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HIGH INTENSITY ACOUSTIC TESTING AT BRITISH AEROSPACE, WEYBRIDGE

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CONTENTS

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1. INTRODUCTION

The Acoustics Department of British Aerosapce covers a wide range of aerospace associated noise problems. Air to ground testing, including aircraft noise certification to FAR and ICAO requirements, internal noise prediction and measurement, structural and silencer design and similar operations are dealt with by the Acoustics Technical Office. High intensity noise testing is done in the Acoustics Laboratory. This was built in 1966 and Figure 1 shows the general layout, with a central control room and a number of test cells. In addition there is a model jet rig situated some distance away and space at the rear of the building for the construction of enclosures for specific tests.

2. TEST REQUIREMENTS

The design and building of aircraft often produces unusual problems due to noise and vibration. Figure 2 shows some of the possible noise sources on an aircraft. Military and civil aircraft have different design and operating philosophies leading to different kinds of problems. One example being the design life of the aircraft structure, where a civil aircraft operational life may be ten times that of a similar military aircraft. The structural integrity of the airframe with respect to acoustic fatigue and acoustically induced vibration must be demonstrated. This is usually done in a siren test rig.

Electronic equipment in aircraft, guided weapons and spacecraft must withstand the vibration caused by high noise levels. There are various specifications to be met by modern equipment, e.g., MIL-810 C and BS 3G 100, and acoustic testing is usually done in a high intensity reverberant chamber, as are structural response measurements on weapons and space craft.

Community noise is also a problem. One of the major noise generators on an aircraft is the engine which has a number of separate sources:-
jet efflux, shock cells, turbine and compressor. There are restrictions on operating noise and the development of engine nozzles to reduce jet and associated noise usually involves the use of a model nozzle facility.

3. TEST FACILITIES

3.1. Siren Channels

Structural testing is usually done in a siren channel. High intensity acoustic loading is used to determine response frequencies, strain levels, mode shapes, damping and fatigue life. Either discrete frequency or broad band excitation can be used. Grazing incidence excitation along the specimen is usually used as it is more representative of many of the aircraft excitation conditions. There are two siren channels in the BAe Acoustics Laboratory equipped with different noise sources. The basic layout is shown in Figure 3 which is applicable to either channel. Compressed air is delivered from the Laboratory compressor or the factory air system or both, through pipes and manifolds to the noise generators, either Ling-Altec EPT 94B or EPT 200. The noise is fed into horns which expand to the test section then on to an attenuator box.

The air supply must be dry and oil free to prevent malfunction of the noise generators, so a number of filters are necessary in the line. Pressure is controlled in order to control the noise amplitude and, to some extent, the spectrum shape.

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The sirens or air modulators are driven by electrical signals from a power amplifier and the spectrum can be shaped as required by means of ⅓ octave band electrical filters in the signal line.

The horns are of hypex shape (hyperbolic-exponential) to give a good expansion of the wave with a minimum length. The low frequency cut off in Siren No. 1 is 55 Hz and in Siren No. 2 is 200 Hz. They are constructed from bonded glass fibre with metal insets for fixing and are fitted into a sand-filled box.

The test section is basically a duct 12 ft long x 4 ft high x 1 ft wide with a 10 ft long section removed from one side, into which the test specimens are fitted. Channel 1 is constructed from reinforced concrete and Channel 2 is constructed from 1 inch plywood with a 4 inch cavity filled with sand. The test specimens are usually mounted on a trolley for ease of movement during inspection. Figure 4 shows a typical installation for the fatigue testing of aircraft components.

The next section on Channel 1 is a reverberant chamber of approximately 6½ cubic metres volume, also constructed from reinforced concrete, which is used for testing electronic equipment. It contains a removable attenuator box fitted with wedges to prevent reflection back along the channel during structural tests. The original wedges were of fibreglass which rapidly burnt out due to the absorption of acoustic energy being converted to heat (Figure 5). These were replaced by steel wool wedges which are acoustically similar but have not suffered from the same problem due to their better internal heat conduction. The absorption section on Channel 2 also contains wire wool wedges in a box of similar construction to the test section.

3.2. Reverberant Chambers

Reverberant testing of equipment, weapons systems and space craft is done in a number of rooms.

3.2.1. Siren Channel No. 1

The reverberant chamber on Channel 1 is used for testing small electronic components. These are suspended by elastic cords from roof fixtures to prevent wall vibration being transmitted. Test levels up to 160 dB OASPL can be achieved and a set of five microphones is used to measure the excitation spectrum. A typical specimen failure is shown in Figure 6.

3.2.2. Reverberant Suite

Two reverberant rooms with an interconnecting aperture, used for acoustic transmission loss tests, are available for testing larger items such as complete weapons systems. A mobile noise generating system consisting of four EPT 94 B sirens with horns is fitted into the aperture to project into Room 1 (128 cu.m.). Noise levels up to 150 dB OASPL can be produced around the specimens which are suspended by elastic cords from a heavy frame. Instrumentation cables are taken out to the control room through ducts in the floor.

3.2.3. Noise Room

The large Noise Room (710 cu.m.) normally contains Siren Channel No. 2. This channel can be dismantled and the EPT 200 sirens used to generate high noise levels in the room. They have been used in combination with four EPT 94 B sirens to generate levels up to 147 dB OASPL for the testing of space craft components. The sirens are fitted into the corners of the room to give a diffuse noise field. The item being tested is suspended in the middle of the room from a high frame. The facility exists for modifying the noise field by use of a Hartman generator when discrete frequencies are required.

3.3. Jet Noise Rig

The development of jet propelling nozzles and associated silencing devices can be done with the model jet rig. This uses compressed air from the factory system through a long pipe with a hydrogen burner near the exit (Figure 7) giving gas temperatures up to 800°C. Full scale effects are simulated using model nozzles which can be modified more quickly and cheaply than full size nozzles.

3.4. Combined Loading

In structural integrity demonstration tests it is sometimes necessary to perform the tests using combined loads of noise and pressure or in-plane stresses, e.g., to check crack propagation rates. Care must be taken with all pressurisation tests for obvious safety reasons. One such test, with a fuselage subjected to noise and pressure, was conducted in a special sandbagged enclosure built to contain the results of a possible catastrophic failure. A mobile siren test rig was used to generate noise on the fuselage and compressed air supply provided the pressurisation. Figure 8 shows the configuration of horns and fuselage during the rig build outside the enclosure. The test consisted of varying the noise and internal pressure levels which were programmed to represent a typical flight.

Another type of combined loading test was done in the siren channel on an aircraft fin box containing various systems (Figure 9). During exposure to high intensity noise the hydraulic electrical and mechanical systems were operated and their performance monitored. In general the various systems operated satisfactorialy but the test did reveal several problems with the structural supports, attachments and bearings.

4. INSTRUMENTATION

During structural development testing it is necessary to measure strains and accelerations as well as noise. The strain gauges used are small so that there is minimum effect of mass on lightweight structures and to measure strains close to areas of stress concentration. Figure 10 shows the siren data collection system and the circuits used for static and dynamic strain measurement. The gauges are restricted to 120 Ω or 600 Ω to fit the half bridge system installed. Ambient temperatures in the channel are usually stable and a stabilised power supply or batteries are used for power. The weak link is the attachment of the wires to the gauge tags and these have to be bonded to the structura with RTV silicone adhesive to prolong their fatigue life.

Acceleration measurements are made using very small accelerometers (B&K 4344 2 gms). These are bonded to the structure and a conditioning (charge) amplifier system with measuring amplifiers allows the signals to be either read directly or recorded. They are kept in place for a minimum time to avoid fatigue failures of the cables.

5. ANALYSIS METHODS

A comprehensive collection of analysis tools is available and this is basically divided into two groups:-
(a) Hardware. Simple analysis is done in the laboratory during or immediately after the test. Data can be analysed in octave or ⅓ octave bands, using stepped or real time analysers. or in narrow bandwidths (usually 6% frequency) using frequency sweeping analysers. Sometimes this is done as a "first look" approach in order to set up a particular test spectrum or to check the output of strain gauges or accelerometers before doing a more detailed analysis. Outputs can be plotted directly using level recorders or an X-Y plotter, U-V trace recorder or Polaroid pictures.

(b) Computer. For more detailed analysis, particularly on structural tests, the data is recorded on magnetic tape then analysed on a computer system. This detailed analysis programme yields Power Spectral Densities of strain, acceleration or acoustic excitation, structural mode shapes, auto and cross correlation, statistical properties and damping factors. This method can be used with discrete frequency or random excitation tests. The output can be plotted in a number of ways. PSD's are plotted directly and mode shapes are derived from gain spectra and phase relationships using a common datum strain gauge or accelerometer. Damping ratios can be obtained from random data information by using a basic Kennedy-Pancu system and the display of phase and a reference gauge. A VDU inter-active system for circle fitting with a printed output gives damping factors at resonant frequencies.

6. CONCLUSIONS

A wide range of high intensity noise testing facilities is available in the BAe Acoustics Laboratory. Siren channels, reverberant chambers and a jet nozzle rig are backed up by a comprehensive computer analysis system to cover the variety of problems assocaited with the aerospace industry.

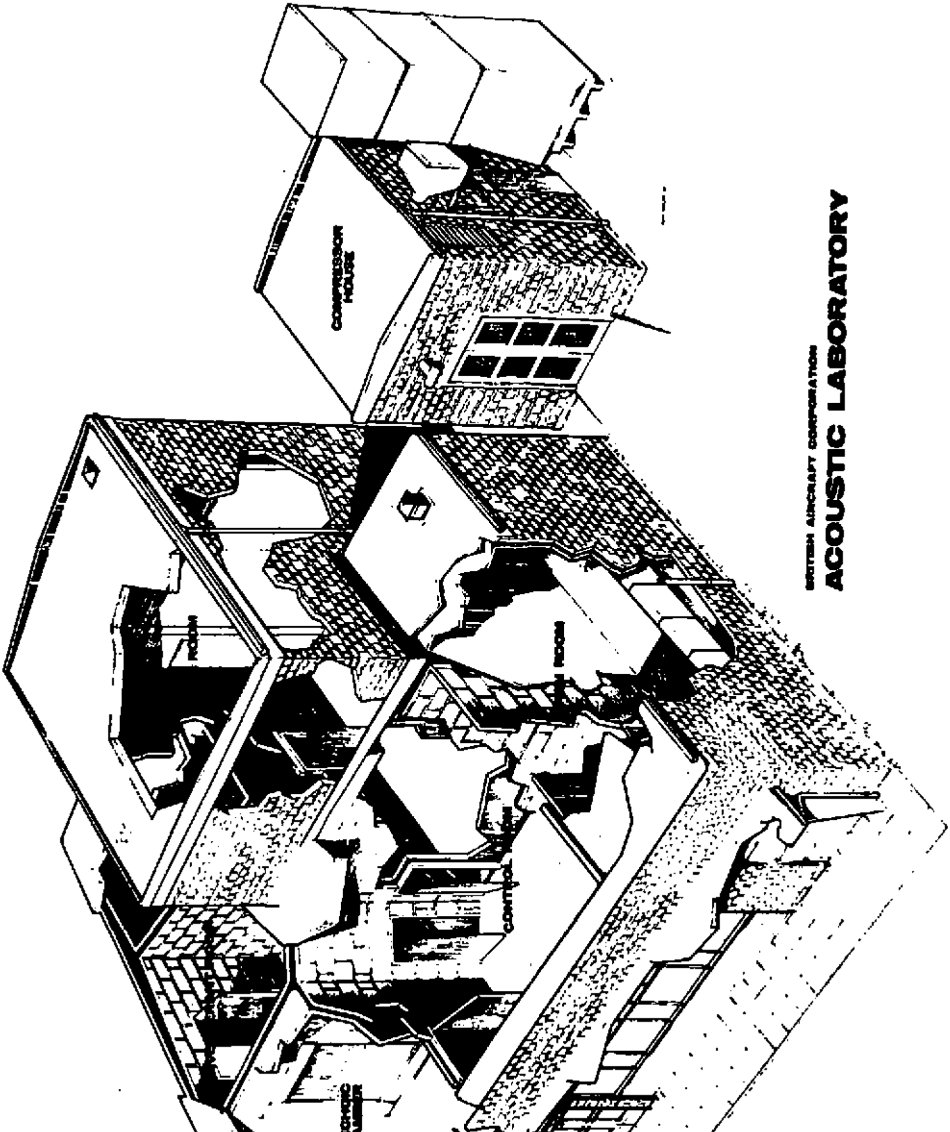
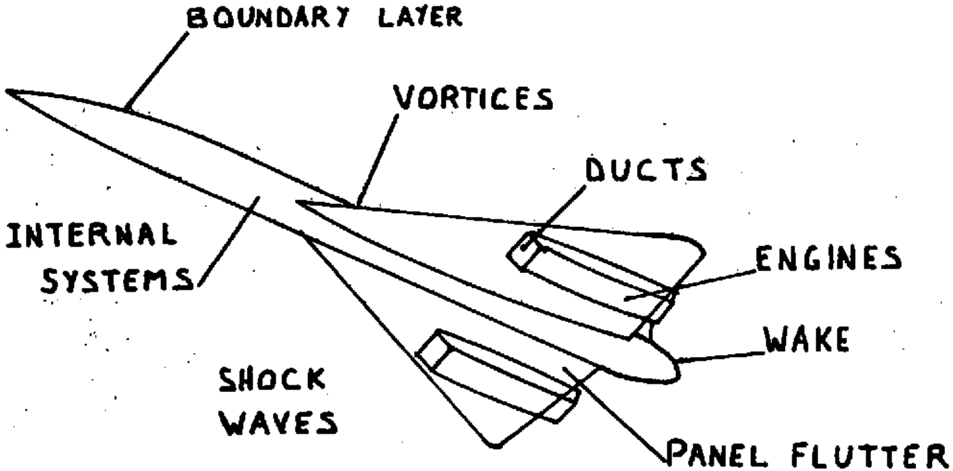


FIG 1



NOISE SOURCES ON A SUPERSONIC AIRCRAFT

FIG 2

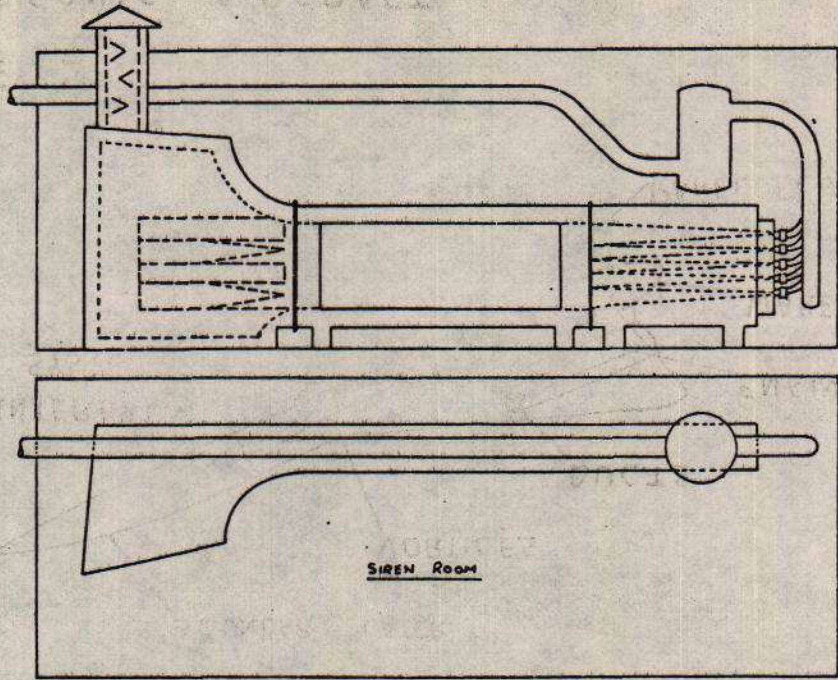
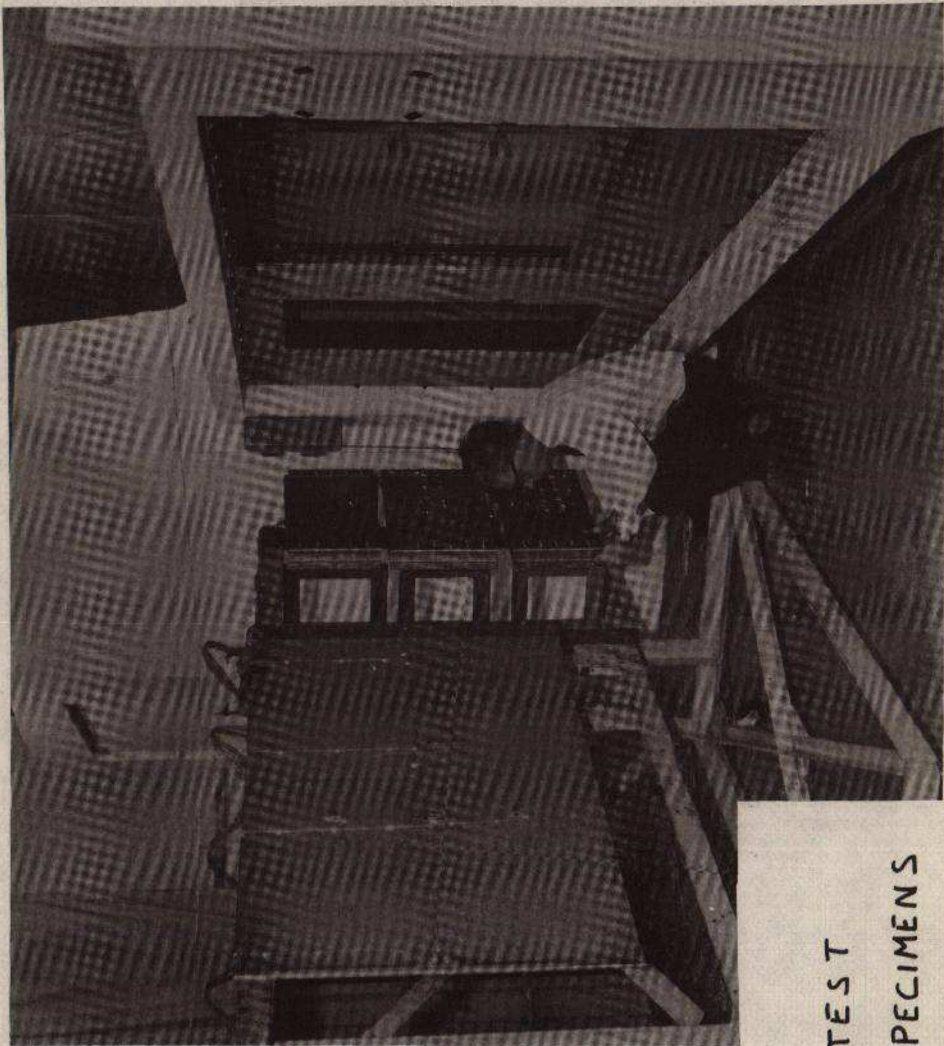


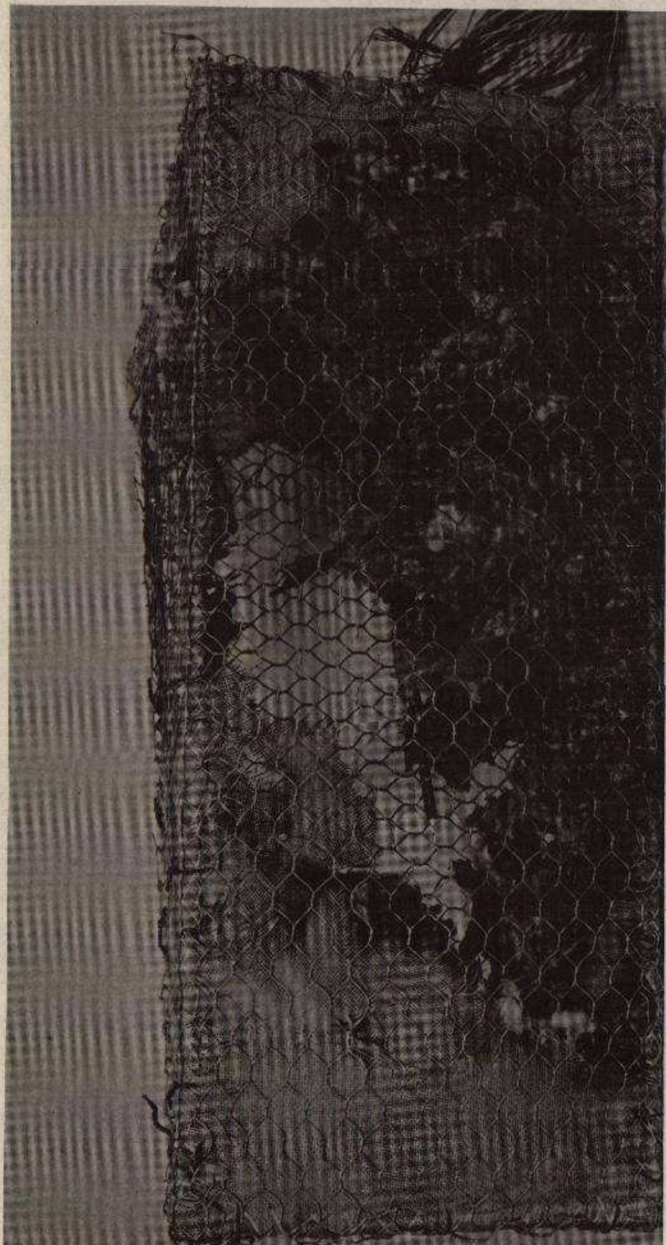
FIG 3

SIREN TEST CHANNEL



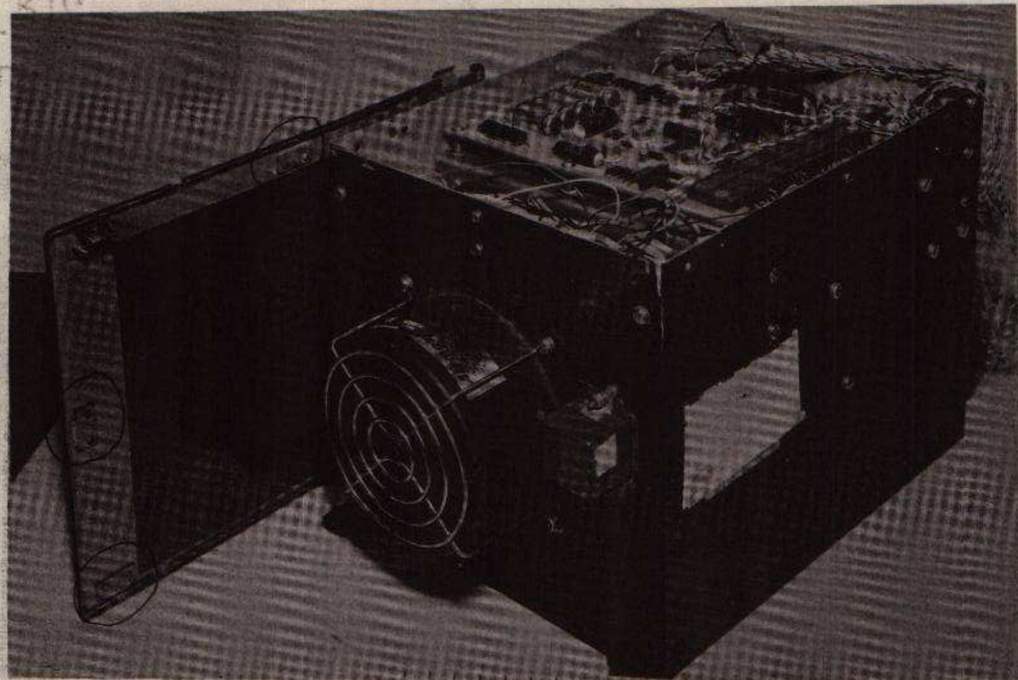
TEST SPECIMENS

FIG 4



BURNT WEDGE

FIG 5



SPECIMEN FAILURE

FIG 6

MODEL NOZZLE TEST RIG

FIG 7

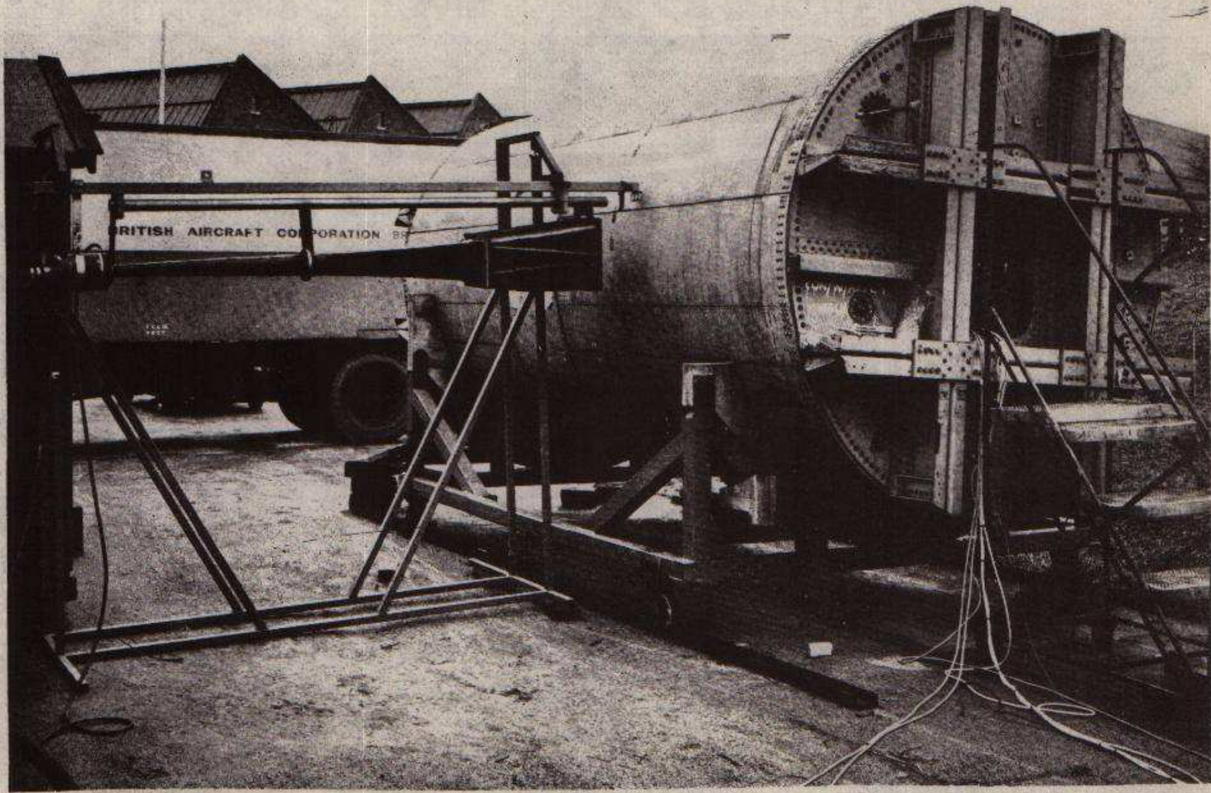
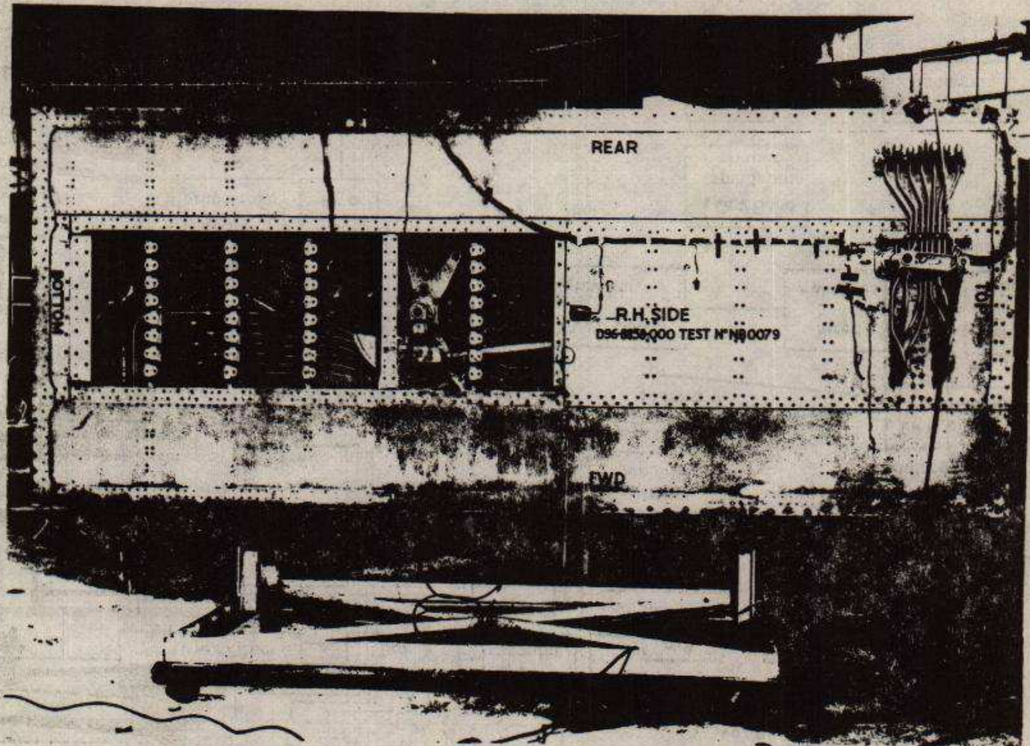


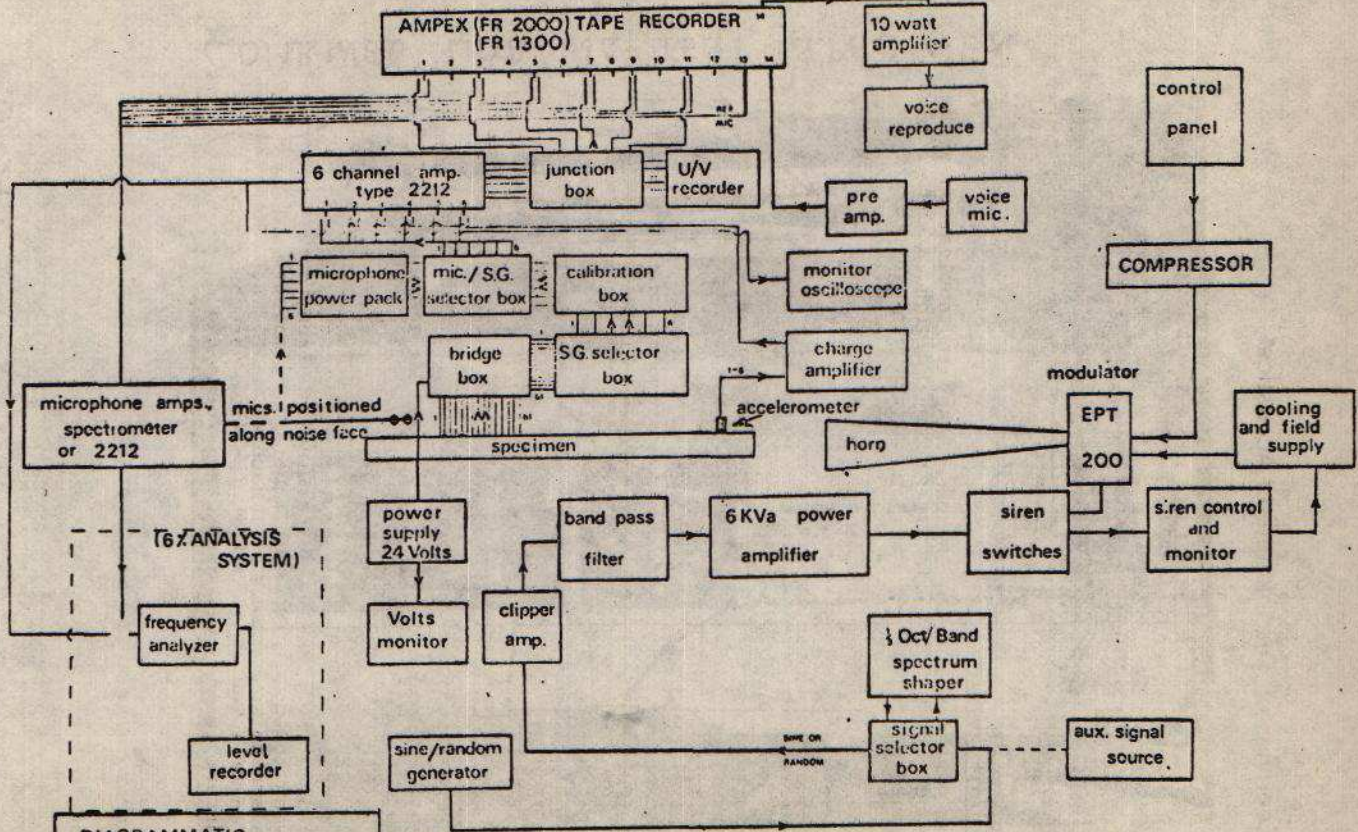
FIG 8

COMBINED LOADING TEST

FIG 9



COMBINED LOADING TEST SPECIMEN



DIAGRAMMATIC REPRESENTATION OF **INSTRUMENTATION** RIG 2

FIG 10