Nonlinear Acoustics,* in Austin, Texas. Details from: Mark Hamilton, Department of Mechanical Engineering, The University of Texas at Austin, Austin TX 78712-1063, USA.
October	*29th Acoustical Conference on Room and Building Acoustics* – Czechoslovakia.
26–30 November	Meeting of the Acoustical Society of America – San Diego, California.

Information relating to meetings of possible interest to readers should be with the Editor at the address on page 1 no later than four months before the date of the meeting.

Noise and Vibration From Railways: A Problem Risen From The Grave?

David Trevor-Jones

London Scientific Services

No major railway construction project has taken place in the UK, apart from the diversion of the East Coast Main Line round the Selby coalfield in 1982, since the end of the 'golden age' of railway construction at about the turn of the century. Railways have become as much a familiar feature of the landscape as trees and terraced houses, the subject of Ealing comedies, the butt of commuters' wrath and comedians' humour; in general the British public has learned to live with railways and has come to see them as a benign, perhaps reassuring component of the environment. Or has it?

Noise complaints

Notwithstanding research which has shown that in Europe (though not in Japan where the history and role of the railways and therefore social attitudes towards them are apparently different) people are generally more tolerant of railway noise than of noise from any other form of transport, the number of complaints received by environmental health departments seems to have increased significantly in recent years. Furthermore, the Channel Tunnel development and increasing use of the railway system, especially in the South East, are now beginning to spawn reopenings of lines which had previously been closed to passenger traffic and are leading to proposals for the construction of entirely new lines on a scale not seen since the nineteenth century.

Vibration complaints

Along with complaints about noise have come a great many complaints of vibration from trains. While the new generation of BR passenger trains, typified by the 'Wessex Electrics', are very much quieter than anything that has run on BR tracks to date, the construction boom in the South East has given rise to the transport of aggregates in huge tonnages on a greater scale than for many years, in trains which are among the heaviest ever to have been run in Britain. Since the ground vibration generated by a moving train is a function of its axle loading, among other things, the passage of these heavy aggregate trains over minor routes has introduced quite serious vibration to lineside areas which had previously enjoyed a peaceful existence.

The broad picture, then, is one of increasing levels of rail traffic which is probably quieter on the whole than trains used to be, but some of which generates more vibration. Especially in urban and suburban areas people are disturbed by new vibration and seem to be less tolerant than they use to be of the noise from their local railways. The residents of towns and villages along the proposed high speed Channel Tunnel Rail Link have caused something of a political storm by vigorously drawing attention to the effects which they perceive that the new high speed trains might have on their hitherto peaceful environment. What scientific and legislative remedies are available to mitigate the adverse effects, and how much do we know about them?

Measuring standard

The first need of the environmental health officer or consultant is for some consistent way of measuring or predicting the noise or vibration and then for an objective standard or guideline with which to compare the results of the exercise. Ideally, the standard should give a clear indication of what would be acceptable to the average person and what would be unacceptable. It should, therefore, be expressed in terms that reflect the average person's perception of the source noise or vibration. British Rail responded to the public furore over the noise implications of the rail link through Kent which killed the 1974 Channel Tunnel proposal by commissioning a survey of community response to railway noise from the Institute of Sound and Vibration Research (ISVR) at Southampton University. The result, published by Fields and Walker in 1982[1] was that the A-weighted equivalent noise level L_{Aeq} (24 hour) dB(A) was as good a parameter as any to reflect disturbance. They did not suggest a critical value, but the GLC had adopted 65 dB(A) some years earlier and this criterion stood, widely recognized and adopted, as the best available for assessing railway noise at lineside façades for many years. Recently, however, Walker has supplemented the original ISVR report with the publication of proposals for criteria[2]. On the basis of a comparison of the annoyance arising from levels of road traffic, aircraft and railway noise he has proposed that a value of 70 dB(A) (L_{Aeq}, 24 hours) external is 'tolerable' at façades affected by railway noise, but concedes that a lower level might be appropriate at night and that the 'clearly acceptable' level is some 5-10 dB(A) below the suggested 'tolerable' value[3].

Disturbance at night

There are many who feel that there should be some sort of criterion to protect the residents of lineside dwellings from disturbance at night. This argument is especially persuasive when referred to situations where the traffic distribution is strongly skewed towards the night-time period, as is likely to be the case, for example, on the freight routes from the Channel Tunnel through Kent, Surrey and London. Because the density of passenger traffic to and through the tunnel is likely to be so high during the day much of the freight movement will be at night. Freight trains not only tend to run with higher axle loadings and are therefore more potent sources of vibration than modern passenger trains, but also tend to be a good deal noisier. One is instinctively attracted to the concept of a split day/night criterion, despite the conclusion drawn from the original Fields and Walker study that no such special consideration of night-time noise is warranted. LSS is responding to this perception in its reworking of the GLC Noise and Vibration Guidelines, due to be published later this year. Although the 65 dB(A) L_{Aeq} 24 hour criterion is likely to be retained it will probably be augmented with separate day and night 'action levels' for new railway lines affecting existing dwellings and with similarly dichotomous 'design criteria' for new buildings planned for lineside sites.

Intermittent vibration assessment

Intermittent vibration is more difficult to measure than noise and until recently was very difficult to assess. Although a British Standard (BS 6472:1984) for assessing vibration in buildings exists it is ambiguous and limited in its scope with respect to discrete but irregular events such as vibrations from trains.

The problem is that different trains produce rather different event profiles, depending on their speed, length, axle loading, suspension design, general condition and so on, and the Standard does not satisfactorily address this kind of situation. It is ironic that a noise standard has been generally accepted (until, that is, perceptions of the type of nuisance that might be caused by the Channel Tunnel high speed passenger and night time freight traffic led to calls for separate day and night standards) despite the absence of any BS or legislation, while vibration has remained a contentious issue despite the existence of a BS.

New technique

Fortunately the development of a new analytical technique has provided a useful and, on the basis of a limited amount of investigation, an effective method of assessing such variable, intermittent events with respect to their acceptability to an affected population. Vibration dose values (VDVs), developed by the Human Factors research team at ISVR and defined in BS 6841:1987, cannot yet be directly measured using generally available proprietary equipment but estimated dose values (eVDVs, also defined in BS 6841) can quite easily be obtained by using a conventional dedicated vibration meter and accelerometer. The estimates are reasonably accurate within quite wide frequency limits[4].

The advantage of eVDVs is that they take full account of the distinctive characteristics of every vibration event, and, once calculated, can be added together in any combination to obtain cumulative values for different situations. In this sense they might be thought of as the vibration equivalent of SELs. An effective limiting cumulative dose over a defined period should be obtainable from manipulation of the existing criteria given in BS 6472, so that both a flexible parameter and an effective method of assessing measured values are now potentially available. This technique for vibration assessment will really come into its own when the next generation of direct reading equipment becomes available, but is already useful.

Remedies

So, means of assessing and anticipating complaints about railway noise and vibration are available; what about remedies?

At present there are no statutory regulations for compensation or any other sort of legal remedy to be made available to people affected by railway noise, whether generated from new lines or from existing ones. British Rail has maintained that it, like other promoters of business, is subject to the provisions of the Control of Pollution Act but there seems to be an understandable reluctance among local authorities to act against BR, a statutory undertaker charged with a duty to run an efficient service by the provisions of the Transport Act 1962, with respect to nuisance arising from the running of trains.

However, BR has publicly stated that it will adopt a policy similar in effect to that of the Noise Insulation Regulations covering traffic noise from new roads which will allow for the mitigation of noise disturbance from the Channel Tunnel Rail Link (CTRL). In a brief summary leaflet distributed to properties along the proposed route BR stated that it will act to reduce noise or mitigate its effects where a level of 70 dB(A) L_{Aeq} (24 hour) is exceeded (presumably as measured or predicted at affected façades). Additionally it is stated that compensation may be payable under the terms of the Land Compensation Act to people whose property is reduced in value as an effect of an increase in noise. More doubt might be cast on the willingness of private sector developers to offer equivalent compensation to residents along new rail link routes if not compelled by law to do so.

Important principle

The introduction of Regulations under the Land Compensation Act would clearly define the terms for compensation, similar in effect to those provided by the Noise Insulation Regulations 1975 for road developments which are likely to cause significant increases in noise affecting occupiers of premises along the route. This idea has been promoted by a number of authorities from Selby District Council when faced with the main line diversion in the 1970s to the Kent authorities once again confronting high speed rail link proposals in the late 1980s. Apparently the government has at last taken notice and new regulations covering railway noise are in preparation.

Unfortunately there is an important principle which the DTp/BR side has in the past rejected out of hand, that the current Regulations applying to road traffic noise are triggered when a significant improvement to a road results in a greater traffic flow as well as when an entirely new road is built. Because a railway has a considerably greater inherent capacity (and few in Britain are operated to the maximum) it is possible to increase the traffic flow rate enormously without carrying out any physical improvement work (other, perhaps, than to signalling). Effectively it is possible to convert a line carrying the equivalent load to a minor country lane to one carrying the equivalent to a trunk road without altering it. If a similar increase in traffic was to be planned for a road, alteration work would almost certainly be involved and the Regulations would be triggered but the DTp/BR will not countenance any such suggestion that increases in noise through intensification of use of rail routes should attract compensation.

The Kings Cross Bill which will enable the construction of the second Channel Tunnel London terminal is before parliament now; the Bill to enable the construction of the CTRL through Kent is expected to follow in the next session, and it seems likely that the Transport Secretary will accede to the recommendations of the Central London Rail Study and give the go-ahead for a new phase of railway construction in and around the capital. In addition rail based light rapid transport schemes are set to go ahead in several other towns and cities. The arguments sketched out in this article will no doubt receive a thorough airing during the months ahead as progress is made by the local authorities and consultants involved towards the formulation of more sophisticated noise criteria, greater understanding of and a standard for vibration dose measurements and interpretation of draft regulations.

(Reproduced from the Spring 1989 issue of the London Environmental Bulletin, *and updated by the author.)*

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3 Walker, J G (1988), A criterion for acceptability of railway noise. *Proc. Inst Acoustics 10*, (8), 195–199.

4 Griffin, M J (1986), *Evaluation of Vibration with Respect to Human Response.* SAE Technical Paper Series no. 860047 (reprinted from P-147 Passenger Comfort, Convenience and Safety; Int. Congress and Exposition, Detroit, Mich., Feb. 24-28, 1986).

Conference Organizers

Please remember to send Abstracts of your Conference to the *Bulletin* Editor for publication, at the earliest possible date, to: 14 Witney Road, Long Hanborough, Oxon OX7 2BJ.

isvr Short Courses 1990

20-22 March	Noise Measurement and Instrumentation
20-22 March	Condition Monitoring
26-30 March	Clinical Audiology
26-29 March	Image Processing
2-4 April	Active Control of Sound and Vibration
18-20 April	Engineering Applications of Statistical Energy Analysis
April	Adaptive Signal Processing
April	Digital Audio Signal Processing
June	Applied Digital Signal Processing
9-13 July	Noise Control for Engineers in Processing Industries
9-13 July	Practical Course in Community Noise and Vibration
17-21 September	19th Annual Advanced Course in Noise and Vibration
September	Technical Audiology
September	Introduction to Mechanical Vibration Measurement Techniques
September	9th Annual Engine Noise and Vibration Control Course

Further information from: ISVR Conference Secretary, Institute of Sound and Vibration Research, The University, Southampton SO9 5NH. Tel: 0703 592310.

Anti-sound Expert Honoured

John E Ffowcs Williams, the Rank Professor of Engineering at Cambridge University, has been elected a Foreign Honorary Member of the American Academy of Arts and Sciences.

Internationally recognized for his pioneering work on the generation and control of aero and hydrodynamically generated noise, Professor Ffowcs Williams' theoretical work forms the foundation of much of today's work on the subject. He also led the research team tackling the Concorde noise problem twenty years ago.

In recent years he has broken new ground in the science of anti-sound: the creation of sounds in anti-phase to noise, which enables undesirable noise to be cancelled out. An anti-sound silencer was installed by British Gas to deaden exhaust noise at their gas turbine compressor plant at Duxford, Cambridge. The professor's current work extends these ideas to the control of unsteady flows.

Professor Ffowcs Williams is one of the pioneer academic entrepreneurs of the Cambridge Phenomenon, founding Topexpress, an international computer consultancy, in 1978. He is chairman of Topexpress, and a director of its parent company, VSEL Consortium plc.

Copy for the *Bulletin*

Contributions and information for the January 1990 issue of *Acoustics Bulletin* should reach Marjorie Winterbottom at 14 Witney Road, Long Hanborough, Oxon OX7 2BJ, no later than Wednesday, 22 November.

Lucas CEL Courses 1989/90

The following courses cover the use of instrumentation in the Environmental, Industrial and R&D sectors for the period November 1989 to August 1990.

This is a significant period as it spans the introduction of new noise regulations. From 1 January 1990 businesses which generate noise during manufacturing processes will have to be aware of two new thresholds for noise – 85 dB and 90 dB. How these levels are calculated and what actions are required are covered by a CEL course.

All of the courses are notable for their emphasis on theory and practical 'hands on' experience, achieved by providing a wide range of CEL and Datalab equipment together with the expertise of qualified engineers.

At the end of each course, every delegate will be provided with extensive course notes and a Certificate of Attendance.

Numbers are strictly limited to enable delegates to derive the maximum benefit from each course. It is advisable therefore, to book places in good time.

Course Title	1989	1990
Environmental Noise – Standards and Techniques	10 November	16 March; 27 April
Sound Power – Measurement and Applications		30/31 August
Instrument Workshops		
Sound level meter	24 November	30 March; 1 June
Environmental Noise Analyser	8 December	12 April
Industrial Noise – Measurement and Control	21/22 November	22/23 March
Industrial Noise – 1990 and New Regulations	8 November	9 March; 4 May
Data Acquisition and Digital Signal Processing		19/20 April
Building Acoustics		23 February

For further information please contact: Mrs Melanie Pugh, Lucas CEL Instruments Ltd, 35-37 Bury Mead Road, Hitchin, Herts SG5 1RT. Tel: 0462-422411.

Minister promises help for hearing aid users

There was a major breakthrough in July in the national campaign for better hearing aid services.

In a Parliamentary written answer to the 'Fair Hearing' campaign of The Royal National Institute for the Deaf, Roger Freeman MP indicated the Government's commitment to developing a quicker and more accessible munity-based service. He promised Department of Health backing for community delivery of hearing aids via direct referral schemes – enabling NHS patients to be referred by their GPs direct to the audiology service for a hearing test and fitting. Health Department officials have been asked to draw up plans for the next financial year.

Plans also include the development of a national qualification in audiology, identifying the necessary skills, and closer cooperation between NHS audiologists and private dispensers, with built-in safeguards for the patient.

Up to four million people could benefit from the junior Health Minister's pledge to re-vamp hearing aid provision throughout the UK.

BRANCH AND GROUP NEWS

London Branch Meetings

Visit to London City Airport

On 22 February, thirty people were involved in the branch visit to London City Airport. The meeting was held in the well-equipped Business Centre. Bill Charnock, Managing Director of Mowlem Airport Projects welcomed the delegates to the meeting and outlined some of the factors which had attracted Mowlem to develop in the Docklands area and their aspirations for future development on the site. Phil Norris, the Airport Development Manager, displayed his extensive knowledge of the STOLport as he conducted the delegates on a tour of the facilities. This included an inspection of the apron (after the necessary security checks), where we watched the take-off of a Dash 7 destined for Paris.

After tea, technical papers on the theme 'Community reaction to aircraft noise' were presented by three invited speakers. Dr Bruce Critchley presented a paper entitled 'Reaction of the community to noise from major airports', in which he explained the role of CAA, reviewed the history of aircraft noise indices and summarized the findings of the United Kingdom Aircraft Noise Index Study, 1985, and the Commission of the European Communities Joint Study of Community Response to Aircraft Noise, 1984. Dr John Walker's paper, 'Reaction of the community to noise from general and business aviation', summarized the Department of Transport Study of Community Disturbance Caused by General and Business Aviation Operations, conducted in 1988. Finally, Mr Mike Smith of Rolls-Royce Aero Engines Division presented a paper entitled 'The implications of community reaction to aircraft noise on the engine manufacturer', in which he reviewed developments in engine design and fleet growth and discussed the choice of noise exposure indices and their effect on future projections.

The papers stimulated a lively discussion session which was chaired by John Simson of London Scientific Services who is Chairman of the London Branch. The attitude of the public to aircraft was considered to be changing – though the increased awareness of environmental problems would perhaps be offset by the increased accessibility of air travel to the general public. The sensitivity of the public to noise at night was discussed. All the surveys have looked at situations where there are relatively few night movements. Though there is no evidence that a night weighting is needed, an increase in night movements might upset the relationship established between community response and 24 hour L_{eq}. Airports appear to have only two possible choices to cope with increasing volumes of passengers; either night movements must be increased or bigger aircraft used. There was some discussion on the small percentage of people who are apparently always disturbed. Do they exist, or are they a by-product of the survey method?

The formal proceedings were brought to a close at 6 p.m. and dinner was served to the delegates in the Airport Brasserie.

John Millar

Computerized Sound Level Measurements

On 15 March a small band of London Branch members attended an excellent talk by Bob Selwyn, the UK Sales Manager for Lucas Cel Instruments Ltd. The talk covered the new Cel-238 Secondary Processor which is a multi-task machine capable of accepting data from a variety of sound level meters and presenting it in a number of formats. The secret of its adaptability lies in a series of program cards which have been developed especially for the instrument. Resembling a standard credit card in size, they can carry a program to suit almost any measuring task. The instrument incorporates a printer for instant on-site hard copy, or the data can be downloaded to a PC at a later date.

Bob also showed the latest addition to the Cel-262 environmental noise analyser which utilizes the lid to store the data which can then be downloaded to a PC. It is said to be the most expensive lid on the market: but an inexpensive method of storing data.

Ken Scannell

Vehicle Noise and Vibration

On 19 April the London Branch held its first meeting in the new venue at Great Guildford House, 30 Great Guildford Street, London SE1. This may be the reason why only a few members found their way to the evening meeting.

However, a very interesting talk was given by A V Phillips from Fords Advanced Vehicle Concepts Group at Dunton in Essex. Mr Phillips described some of the many airborne and structure-borne noise sources that Fords are working to reduce. The noise can be generated from the engine, drive train, exhaust, tyres, fans as well as external air movements.

Fords are working on both the sound insulation, and sound absorption within the car and using sound intensity contours, active noise methods and holographic techniques.

The noise annoyance within cars is taken very seriously. Measurements are made with tape recorders utilizing a binaural head. The tapes are then used to obtain subjective, paired comparisons from listening panels. These results are analysed using Kurtosis methods and r.m.q. (root mean quad) which places the emphasis on impulsive sounds; particular attention is paid to the 100–200 Hz boom which causes tiredness on long journeys.

Ken Scannell

Auditory Demonstrations

The second evening meeting of the London Branch to be held at the new venue featured Ken Scannell and

Richard Clough, from Wimpey Laboratories Limited, on 17 May.

They presented a Compact Disc which was issued jointly by the Acoustical Society of America, the Institute for Perception Research, Holland and Northern Illinois University. (Permission to play the disc was obtained from Phillips Ltd.)

The demonstrations, covering hearing perception and auditory effects, included sections on:

Frequency analysis and critical bands
The decibel scale and loudness scaling
Masking
Pitch and auditory illusions
Timbre and beats

Most members attending the meeting agreed that it was very useful to hear some of the wellknown acoustic phenomena that we read and speak about, but probably do not hear under controlled conditions.

For further details on the Compact Disc members should contact the Acoustical Society of America, Woodbury, New York 11797 or Ken Scannell at Wimpey Laboratories, Hayes, Middlesex (01 573 7744 Ext. 349).

Ken Scannell

Southern Branch

Active attenuation of noise in enclosures

On 14 June, some 35 Southern Branch members *et al.* attended Phil Nelson's splendid presentation of the state of the art in the active control of noise in enclosed spaces.

After a lucid outline of the principles and mechanisms involved, the talk turned to a description of the techniques that have been developed for reducing total sound intensity inside the enclosure. As far as performance is concerned, most success was to be found in the cancellation of the longer wavelength room modes, just the area, in fact, where conventional passive noise control methods are least effective.

Energy could be controlled in high frequency and diffuse fields but only over very limited volumes of the enclosed space. Typical regions where attenuations of, say, 10 dB could be achieved were spherical volumes of $\lambda/10$ diameters. At 1 kHz for example, that space would be 3.4 cm across. The improbability of workers in industrial environments being able to keep their heads that still brought considerable cheer to the designers and suppliers of factory absorptive treatments and acoustic enclosures present – their services will be required for some time yet!

Indeed, that was one of the messages of the meeting. Active attenuation comes into its own for noise fields where passive noise control is either ineffective or at best very inefficient. Just how effective active attenuation could be was amply demonstrated by the result of two projects which Phil Nelson and Steve Elliott are working on. The first was the control of 'boom' in a sports car body cavity. By gearing the frequency of the cancellation signal to engine speed, it was possible to reduce the intensity of the enclosure modal frequencies by up to 15 dB over a wide range of vehicle operating conditions.

The second project described was the reduction of propeller noise inside an aircraft cabin. After a detailed analysis of the behaviour of the fuselage shell and its internal sound field when excited by propeller blade passing frequencies, it was found possible to determine an array of sensing microphones and secondary sources which would significantly reduce the intensity of the lower order cabin modes. Flight tests had shown general cabin noise reductions of some 14 dB at the fundamental frequency, and around 4–7 dB at higher harmonics.

The highlight of the evening was a demonstration, arranged by Steve Elliott, of the subjective impression of effective control in a mock-up of a fuselage section. The effect of switching on the active system whilst standing inside the enclosure can only be described as remarkable. After that experience, no one had any doubts of the potential of the work being carried out at Southampton on active noise control.

I Sharland

Visit to TRRL, Crowthorne

Approximately 25 people enjoyed an interesting afternoon at TRRL on 3 May last. The visit included a tour of the site, with a trip around the figure-of-eight research track, including the banked bend.

A film covering the research carried out by TRRL was followed by a presentation by Dr G R Watts on the vibration studies carried out by the Vehicle and Environment Division. Dr Watts detailed the results of a national survey on vibration disturbance, which found that up to 37 per cent of the adult population were affected by vibration, with up to 8 per cent severely affected.

A TRRL study was covered in which the possible link between traffic-induced vibrations and building damage was examined. This involved the exposure of an unoccupied house to simulated traffic vibrations.

A stimulating and enjoyable afternoon was had by all.

Rose Green

North West Branch

Evening Meeting

On a hot summer's evening in June, 23 members attended a presentation at the Building Design Partnership in Manchester. The meeting started with a delicious buffet followed by presentations of recent projects in environmental and building acoustics.

Duncan Templeton gave an overview of the work, describing projects ranging from the *Daily Express* Offices in Manchester to the new RAC building near the M6. He emphasized the range and international nature of the work with projects all over the world. Small projects such as practice rooms for music in schools were just as important as the work for the Royal Opera House in London. Closer to home, Duncan described the work involved in the design of the new Albert Halls in Bolton.

Jo Webb gave a presentation on the

Letter from the Vice-President Groups and Branches

One of the aims and objectives of Branches listed by the Council Committee appointed in 1981 to define Institute policy towards Groups and Branches was 'To provide a forum for local discussions on the business and professional needs of the Institute'.

I think that objective has been and continues to be met by the active Branches. There are, however, a good many members, especially in areas away from local centres, who never get the opportunity to meet other members to discuss IOA business or acoustics matters in general other than at formal meetings.

Recently I was contacted by a member in South Wales who wanted to be put in touch with other members in that area so that they could discuss local acoustic issues. I was able to pass on the information with the hope that they might get together to arrange an informal group of members which might help promote IOA activity in the area. There are too few members in South Wales to form a separate Branch and the area is allocated to the presently inactive South West Branch. Perhaps there are other local concentrations in that branch's catchment area where members may wish to get together. Any volunteers?

Indeed I would like to hear from any member who thinks there might be some advantage in this idea, particularly if he or she lives in an area remote from the main branch centres.

Geoff Kerry

design and construction of the new rash of multiplex cinemas currently spreading all over the country. She explained how each room was finished to reduce flutter echo and described in detail how the dividing walls were constructed to give adequate sound insulation. Problems with flanking have to be overcome by great attention to the design and construction of doors, door seals and roofing. Finally Jo discussed the results of field tests on the wall panels which were surprisingly good within many RW values lying within 1 dB of the manufacturers' measured laboratory results.

Peter Sacre discussed environmental and planning type projects, in particular the construction and layout of the Folkestone Terminal for the channel tunnel. He described how he assesses the noise control requirements by carrying out noise predictions using a computer model developed by David Leeming. Peter and David then demonstrated a range of computer modelling packages developed over the past few years. Of particular interest was a model which showed the effects of the introduction of barriers to provide adequate screening from noise.

The final presentation was made by Bob Davis who described the design work for the *Daily Mail* printing building; this is situated in the recently developed London docklands. The printing building contains many noisy presses that run between 10 p.m. and 4 a.m. The problem was to reduce the noise levels to an acceptable level for the residents of the expensive housing sited as near as 150 m from this large building. Bob described the design approach; firstly an external noise survey which gave a night time L_{90} in the region of 38 dBA. Measurements were then made on the German printing presses which could well produce 96 dBA in the pressing hall. As the building had to be of light and relatively cheap construction, it was clearly going to be a problem to get adequate sound attenuation. Bob illustrated the use of computer modelling to calculate the noise radiation and investigate the effects of different types of cladding material. Finally he described some of the more interesting problems associated with this complex building, and was happy to report on the final success of this project.

Mike Ankers thanked our hosts for an interesting evening and discussions followed whilst we finished the buffet.

Chris Waites

Southampton Students Acoustics Society

The Southampton Acoustics Society was formed in 1987 by a small group of undergraduates. For the 1988/9 Session, most of the 26 members were undergraduates, but there was also a small MSc membership.

The SAS arranged trips to, and visits from various companies. These included Naim Audio, the National Physics Laboratory, Cirrus, ARE Portland (Underwater Acoustics), Sound Attenuators Ltd, Acoustic Technology Ltd, and Sound Research Laboratories. The committee also involved itself in helping to organize interviews for finalists, and presentations from visiting companies.

Also popular were the trips to our three favourite watering holes, sometimes being driven there in the Engineering Faculty Society's ancient 'Toastrack' coach.

Increased contact with industry led to more awareness of the areas it is possible to enter from this degree. The trips and visits gave the students who took advantage of them an insight into many fields of work, including acoustic consultancy, community noise, acoustic instrumentation, electroacoustics, underwater acoustics, and noise and vibration control of turbines, engines and aircraft.

The 1988/1989 committee consisted of Claire Herbert (President), Susan Boyle (Secretary) and Stephen Marvin (Treasurer), and these three were helped by one representative from each year.

Good luck to the society in the future!

Claire Herbert

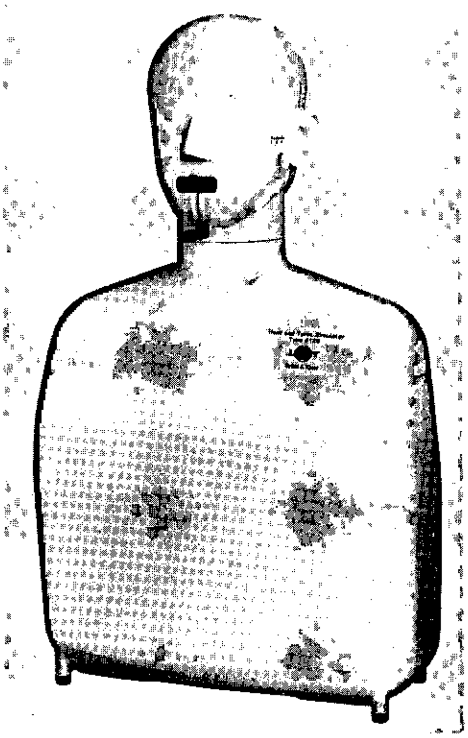
New Products

Submissions for inclusion in this section should be sent direct to J W Sargent, Building Research Establishment, Garston, Watford WD2 7JR.

Head and torso simulator aids

Available from Bruel & Kjær is a head and torso simulator with a wide range of applications in evaluation of electroacoustic devices and determination of building and automotive acoustics.

Applications include simulated *in situ* and insertion performance measurements on telephones, headsets and hearing aids, evaluation of hearing protectors and close-talking or noise-cancelling microphones, investigation of room acoustics and speech intelligibility, and stereo sound-field evaluation. The simulator is ideal for automotive investigations, such as quality of audio systems and effectiveness of noise control measures, because it permits accurate reproduction of the interference in the sound field produced by head and body of the driver and passengers. Physical dimensions and acoustical performance conform to the requirements of ANSI S3.36–1985 and IEC 959.



The manikin accurately simulates the acoustic field around a human head and torso. It also features a built-in low-distortion mouth simulator which closely replicates the sound field generated by the human mouth, including the frequency-dependent motion of the acoustic centre in the frequency range which is important for testing noise-cancelling microphones. A calibrated ear simulator complying with IEC 711 and ANSI S3.25 is supplied as standard, with the option to add a second ear to enable measurements to be made on two ears simultaneously.

Realtime Frequency Analyser Type 2143

Bridging the gap between the best of Bruel & Kjær's sound level meters and the company's top-of-the-range 2123 realtime signal analyser is the new, portable Type 2143 Realtime Frequency Analyser.

The 2143 provides analysis down to 1/24 octave, in realtime, in the field Large internal memory plus disk storage allows for storage of set ups and reference data for field use. Measurements can be analysed on the spot, or downloaded back at base into a computer for more exhaustive analysis. The 2143 weighs less than 22 lb and is weather resistant, with a battery life in excess of four hours.

B&K report great interest in the new instrument, launched at a series of seminars at various UK venues between October 16 and 20.

Sine/noise generator Type 1054

The high-accuracy Type 1054 sine/noise generator with a frequency range from 0.01 Hz to 2.54 MHz is designed for automatic test and calibration of electrical and mechanical equipment in product design, development, production and service applications. The generator is also eminently suitable for swept-frequency measurements in electroacoustic and building acoustic applications, vibration testing and audiological research. Narrowband, pink and white noise outputs are available.

The Type 1054 meets today's requirements for spectral purity and stability, offering a calibrated output from 1 mV to 5 V with better than −60 dB harmonic distortion. Amplitude linearity is ±0.1 dB in the 20 Hz to 20 kHz range. A built-in compressor provides 118 dB of 'live' amplitude regulation for active control of sound or vibration level at the exciter output. The user can select linear or logarithmic sweeps in either single, repetitive or continuous sweep modes, with sweep rate and delay adjustable over wide ranges. A seven-decade frequency sweep in one continuous range is available with presettable lower and upper limits. A built-in 5 MHz crystal clock can be used as a test system master clock or synchronized with an external clock.

The generator is designed for ease of use, featuring a powerful IEEE interface, storage for up to nine frequently-used configurations, and 40-character front panel line display of four control functions.

Remote control of level, X–Y and graphic recorders enables synchronous recording of amplitude, phase and distortion responses. Storage is also provided for a 1024-point amplitude weighting, for equalizing non-flat transducer responses or non-linear circuit behaviour. Complex amplitude weightings are quickly entered either manually by means of an automatic interpolation feature, or learned in conjunction with the built-in compressor.

For further information contact Les Minikin, Bruel & Kjær (UK) Ltd, 92 Uxbridge Road, Harrow HA3 6BZ. Tel: 01-954 2366. Telex: 934150 BK UK G. Fax: 01-954 9504.

Audio precision system one

This system from Island Acoustics provides a full set of audio measurements controlled by an IBM PC, AT or clone. Menu driven software provides multi-parameter tests which can be further linked into complex procedures including go/no-go limits. In R&D System One allows the unit under test to be examined in detail using graphical or tabular displays, while in production results can be limited to pass/fail. Swept measurements include noise, frequency response, CMRR, THD+N, IMD, 1/3 OCT band filtering, phase, crosstalk, W&F and polarity. The instrument's residual noise of $<1.5\ \mu V$ (−114 dBu) over a 22 kHz BW permits examination of DAC and ADC performance up to 20 bits linearity. The generator provides sinewaves with <0.005% (−106 dB) THD over a level range from −90 dBu to +30 dBu. Squarewaves, sine burst and twin-tone test signals are also available from 10 Hz to 200 kHz. System amplitude flatness is better than ±0.05 dB over the audio band.

Audiograph

Island Acoustics announces the Audiograph modular audio/acoustic test system from Neutrik AG. Audiograph consists of a mainframe and a series of plug-on modules providing a variety of test features. The mainframe includes the system power supply and a chart recorder using industry standard 50 mm charts. A basic system usually includes an input module and an output module. The output module provides a logarithmic or linearly swept sinewave or warble tone over the frequency range 20 Hz to 40 kHz. The input module can be connected to any external source and provides a pre-amp and powering for Neutrik's own precision ¼-inch and ½-inch microphones.

Further modules provide phase and group delay measurement, switchable 1/6, 1/3 or 1 octave bandwidth tracking input and output filters; filtered noise output; compressor; frequency expanding module; and synchronizing module for remote measurements. Configuration is easy since most of the required interconnection takes place automatically over the system bus. Accessories include microphones, an artificial ear to IEC Rec-303 and empty module housings for custom requirements.

Island Acoustics provides a complete support service including customization. Recent projects include a 1/12 octave offset tracking filter for swept measurement of loudspeaker distortion products.

For further details contact Sam Wise, Island Acoustics, 25 Crossfield Avenue, Cowes, Isle of Wight PO31 8HN. Tel: 0983 297780. Fax: 0983 294704.

LMS Computer aided dynamic analysis

The LMS Computer Aided Dynamic Analysis system for Unix (CADA-X) workstations has recently been enhanced by the addition of two new modules.

In the acoustics area there is now a very comprehensive suite of programmes. The facilities offered include support of multiple microphone intensity probes and microphone arrays. Data are acquired in a similar way to LMS Modal. Display options include coloured iso-lines, animated modes and moving vectors. Computed values include total sound power, peak power and power through any area. For rotating machinery analysis LMS have introduced a signature package. Acquisition techniques include

1 normal block input, i.e. sampling as fast as possible, the tracking parameter being time;
2 taking blocks at specified intervals using a fast counter;
3 phase locked tracking;
4 adaptive order tracking which ensures accurate higher orders have been implemented.

For the Hewlett Packard 3565S systems a unique implementation of an entirely new digital filtering algorithm has been used. This results in extremely fast order computation and the ability to follow almost any run up, no matter how fast.

For further information please contact Alan Bennetts, LMS UK Ltd, Cheddar Industrial Park, Wedmore Road, Cheddar, Somerset BS27 3EB.

Maximum length sequence systems (MLSSA)

Windmill Munro Design Limited announce their appointment as distributors and consultants for MLSSA, a new sound measuring system from DRA Laboratories. MLSSA, pronounced 'Melissa', is short for Maximum Length Sequence Systems Analysis.

It provides a rapid means of acquiring the complete impulse response and transfer function of any audio or acoustic system. MLSSA overcomes many of the problems associated with standard impulse tests and complex methods such as Time Delay Spectrometry by utilizing the power of PC compatible computers together with a unique hardware package which fits into any standard expansion slot.

The system as supplied can be preprogrammed to give a series of standard room analysis routines. If required recording studios may return test discs for further analysis and recommendations. This is made possible by virtue of the fact that one single measurement defines the entire impulse response of the room under test and all data are subsequently obtained by post processing.

The entire MLSSA system is menu driven.

Further details, brochure and demonstration disks may be obtained from Windmill Munro Design Ltd, Warehouse D, Metropolitan Wharf, Wapping Wall, London E1 9SS.

MISCELLANY

EBIS move to new premises

EBIS Ltd, the suppliers of thermal and acoustic insulation, are celebrating their tenth anniversary with a move from Willenhall in the West Midlands to new and larger premises in Bloxwich.

Founder and Managing Director Adrian Bevan says that growth over the last two years has enabled them to make this move, which increases the available floor area to 14,500 sq. ft. This will enable the company to fulfil the requirements of customers in the thermal and acoustic insulation industries.

New Company address: EBIS Ltd, Fryers Close, Bloxwich, West Midlands WS3 2XQ. Tel: 0922 710727.

Ivie sound analysis products

Smart Acoustics Ltd have recently been appointed European sales and service centre for Ivie sound analysis products (formerly Cetec-Ivie).

PIPAC – Puslation Simulation

PIPAC (PIPework ACoustics) is the service provided exclusively by Accent Systems (formerly ICI Acoustics) to oil companies, engineering contractors and compressor manufacturers to simulate the effects of excessive compressor pulsations in pipework (as required in API 618).

Accent have announced that their suite of programmes is now available to run on their in-house VAX mainframe computer. This means that for particularly complicated projects, Accent can use their traditional link with the ICI Engineering computer centre in combination with their own computer facilities such that large and complex pulsation simulations can now be undertaken with short turnround times.

By speeding up the simulation, Accent believe that clients need no longer wait lengthy periods before having piping designs cleared for manufacture.

Further information from: Andrew Corkill, Consultancy Group Manager. Tel: Biggleswade (0767) 318871.

Alfred Peters Limited

In August this year, the Scientific Measurements Group took over Alfred Peters Limited.

Originally formed in Sheffield in the 1950s, Alfred Peters & Sons became part of the Meditech Group in 1984. As Alfred Peters Ltd, the firm will continue production of most of the existing range of instruments, and a new computerized instrument is expected to be announced in the last quarter of 1989. Support will be maintained for Peters instruments in the field and a full range of spares will remain available. Both Cirrus Research and Delmart also manufacture audiometers and while the Cirrus Research range of screening audiometers will remain, the Delmart range will, in future, become part of the Alfred Peters catalogue.

Jack Hawksworth, an engineer with Alfred Peters since 1968, has been appointed Commercial Director and Terry Goodrich, who has been with them since 1971 – latterly as Chief of Test, is the Engineering Director.

ANC REPORT

Association members have continued to be engaged in a wide variety of consulting briefs worldwide. The ANC report in the April issue of *Acoustics Bulletin* described some activities in building acoustics and concert hall acoustics in which members have been involved.

ANC members cover a wide range of acoustics interests and expertise. At the dirtier industrial end of the spectrum of work, some recent projects have included the investigation of potential noise nuisance from an adhesives factory, which proved to be inaudible, and assistance with a planning application for the extension of a stone sawing works. A common thread linking these projects and many others is that the processes being carried on in the works are relatively quiet and in themselves unlikely to be a justifiable cause for complaint. Unfortunately road transport and loading operations are also necessary and it is the movements of these vehicles which are far more likely to cause annoyance, not only due to noise.

At least one member is involved in research into applications of Statistical Energy Analysis to engineering problems. The SEA technique has been around for many years and was used for ship noise prediction in its early days. However, until fairly recently practical applications do not seem to have been energetically pursued outside Universities. With the ever-increasing availability of computing power at lower prices, SEA now appears an attractive proposition for the prediction of noise and vibration propagation in structures such as aircraft and road and rail vehicles. There is still some way to go in defining and understanding the propagation of vibration through complex structural junctions such as are found in vehicle structures. Current technique development efforts are being applied to exploring the limitations of SEA methods when applied to real situations.

Textile machinery vibration problems have occupied the interest of one member. This is another area of constant development, where the commercial need to extend the process possibilities stretches the capabilities of the machinery involved. Machinery speed and size has been increased over the years but the requirement for longer and longer lives between overhaul has also increased, so extra attention must be paid to vibration, both as an indicator of machinery and process condition and as a cause of machinery degeneration.

The ANC has recently given its views to DOE on consultation documents on Noise from Audible Bird Scarers and Noise from Clay Pigeon Shooting, both activities which have little impact on the majority of town dwelling UK citizens.

The joint IOA/ANC meeting on 'The Acoustical Consultant' has been held since the last *Bulletin* report. Attendance at this meeting was rather disappointing. Perhaps this is an indication of how busy acoustic consultants are. Despite the low attendance those present found the papers and discussion to be valuable. A report appeared on page 31 of the July, 1989 issue of *Acoustics Bulletin*.

A H Middleton

Institute of Acoustics Meetings

1989			
23 October	LB	Planning and Noise	Regent's College, London
2-5 November	M	**Reproduced Sound 5**	Windermere
15 November	LB	Active Noise Control (Evening meeting)	LSS Offices, Gt Guildford Street
23-26 November	M	**Autumn Conference – Industrial Noise**	Windermere
December	M	PC Programmes in Acoustics	London
6 December	SB	Acoustic Design of Exhibition and Conference Centres	Southampton
11-13 December	UAG	Digital Signal Processing in Sonar	Loughborough
12 December	BAG	Noise Within Buildings	London
13 December	LB	Channel Tunnel Rail Link – a Kent EHO's Perspective	London
1990			
February	M	Entertainment Noise Control and other current Local Authority Problems	Venue to be announced
February	M	Noise from Electric Motors	Nottingham
27-30 March	M	**Spring Conference – Acoustics '90**	University of Southampton
May	M	Noise and Vibration from the Channel Tunnel Project	Kent
May	M	Measurement of Vibration in and Around Buildings	Venue to be announced
June	M	Military Aircraft Noise	RAF Mildenhall

Key

M = Meetings Committee Programme
BAG = Building Acoustics Group
ING = Industrial Noise Group
MAG = Musical Acoustics Group
PAG = Physical Acoustics Group
SG = Speech Group
UAG = Underwater Acoustics Group
LB = London Branch

EB = Eastern Branch
EMB = East Midlands Branch
NEB = North East Branch
NWB = North West Branch
SB = Southern Branch
ScB = Scottish Branch
SWB = South West Branch
YHB = Yorkshire and Humberside Branch

Further details from:

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