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AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Aircraft Structures Technical Memorandum 531

EXPERIMENTS IN PASSIVE VIBRATION REDUCTION

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SUMMARY

Interest has recently been renewed by the Aeronautical Research Laboratory in the use of constrained layer damping for passive vibration reduction. This report describes the authors' experiences in applying the techniques to a variety of practical problems.

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1 INTRODUCTION

Damping has been under investigation for many years. Damping has been connected with vibration since the nineteenth century. It was recorded in 1850 [1] that Professor Wheatstone had demonstrated a device to illustrate the human voice, which incorporated a damper. Since that time various researchers have investigated the damping properties of many materials and configurations. A search of the literature reveals an increase in activity in the period from 1960 to 1970. An extensive paper on the use of constrained-layer damping was published by Ruzicka in 1961 [2]. There is little evidence of significant application of the technique. However, in recent years there has been a renewed interest with many workshops, conferences and subsequent publications [3,4,5,6,7].

This report sets out the progress in recent years at ARL and evaluates some of the materials that are available in Australia. A number of practical applications are described.

It is difficult for the practising engineer to predict the effects of applied damping treatments in many applications because of the complexity of the analysis required and the difficulty in obtaining valid damping information on the materials.

In the Aircraft Structures Division of ARL the emphasis of vibration reduction work has usually been to isolate the sensitive object from the surrounding environment, isolate the source or use tuned mass damping systems. One instance of a dynamic vibration absorber was the tuned absorber installed in four of the ships in the Royal Australian Navy's Landing Craft (Heavy) squadron [8,9,10].

Many of the proprietary constrained-layer damping materials, available in USA, do not appear in the catalogues of the Australian agents or subsidiaries, or if they do, they are only imported to order. Clearly these materials are not widely used in Australia.

2 MATERIAL EVALUATION

Tests were carried out on aluminium plate with dimensions of 600 x 200 x 5mm and 600 x 200 x 6mm. Several identical pieces were cut from the same sheet such that they all had the same lengthwise grain structure. No experiments have been carried out to determine whether there is any difference, in stiffness or damping properties, between pieces of aluminium cut in different directions from the same sheet. The test rig is shown in Fig. 1. This simple rig reproduces laboratory results consistently for the many specimens tested.

The test procedure was in two stages. First, a random input was applied to establish the resonant frequencies of the plate, simply supported on soft foam. In the second stage the plate was excited sinusoidally at the first resonant frequency and a decaying acceleration time history captured on removal of the excitation. Both stages were conducted with and without constraining layers attached to the plate. Figure 2 explains the symbols and notation shown in an output from the Wavetek Modal 804A signal processor. The results for the basic aluminium specimen are shown in Fig. 3.

It is possible, using the logarithmic decrement, to provide a measure of damping as a percentage of critical damping. This applies only for a single mode of vibration and treats the structure as a single degree-of-freedom system. The percentage of critical damping, γ, is obtained from Eq. (1).

$$\gamma = \frac{-100}{2\pi n} \ln \frac{x_n}{x_o} \tag{1}$$

where

x_n = amplitude of vibration n cycles after x_o

$\gamma = \frac{C}{C_c} \times 100$

$C_c = 2m\omega_n$

m = mass

ω_n = natural frequency

If the special case is taken where x_N is half the amplitude of x_o, i.e. $x_N = \frac{x_o}{2}$, then

$$\gamma = \frac{100}{2\pi N} \ln 0.5$$

$$\approx \frac{11}{N}$$

where N is the number of cycles to half amplitude.

In general, the mass and stiffness of a plate will vary when a constraining layer is added. The resultant change in natural frequency will require γ to be multiplied with critical damping as shown below, so that comparison with different specimens can be made. In order to make a valid comparison it has been assumed that, because the damping treatment applied in these tests is symmetric about the centre of area of the base structure, the mode shapes for the treated and untreated plates are the same, and consequently the generalised mass for the two cases will be in proportion to the total mass.

Therefore, if the mass has changed in the ratio of $m_2 : m_1$, and the resonant frequency of the fundamental bending mode has changed in the ratio $\omega_{n2} : \omega_{n1}$, then the critical damping will have changed such that

$$C_{c2} = C_{c1} \frac{m_2 \omega_{n2}}{m_1 \omega_{n1}} \tag{2}$$

If the initial damping C_1 was $\frac{\gamma_1}{100} C_{c1}$ then the new damping C_2 will be

$$C_2 = \frac{\gamma_2}{100} C_{c2} \quad \text{or} \quad C_2 = \frac{\gamma_2}{100} C_{c1} \frac{m_2 \omega_{n2}}{m_1 \omega_{n1}} \tag{3}$$

and the proportional change in damping will be

$$\frac{C_2}{C_1} = \frac{\gamma_2 C_{c1} m_2 \omega_{n2}}{\gamma_1 C_{c1} m_1 \omega_{n1}} = \frac{\gamma_2 m_2 \omega_{n2}}{\gamma_1 m_1 \omega_{n1}} \tag{4}$$

and this is how the damping results have been compared in these tests.

In tl e first series of tests three different materials were used as constraining layers on aluminium plate. Thicknesses of 1.5mm carbon fibre cloth laminate, 1.5mm Kevlar cloth laminate and 1.5mm aluminium alloy in each case was bonded to aluminium plate using Flexon F241 acrylic adhesive. These damping treatments were chosen initially as they were the most likely materials to gain acceptance for bonding to service aircraft. The damping characteristics for each treatment are shown in Figs. 5,6 and 7. The resonant frequency for the composite panel has increased and so has the mass. The results are shown in Table 1.

In the second series of tests the effect of the thickness of the constraining layer was investigated. The damping material used was a general purpose double-sided adhesive tape made by TESA*. Constraining layers were aluminium of three thicknesses, 0.3, 0.9 and 1.5 millimetres.

Figs. 8,9 and 10 show the results of transfer function analysis using broad band noise input, and a captured decay signal when the structure was excited at the fundamental bending frequency using a sinusoidal input.

* TESA TAPES is a division of Beirsdorf Australia Ltd.

Table 2 sets out the numerical values for comparison purposes. Unfortunately the TESA tape, although an excellent visco-elastic damping material, has a very low shear strength, and the constraining layer would creep when placed in a vertical position. Work is being undertaken elsewhere [11] to use liquids that can be modified, by the application of an electrical charge, such that their stiffness and damping properties can be controlled. These materials are referred to as electrorheological. This test, however, did indicate that there was little to be gained by increasing the thickness of the constraining layer beyond one millimetre. This will not be the case for other damping materials. Further work is necessary before any empirical rules may be laid down. It is certain, however, that the constraining layer should have a sufficiently high shear strength that it may introduce the maximum strain in the damping layer.

A further investigation was carried out with various combinations of damping materials and constraining layers bonded to 5mm and 6mm aluminium plate, Tables 3 and 4. In each case a single damping layer of dimension 80 x 500 mm was applied symmetrically about the centre of one side of the aluminium plate, Fig. 11.

A damping improvement was investigated for a fibreglass structure. Several specimens were cut from a sheet of fibreglass/polyester-resin laminate. The specimens were approximately 400 x 100 x 8mm in size. A constraining layer of aluminium of dimension 350 x 75 x 3mm was used with a number of different potential damping materials. The specimens were simply supported as shown in Fig. 1. The input excitation was applied at one end, off centre, directly below the accelerometer location. Broad band excitation was applied in the frequency range 0 to 2000Hz, and the amplitude adjusted to obtain a peak response close to 4 volts from the accelerometer/amplifier system. This corresponds to approximately 40g peak. The excitation source was switched off and the decaying signal captured on a Fast Fourier Transform (FFT) spectrum analyser. A single FFT was performed on the captured time history. Figs. 12 to 17 show these time histories and frequency spectra. These figures show that the time for vibrations to decay to zero was far less when proprietary brands of adhesive material were used than when proprietary damping materials with adhesive recommended by the manufacturers were used.

3 PRACTICAL APPLICATIONS

At an early stage in these tests on various specimens it became apparent that constrained layer damping had some distinct advantages over the non-constrained treatments. The opportunity to try constrained layer damping arose in several applications described below.

3.1 Aircraft Stabilator

Aircraft are subjected to buffeting and turbulent airstreams. These inputs excite the various resonant vibration modes of the aircraft. If the structure is lightly damped the vibrations may become large enough to cause structural failure due to fatigue of vital components. Concern was being expressed about the levels of vibration on the tail surfaces of the F/A-18 aircraft in service with the RAAF. An F/A-18 stabilator was made available for a number of tests and the opportunity was taken to investigate whether the damping could be significantly increased.

A number of constraints apply when dealing with aircraft. The increase in mass must be minimal, the aerodynamic properties must not be degraded, and the safety of the aircraft must not be placed at risk. For this experiment a 3M product called 'Scotchmount' Y4965 was used as the damping material. This is a double sided adhesive tape with very good long term bonding capabilities and a good temperature tolerance. The adhesive tape was applied in 25mm wide strips to approximately 70% of both surfaces of the stabilator, Fig. 18. To ensure good bonding, a vacuum bag technique was used. A thickness of 1mm aluminium was used as the constraining layer. This thickness had performed well in earlier tests and was easily shaped to the slight curvature of the stabilator. The improvement in damping was measured using a random decrement analysis technique. This technique has been described earlier and the method works well with lightly damped modes of vibration [12]. The damping in the modes of vibration of concern improved from 1% to 1.5% of critical damping. Changes in mode shape, frequency and mass of the modified structure made it difficult for an accurate comparison to be obtained. The improvements were insufficient to justify any thoughts of making the system airworthy. Further improvements would have required a substantial increase in mass which was considered to be unacceptable. The work is described in more detail in Ref. 13.

3.2 Diesel Generator Set

This problem relates to a diesel-engine-powered generator-set installed in a ship. The set is mounted on six rubber isolation-mounts that have been well chosen and provide attenuation of 90% in the frequency range of concern. The request was made for a reduction in the 10% that passed through the isolation mounts. Fig. 19 shows the generator set on its isolation mounts. The generator set is mounted on a platform comprising of two welded channels and several cross-members. Modal analysis using four electro-magnetic shakers revealed a number of vibration modes, with significant amplitudes at the mounting points, that involved bending of the support channels. The approach taken was to incorporate constrained layer damping into the channels using 3mm thick Isodamp C-1002 material constrained by eight 1600mm lengths of stainless steel angle of dimensions 125 x 125 x 10mm. Isodamp is a product of the E.A.R. Division of Cabot Corporation. U.S.A. The bonding medium used was Araldite K138. Figs. 20 and 21 show the installation of these angle beams to form a channel.

The effectiveness of the treatment was assessed by measuring the acceleration response at each isolation mount for a wide band excitation. Figs. 22 to 25 show 4 of 24 spectra obtained from these tests. Included are the spectra which show the least improvement and those which show the most improvement. The top figure in each case is the undamped situation and the lower figure is the situation after the treatment is applied. An improvement can be seen to be a reduction in response (area under the curve) and removal of major peaks. Increases in some cases are due to sufficient changes in mode shape to place the support mount further from a nodal point. The treatment was considered to be an overall improvement.

3.3 Fibreglass Boat Hull

This application followed the request to reduce the radiated noise from a fibreglass-hulled boat. The hull was constructed from two 8mm skins sandwiching a 60mm polyurethane foam material.

The initial experiments were carried out on a piece of the sandwich material using 3M Scotchmount Y4965 tape to cover an area 1200 x 150mm on the 1500 x 300mm specimen. Several constraining layers were used and the effects on the vibration modes at 141 and 406 hertz were noted. The results of these tests are presented in Table 5. The tests were then repeated using Decibar DS4 instead of Scotchmount tape. Decibar DS4 is a product of Industrial Noise Control Pty. Ltd. The constraining layer used was 6mm fibreglass. At this time, a suggestion was made that an improvement in overall damping may be achieved by cutting the constraining layer into smaller pieces. The theory being that the strain energy is a maximum at the edges of the layer and that the more edges there are, the greater the strain energy. However, the strain energy is proportional to the amount of strain, which is related to the length of the constraining layer. So the total amount of strain energy will increase to an optimum value and then drop away as the segments become so small, in relation to the flexing of the vibration modes, that there will be no strain energy at all. In this experiment, the constraining layer of 1200 x 150 x 6mm fibreglass was cut into 2, 4, 8 and 16 segments. The results are presented in Table 6.

Furthermore, a damping treatment was applied to a larger piece of the sandwich material. The panel dimensions were 2500 x 1500mm, and four pieces of constraining material were used. Three pieces were 1000 x 600mm and the fourth was 1200 x 600mm. The damping material was Decibar DS4 bonded with Araldite K138. Figure 26 shows the panel layout with excitation and measurement points indicated. Figure 27 shows the experimental setup, the foam supports can be seen under the smaller panel in the foreground. The larger panel in the background was supported on four soft springs and excited by a single shaker. Responses to broad band excitation were measured at nine locations before and after the application of the damping treatment. Figures 28 and 29 show the results from the best and worst cases. All locations showed a significant improvement.

At this stage, information became available on another product from the E.A.R. Division of Cabot Corporation in the U.S.A. The product is a damping tile described on the data sheet as MIL-P-23653C (SHIPS) DAMPING TILES. They are 'high physical strength, thermally stable, graphite filled, polyvinyl chloride alloy compounds.' [14]. A sufficient quantity of these tiles, weighing 1270 grams each and of dimensions 305 x 305 x 8mm, was obtained to conduct an experiment with the 1500 x 300mm fibreglass/foam sandwich specimen. The tiles, after being cut in half, were bonded to the specimen using Araldite K138 epoxy resin. To improve the damping further, a constraining layer of 14mm of fibreglass was bonded to the tiles. This was made up of two layers of 7mm each. Figure 30 shows the response to random excitation for both cases. Two further experiments were conducted using Nylex Dyad material 0.5mm thick as a damper. One experiment used the Dyad, bonded with 3M rubber adhesive externally on one side of the specimen and in the other experiment, a specimen was constructed with the Dyad bonded between the foam and fibreglass skins as shown in Fig. 31. The bonding adhesive in this case was Araldite K138. Figure 32 shows the response spectra for these two cases. The test results were inconclusive and indicate that there was less strain in the built-in Dyad than in the externally applied Dyad. This may be caused by the low stiffness of the foam material.

4 DISCUSSION AND CONCLUSIONS

A wide range of materials has been tested in a constrained-layer damping ev uation program. The tests were conducted at room temperature. The resu obtained are a good starting point for further detailed studies.

Comparisons between the performance of damping materials when applied to d ferent specimens are made by considering the ratio of critical damping, mass a natural frequency between specimens. The manufacturers of damping mate als provide complex charts of shear modulus and loss factor for a wide range frequencies and temperatures. There are no such charts for some of the rubb adhesives and double-sided tapes that have been tested. It is worthy of note that 3M product manufactured for its adhesive properties was found to perform bett than the 3M damping products used in the laboratory test.

The practical experiments undertaken with a view to real-world application h some degree of success. Critical damping on the aircraft stabilator was improv from 1% to 1.5%.

On the Diesel Generator Set, certain levels of response were reduced by 60 Other levels were shifted, some remained the same and some increased.

Dividing the constraining layer into smaller segments increased the damping of t fibreglass/foam sandwich panel with an associated drop in natural frequency d to a reduction in stiffness. An optimum level of damping was reached and furth division of the constraining layer tended to decrease the damping. The final choi of treatment for the hull was the ship damping tile without a constraining laye An improvement in noise reduction was measured during sea trials, but details a not available at this time.

REFERENCES

[1] Timbs, J., *The Year Book of Facts in Science and Art*, p. 168, David Bogue, London, 1850.

[2] Ruzicka, J.E., *Damping structural resonances using viscoelastic shear-damping mechanics*, Transactions of the ASME, Journal of Engineering for Industry, November 1961.

[3] Flight Dynamics Laboratory, Damping 1986 Proceedings Air Force Wright Aeronautical Laboratories AFWAL-TR-86-3059.

[4] Flight Dynamics Laboratory, Proceedings of Damping '89, Air Force Wright Aeronautical Laboratories WRDC-TR-89- 3116 Vols. I, II and III.

[5] Australian Vibration and Noise Conference 1990, Institution of Engineers, Australia, National Conference Publication No. 90/9.

[6] Soovere, J. and Drake, M.L., *Aerospace Structures Technology, Damping Design Guide*, Air Force Wright Aeronautical Laboratories, AFWAL-TR-84-3089, Vols I, II, and III, 1985.

[7] Nashif, A.D., Jones, D.I.G. and Henderson, J.P., *Vibration Damping*, John Wiley and Sons, 1985.

[8] Long, G. and Farrell, P.A., *The design and installation of a damped vibration absorber*, Aeronautical Research Laboratory, Structures Note 440, August 1977.

[9] Farrell, P.A. and Goldman, A., *Sea trials of the damped vibration absorber fitted to H.M.A.S. Brunei*, Aeronautical Research Laboratory, Structures Technical Memorandum 286, January 1979.

[10] Goldman, A., *Sea trials of the damped vibration absorber fitted to H.M.A.S. Tarakan*, Aeronautical Research Laboratory, Structures Technical Memorandum 315, May 1980.

[11] Coulter J.P., Duclos, T.G. and Acker D.N., *The Usage of Electrorheological Materials in Viscoelastic Layer Damping Applications*, Proceedings of Damping '89, Volume I, Air Force Wright Aeronautical Laboratories, WRDC-TR-89-3116.

[12] Cole H.A., *On line failure detection and damping measurement of aerospace structures by random decrement signatures*, NASA-CR-2205, 1973.

[13] Goldman, A., Piperias, P. and Rider, C.D., *Dynamic tests on a F/A-18 Stabilator*, Aeronautical Research Laboratory, Aircraft Structures Technical Memorandom 535, June 1990.

[14] Industrial Noise Control, MDS-54 Materials Data Sheet, MIL-P-23653C (SHIPS) DAMPING TILES, E.A.R. Division, Cabot Corporation, 1987.

TABLE 1

Comparison of damping results in first series of tests.

Specimen	Total Mass grams	Resonant frequency Hz	% of Critical Damping γ	Damping* improvement C_2/C_1
Bare aluminium	1608	66.5	0.26	1.0
Carbon Fibre Layers	2090	131.5	0.23	2.27
Aluminium Layers	2446	126.5	0.17	1.89
Kevlar Layers	1970	102.0	0.61	4.41

* Note that this is a ratio, and a value of 1.0 means no improvement.

TABLE 2

Comparison of damping results using different thickness of constraining layer. Damping material is TESA double sided adhesive tape.

Specimen	Total Mass grams	Resonant frequency Hz	% of Critical Damping γ	Damping improvement C_2/C_1
Bare aluminium 5mm	1608	66.5	0.26	1.0
0.3 mm Al. constraining layers	1825	76.0	1.2	6.0
0.9 mm Al. constraining layers	2100	85.0	10.0	64.2
1.5 mm Al. constraining layers	2373	89.5	10.0	76.4

TABLE 3

Comparison of damping results using a wide range of damping materials and constraining layers. Base structure is 5 mm x 600 x 200 mm aluminium plate.

Specimen	Total Mass grams	Resonant frequency Hz	% of Critical Damping γ	Damping improvement C_2/C_1
Bare aluminium 5mm	1608	66.5	0.26	1.0
Decibar DC spread on one side. No constraining layer	1675	68.5	0.46	1.9
Dow Corning Sylgard 184 constrained by 1.5 mm Al.	1810	77.5	1.1	5.5
TESA adhesive tape 0.8 mm Al.	1698	74.5	2.0	9.1
TESA adhesive tape 0.6 mm Al.	1678	73.0	0.92	4.1
Decibar DC paste 0.8 mm perforated Al.	1735	71.0	0.31	1.4
Dow Corning GS75 0.8 mm perforated Al.	1700	70.0	0.35	1.5
Dow Corning 3145 RTV 0.8 mm perforated Al.	1700	70.5	0.26	1.1
Sylgard 170 minimum thickness with 1.5 mm Al.	1830	73.5	0.5	2.4
Sylgard 170 2 mm thick with 1.5 mm Al.	1920	69.0	0.4	1.9
Silastic 3145 RTV with 1.0 mm perforated stainless steel	1820	72.0	0.4	1.9

TABLE 4

Comparison of damping results using a wide range of damping materials and constraining layers. Base structure is 6 x 600 x 200 mm aluminium plate.

Specimen	Total Mass grams	Resonant frequency Hz	% of Critical Damping γ	Damping improvement C_2/C_1
Bare aluminium 6 mm	1930	82.5	0.26	1.0
TESA adhesive tape with 1 mm Al.	2050	90.5	2.75	12.3
3M tape Y-9473 1 mm Al.	2095	87.0	3.14	13.8
3M tape Y-4262 1 mm Al.	2095	91.0	2.0	9.2
3M tape 4965 1 mm Al.	2095	91.5	1.8	8.3
Decibar DS4 sheet bonded with Plio-bond	2185	82.0	0.35	1.5
Decibar DS4 bonded with Plio-bond to 1 mm Al.	2285	92.0	3.7	18.8
Plio-bond 1 mm Al.	2030	85.5	1.37	5.7
Decibar DS4 bonded with Araldite to 8 mm plywood	2410	148.0	2.4	20.7
Decibar DS4 bonded with Araldite to 6 mm 6 mm Masonite	2390	103.0	0.78	4.6

TABLE 5

Comparison of effect of different constraining layers on the frequency and damping of a fibreglass/foam sandwich panel using 3M Scotchmount as the damping layer.

Material	Frequency (Hz)	Damping (% of critical)
Bare panel	141	0.6
3 mm steel	145	1.5
4.5 mm steel	141	1.8
6 mm steel	122	2.2
6 mm fibreglass	141	1.0
Bare panel	403	0.9
3 mm steel	381	2.7
4.5 mm steel	367	3.6
6.0 mm steel	381	5.0
6.0 mm fibreglass	400	2.0

TABLE 6

Comparison of effect of cutting constraining layer into segments on the frequency and damping of a fibreglass/foam sandwich panel using 6 millimetre fibreglass constraining layer and Decibar DS4 as damping material.

Constraining layer condition	Frequency Hz	Damping (% of critical)
Whole	141	0.7
2 pieces	135	1.0
4 pieces	130	1.2
8 pieces	128	1.0
16 pieces	127	1.0
Whole	406	1.6
2 pieces	400	1.6
4 pieces	385	1.8
8 pieces	378	1.6
16 pieces	378	1.8

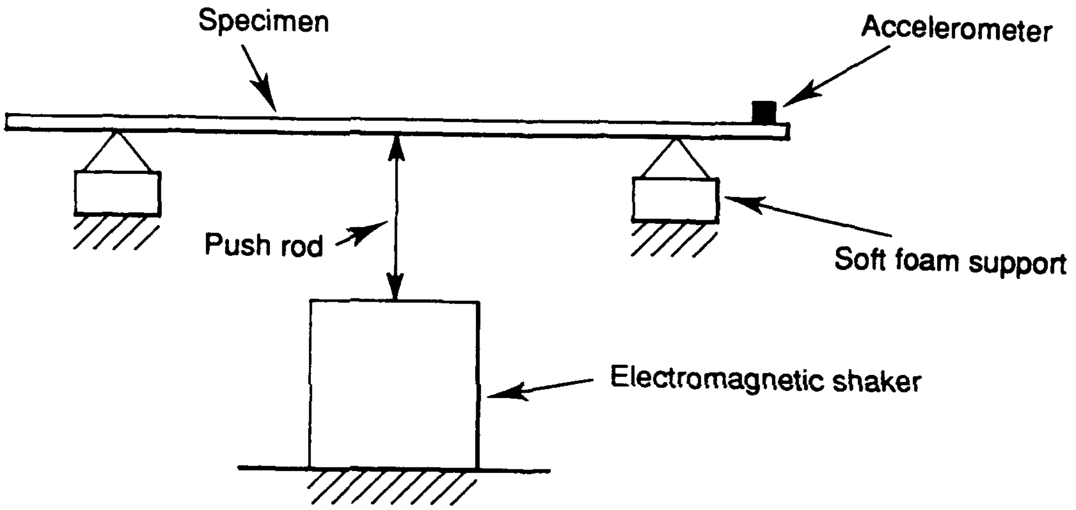


FIGURE 1. SIMPLE SUPPORT RIG FOR TESTING SPECIMENS

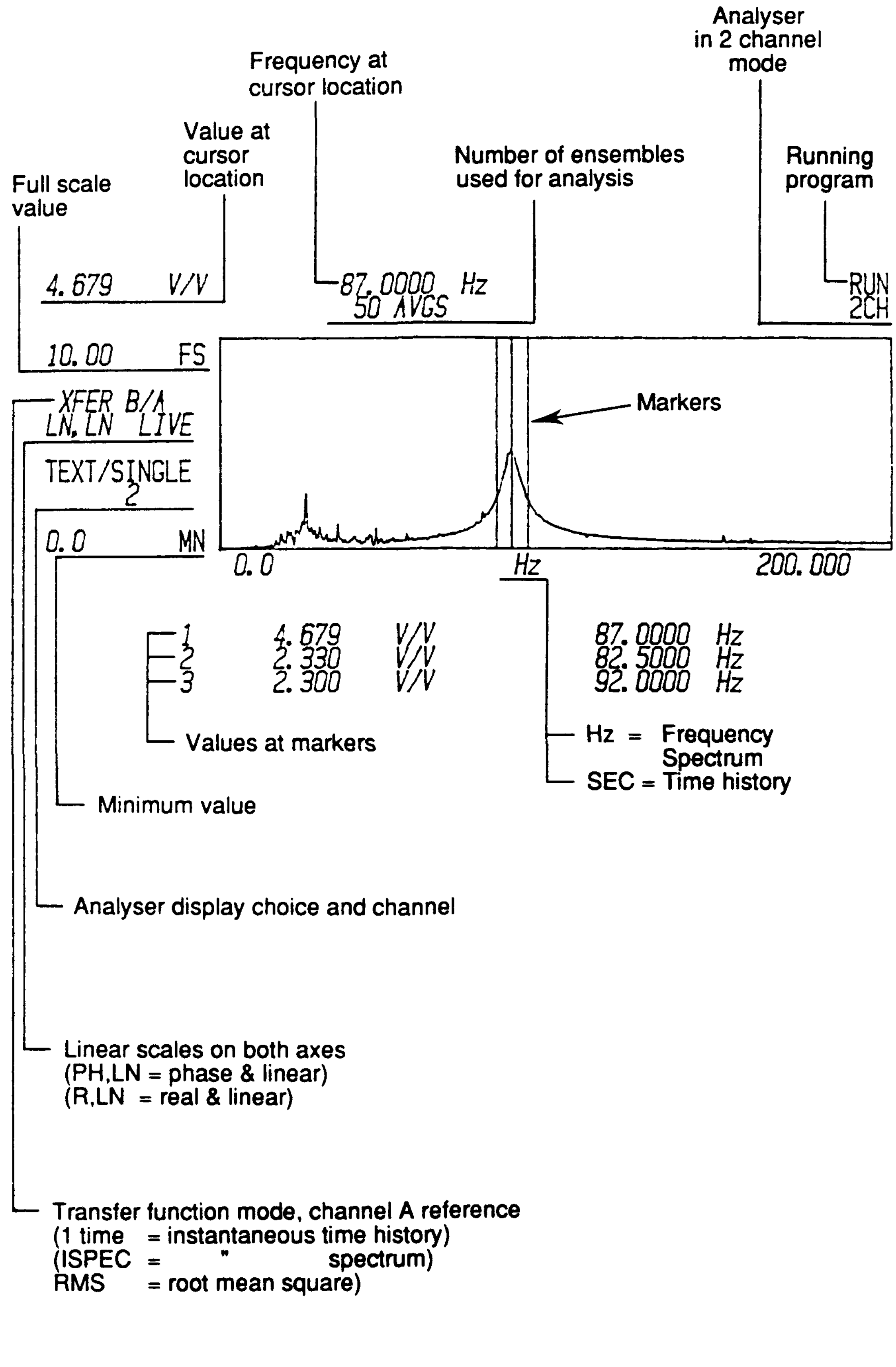
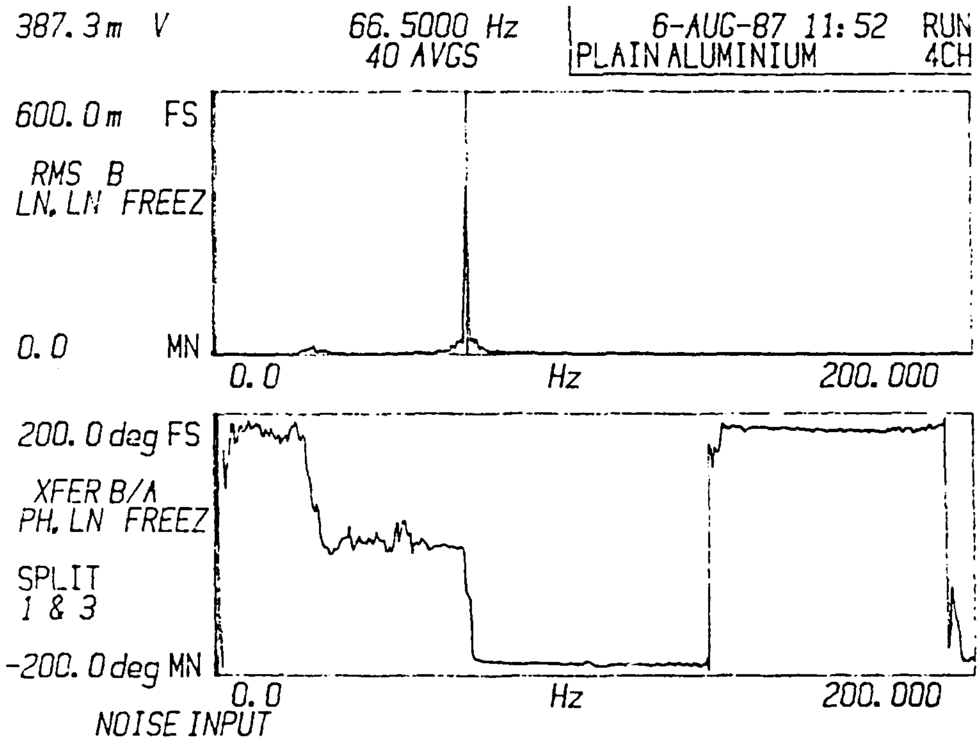
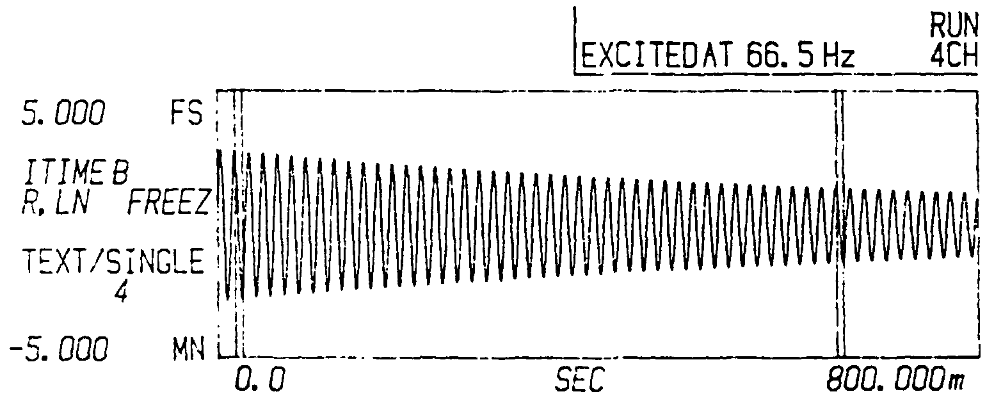


FIGURE 2. LEGEND FOR SIGNAL PROCESSOR OUTPUT





1	2.730	V	17.9688mSEC
2	-2.757	V	25.7812mSEC
3	1.365	V	650.781mSEC
4	-1.393	V	657.812mSEC

PLAIN ALUMINIUM

FIGURE 3. RESULT OF TESTS ON BARE ALUMINIUM SPECIMEN 600 x 200 x 5mm

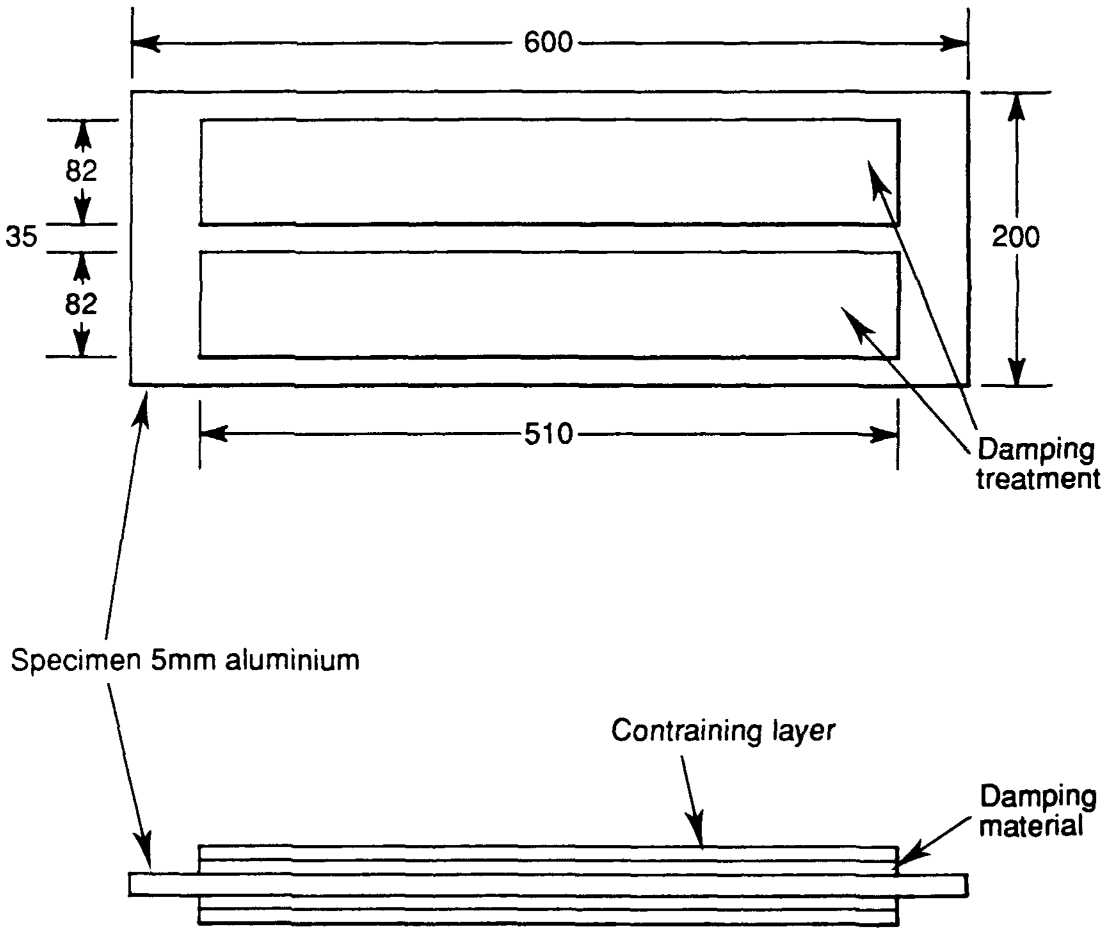


FIGURE 4. CONSTRUCTION OF SPECIMENS FOR FIRST AND SECOND SERIES OF TESTS RESULTS IN TABLES 1 AND 2 AND FIGURES 5 TO 10

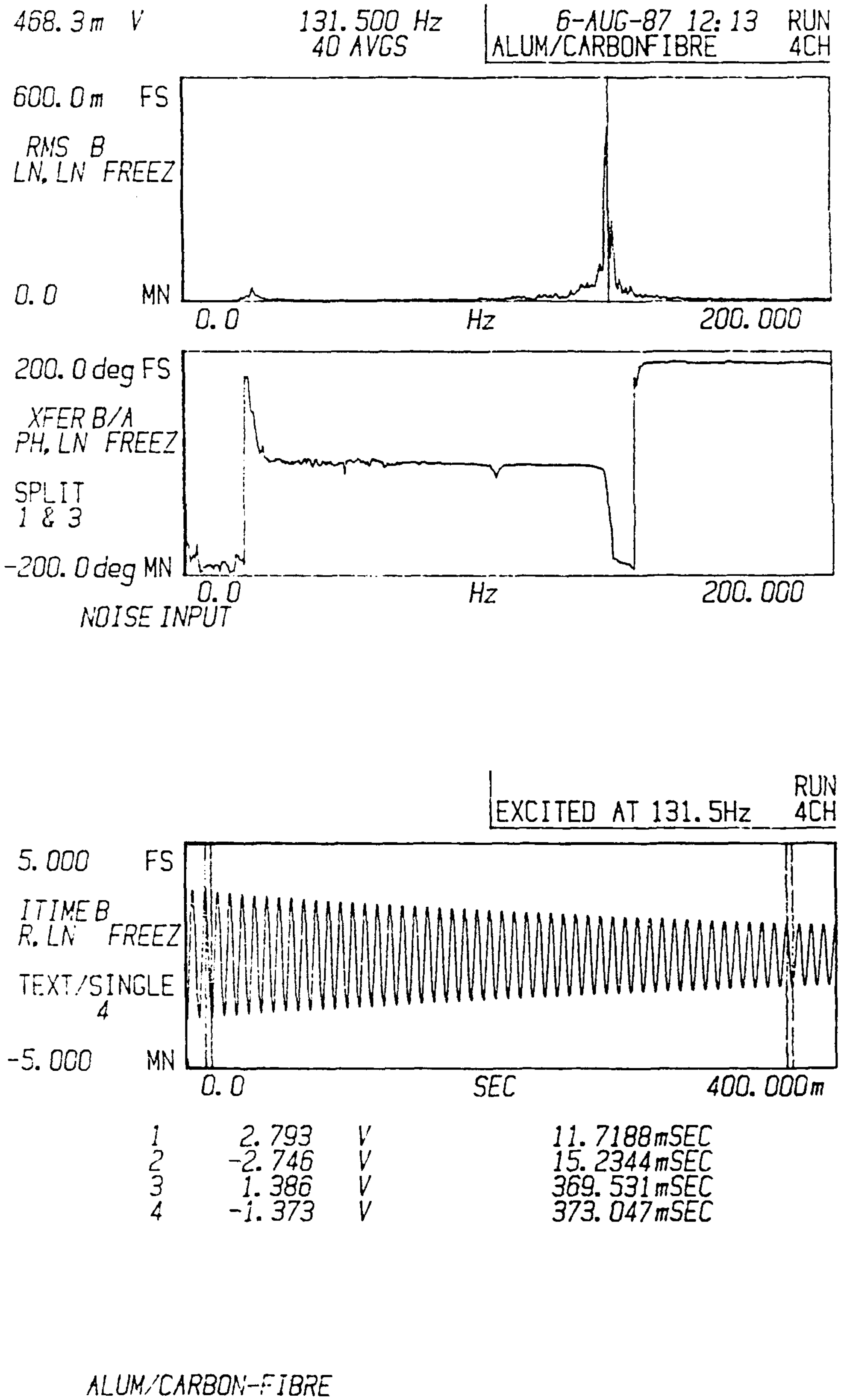
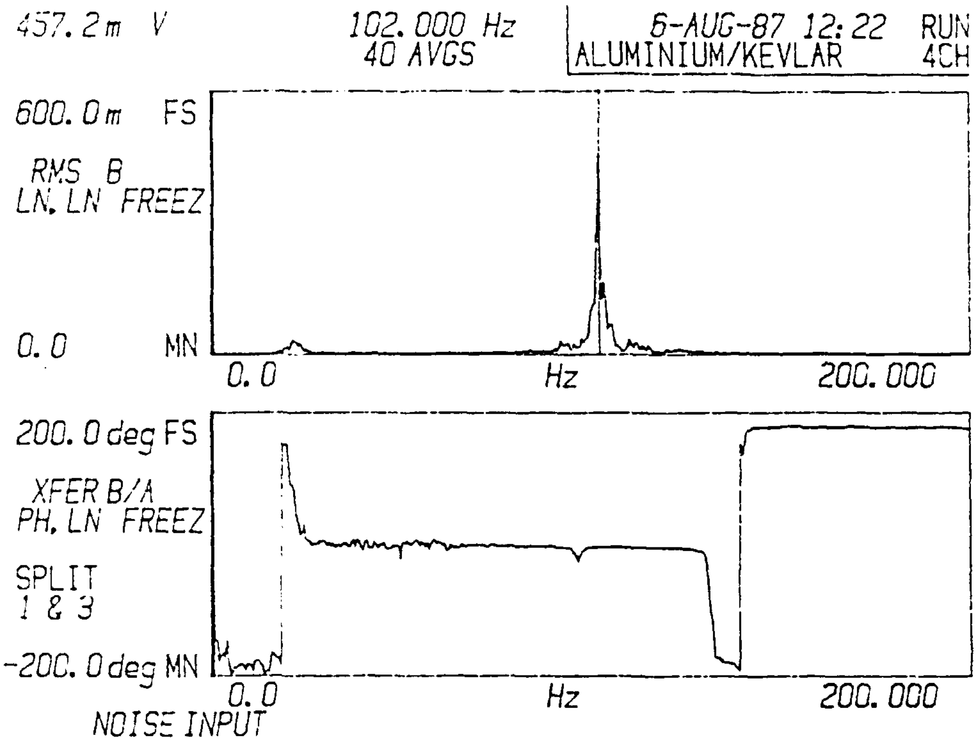
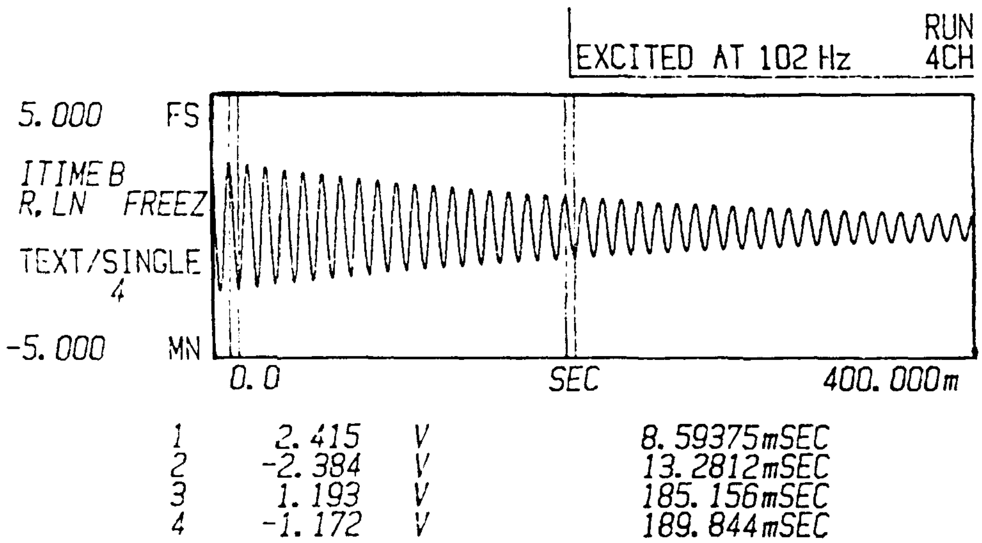


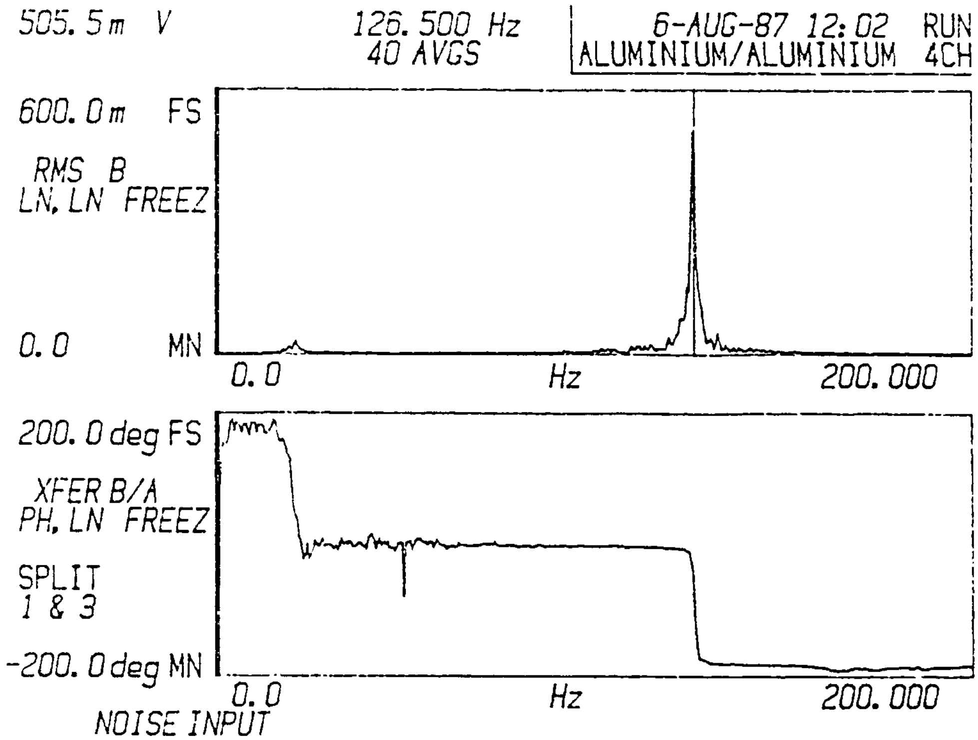
FIGURE 5. RESULT OF TEST ON ALUMINIUM SPECIMEN BONDED TO 1.5mm CARBON FIBRE AS IN FIGURE 4 WITH FLEXON 241 ADHESIVE

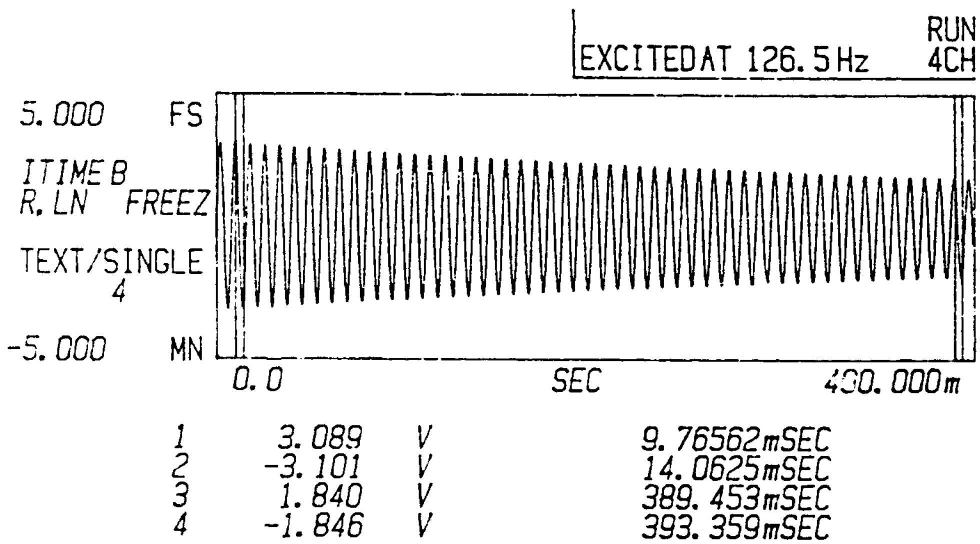




ALUMINIUM/KEVLAR

FIGURE 6. RESULT OF TEST ON ALUMINIUM SPECIMEN BONDED TO 1.5mm KEVLAR AS IN FIGURE 4 WITH FLEXON 241 ADHESIVE





ALUMINIUM/ALUMIN

FIGURE 7. RESULT OF TEST ON ALUMINIUM SPECIMEN BONDED TO 1.5mm ALUMINIUM AS IN FIGURE 4 WITH FLEXON 241 ADHESIVE

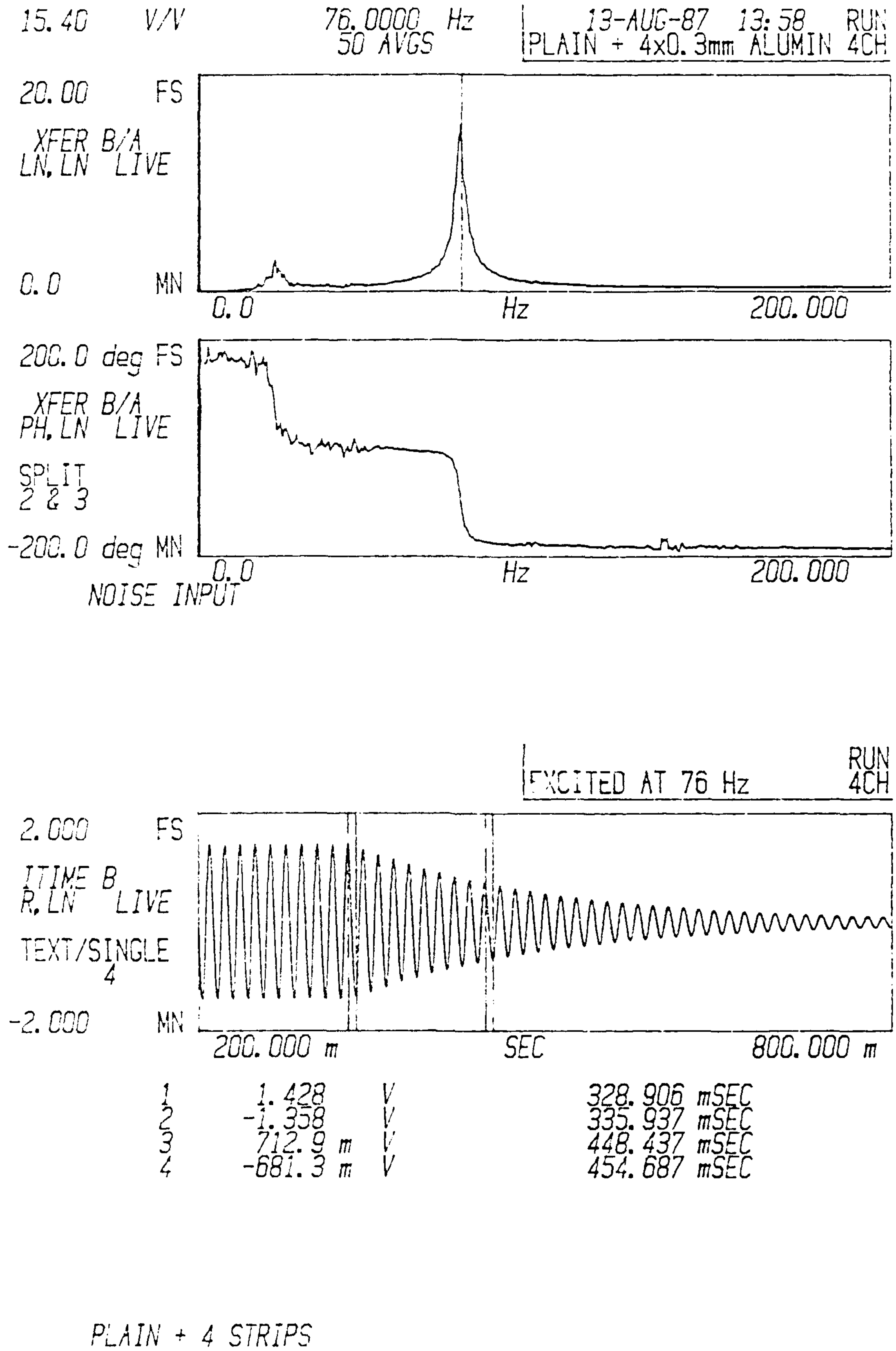
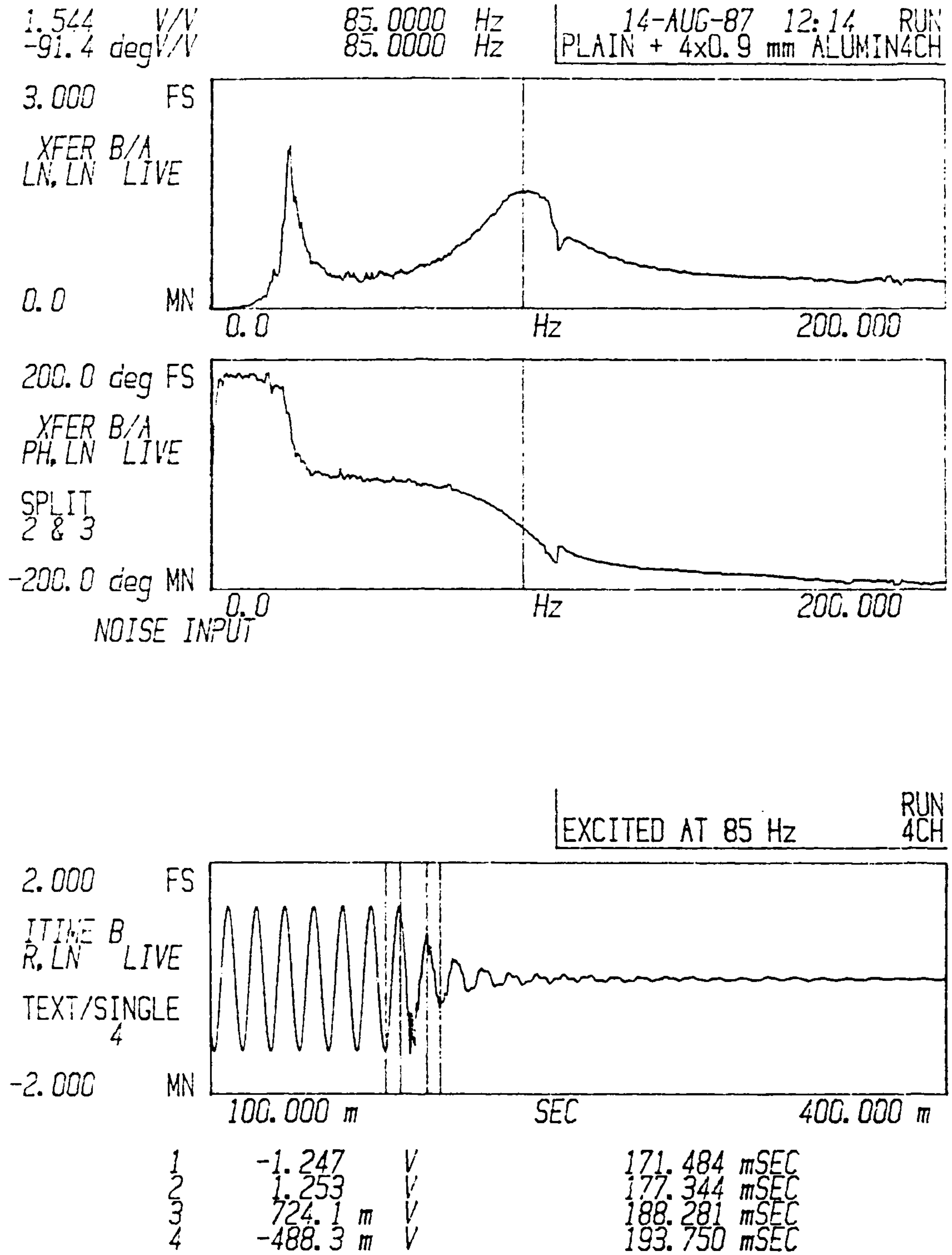
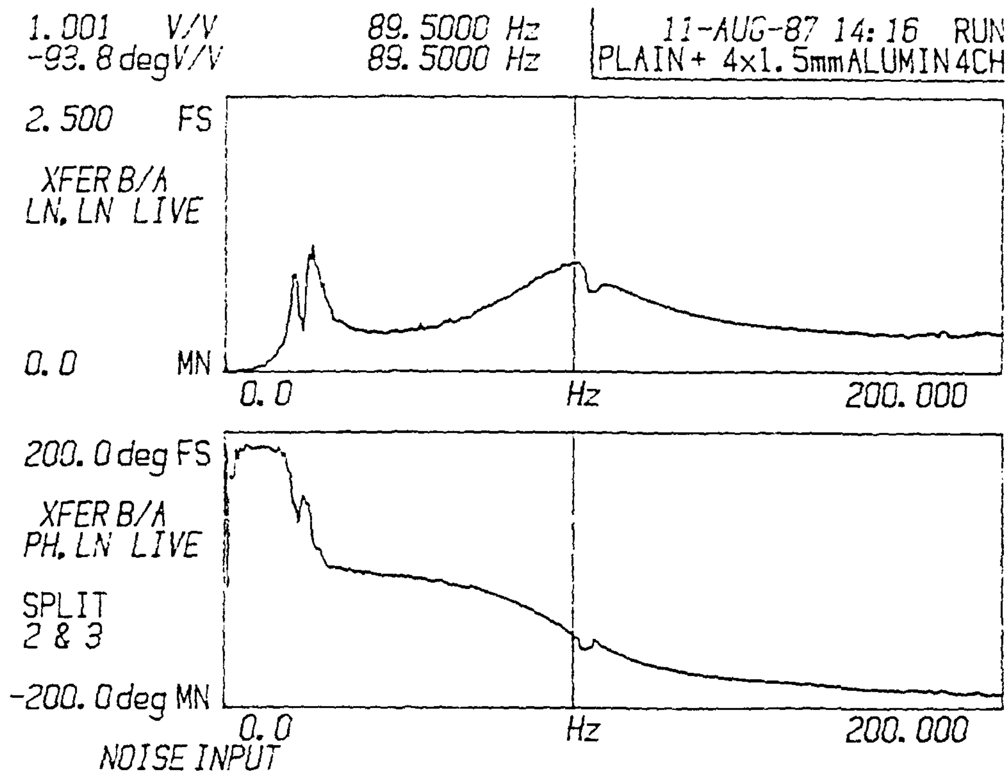


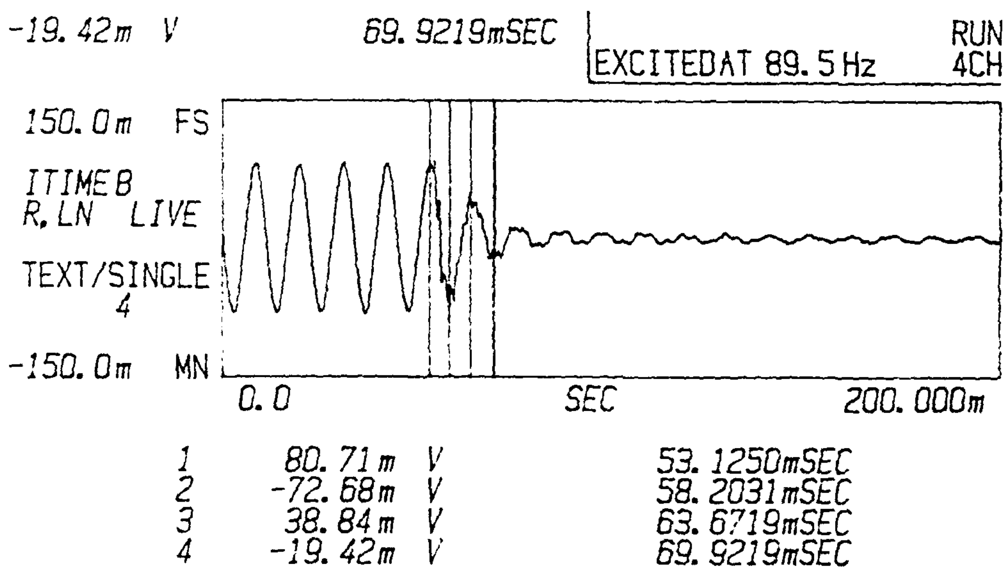
FIGURE 8. RESULT OF TEST ON ALUMINIUM SPECIMEN BONDED TO 0.3mm ALUMINIUM AS IN FIGURE 4 USING TESA ADHESIVE TAPE



PLAIN + 4x0.9 ALUM

FIGURE 9. RESULT OF TEST ON ALUMINIUM SPECIMEN BONDED TO 0.9mm ALUMINIUM AS IN FIGURE 4 USING TESA ADHESIVE TAPE





PLAIN+ 4 STRIPS

FIGURE 10. RESULT OF TEST ON ALUMINIUM SPECIMEN BONDED TO 1.5mm ALUMINIUM AS IN FIGURE 4 USING TESA ADHESIVE TAPE

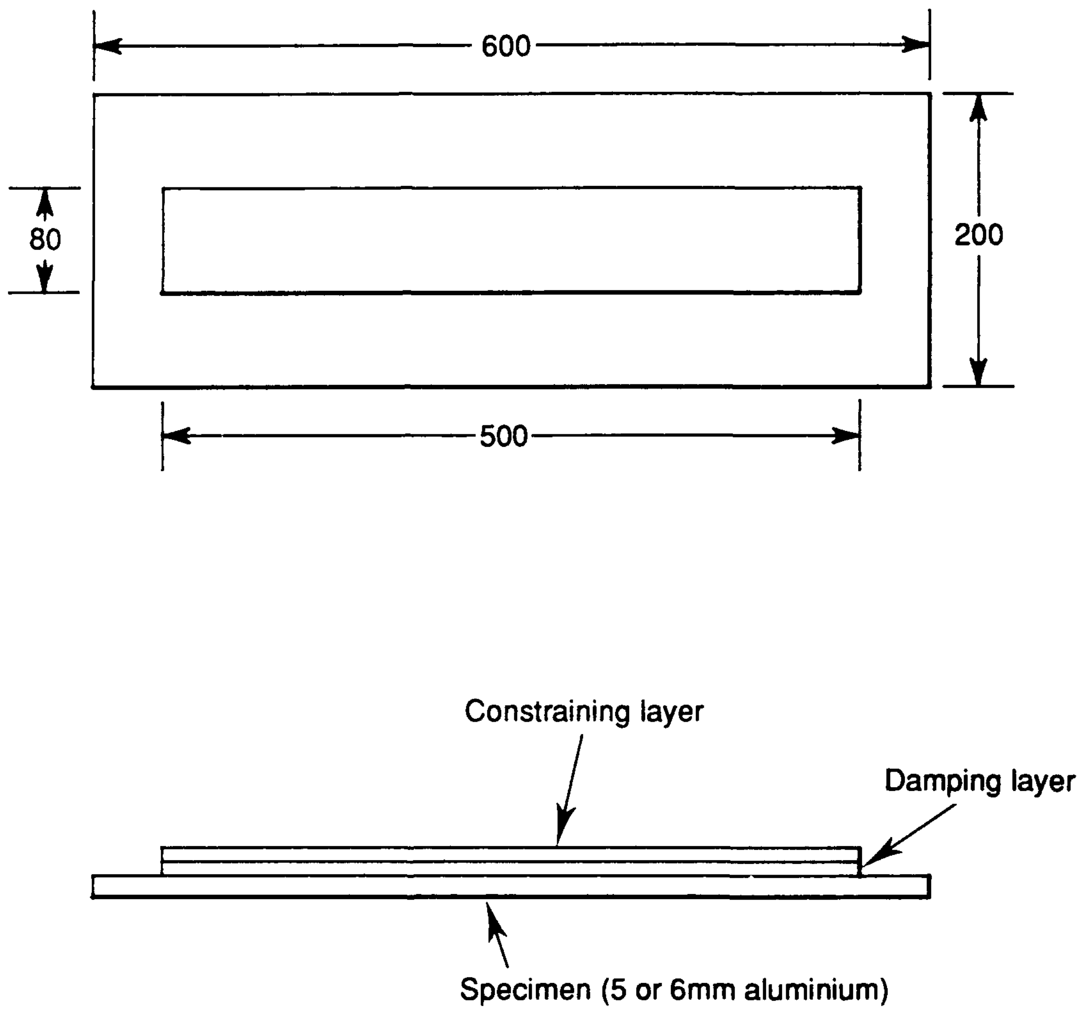
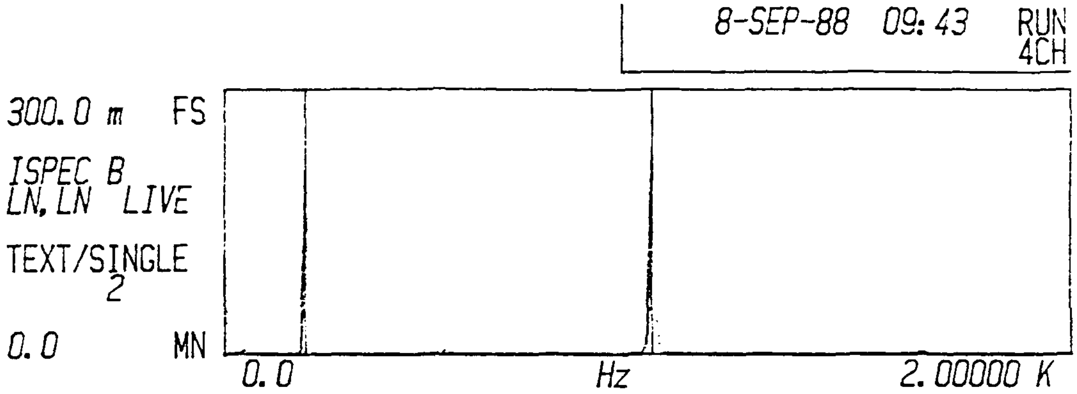


FIGURE 11. CONSTRUCTION OF SPECIMENS FOR THIRD SERIES OF TESTS RESULTS IN TABLES 3 AND 4



1 209.5 m V 190.000 Hz
2 228.8 m V 1.01000 KHz

BARE SPECIMEN

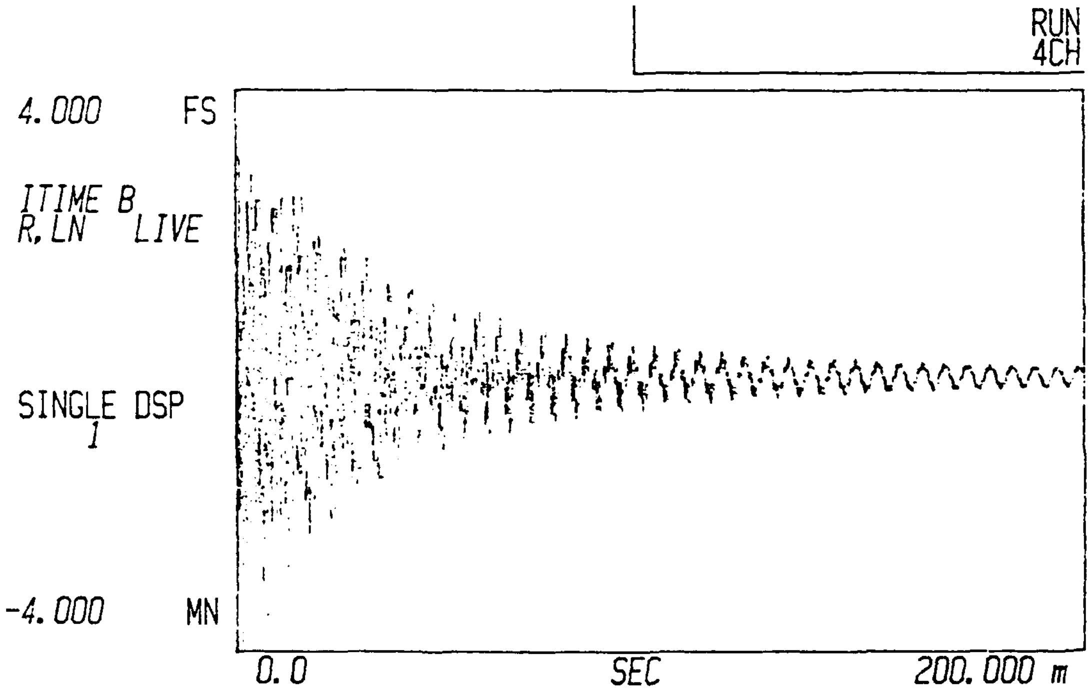
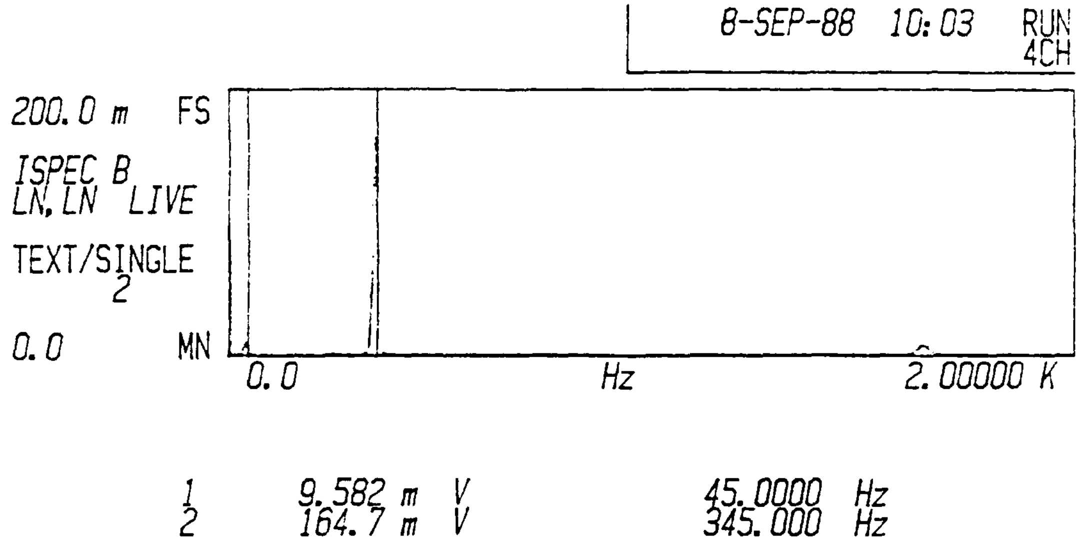


FIGURE 12. RESULT OF TEST ON 400 x 100 x 8mm FIBREGLASS SPECIMEN



DYAD/ARALDITE

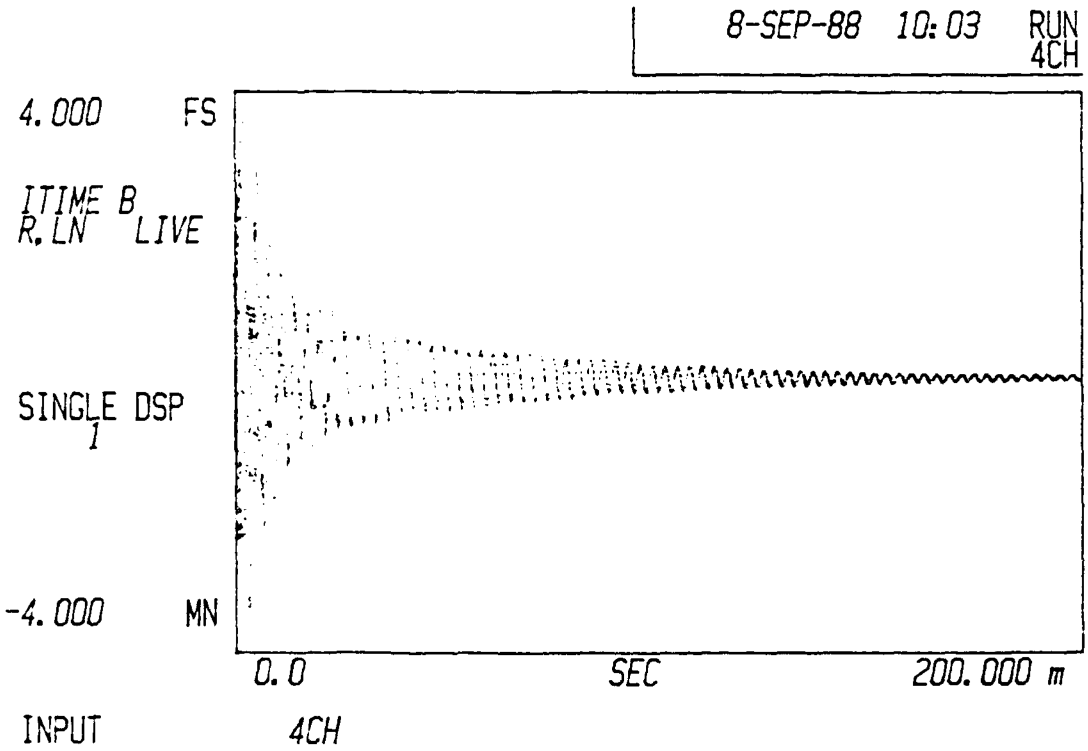


FIGURE 13. RESULT OF TEST ON 400 x 100 x 8mm FIBREGLASS SPECIMEN BONDED TO NYLEX DYAD AND 350 x 75 x 3mm ALUMINIUM USING ARALDITE ADHESIVE

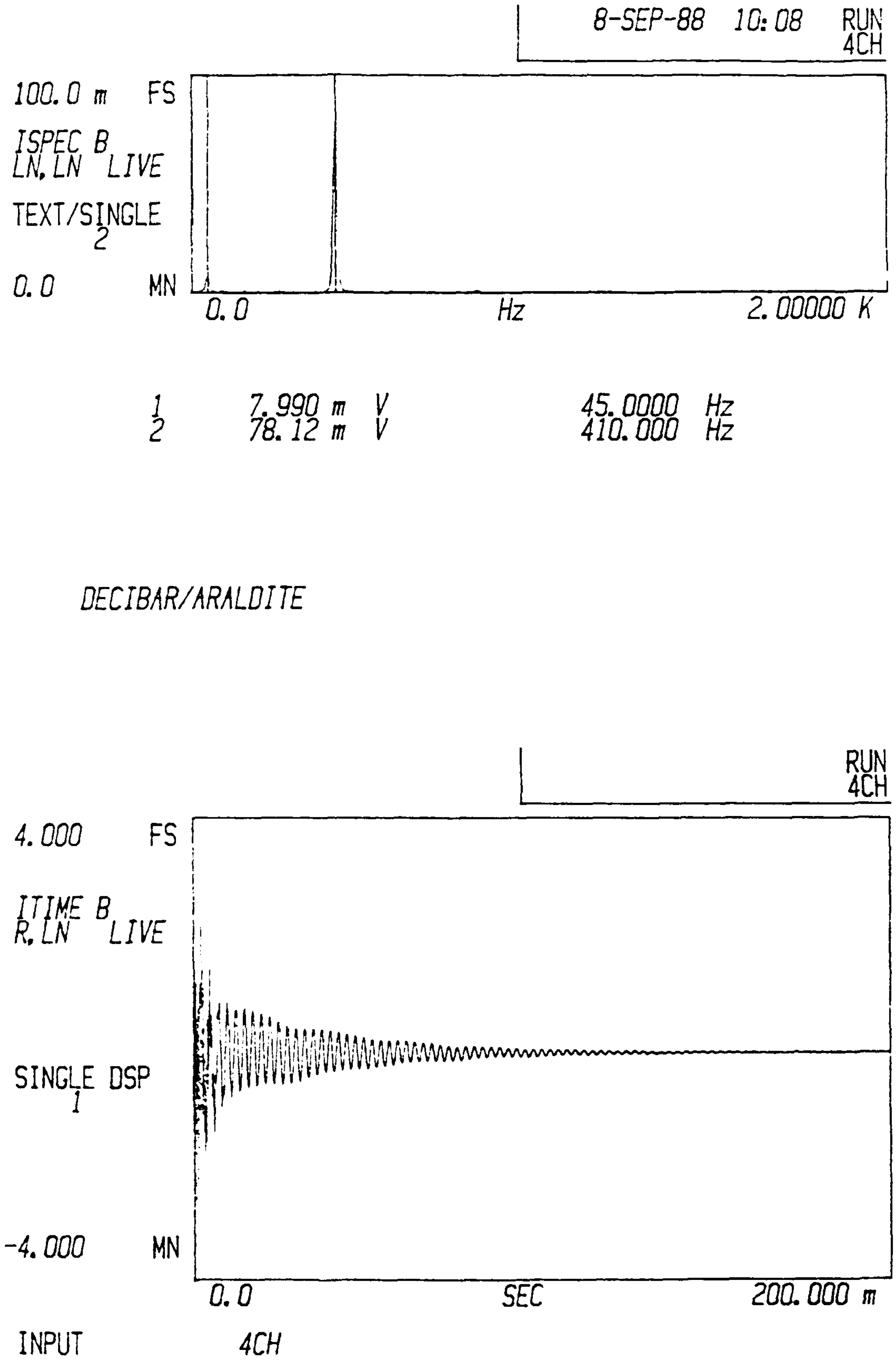
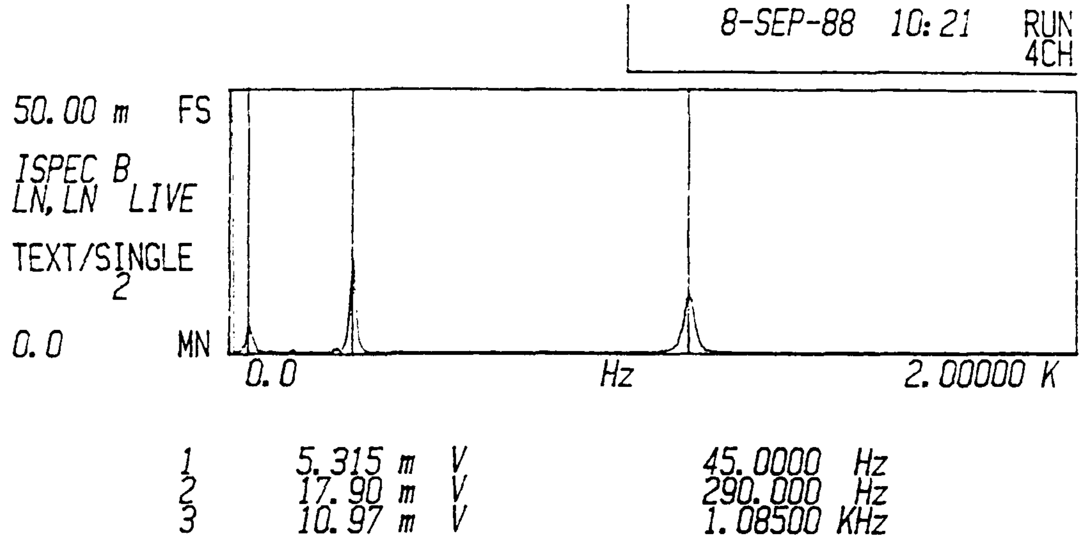


FIGURE 14. RESULT OF TEST ON 400 x 100 x 8mm FIBREGLASS SPECIMEN BONDED TO DECIBAR DS4 SHEET AND 350 x 75 x 3mm ALUMINIUM USING ARALDITE ADHESIVE



3M RUBBER ALONE

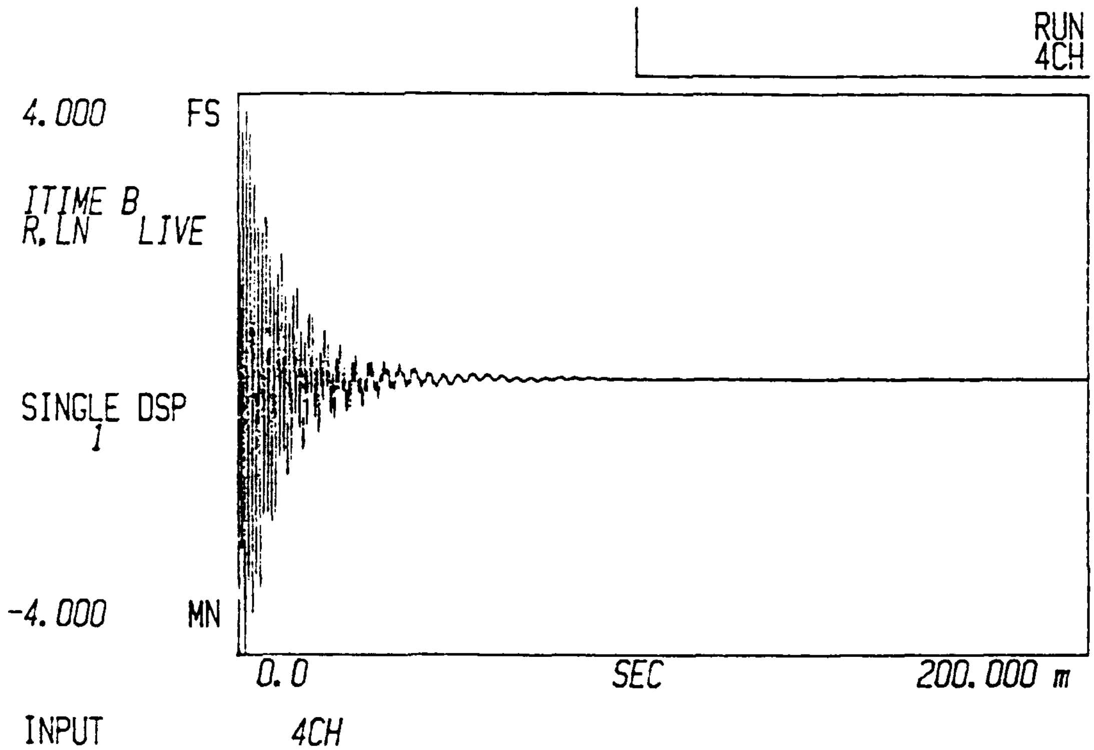
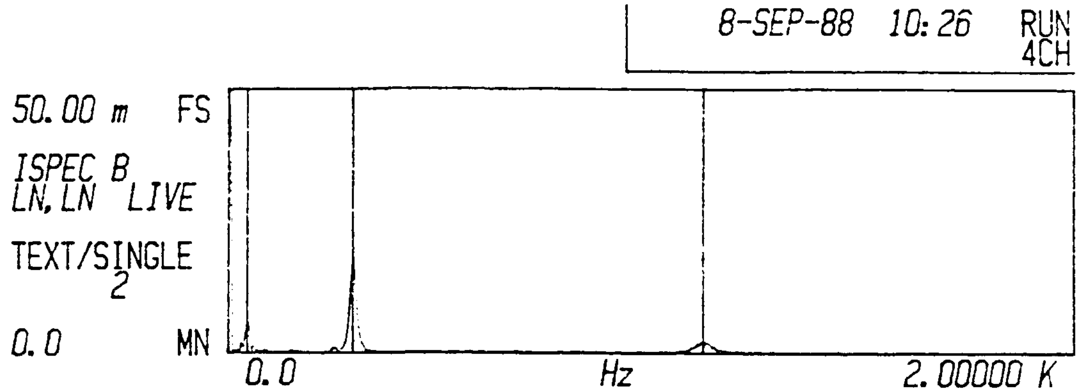


FIGURE 15. RESULT OF TEST ON 400 x 100 x 8mm FIBREGLASS SPECIMEN BONDED TO DECIBAR DS4 SHEET AND 350 x 75 x 3mm ALUMINIUM USING 3M RUBBER CONTACT ADHESIVE APPLIED IN APPROVED MANNER



1	5.739 m	V	45.0000	Hz
2	18.37 m	V	295.000	Hz
3	2.072 m	V	1.12500	KHz

3M RUBBER - DOUBLE

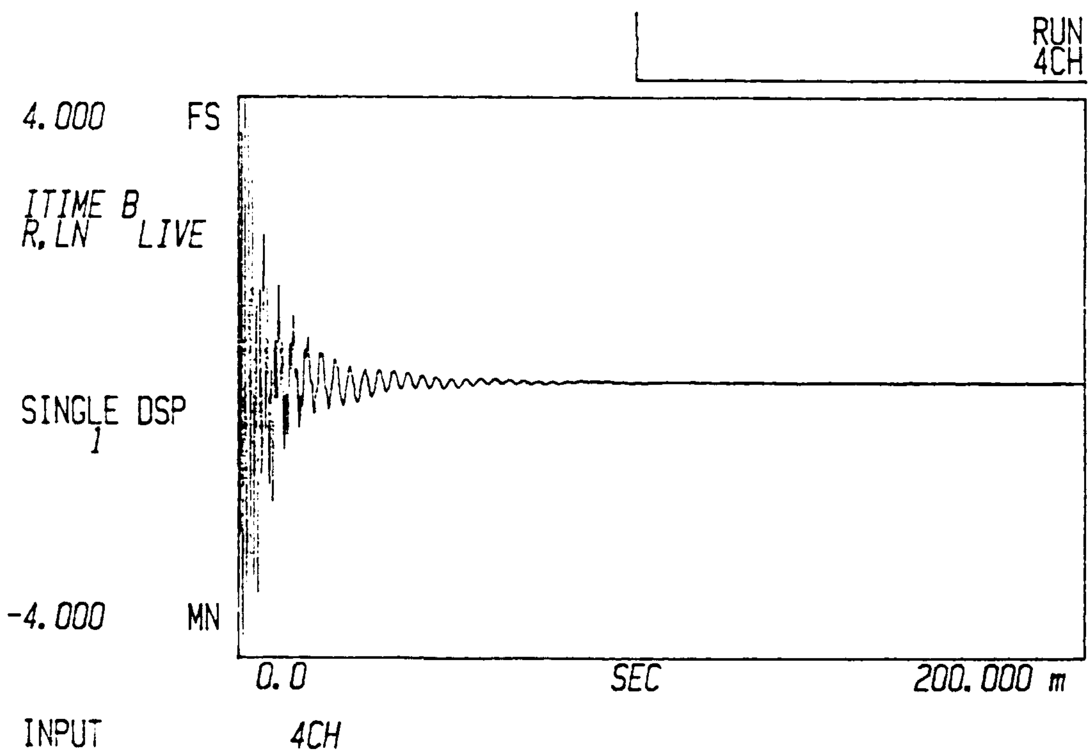
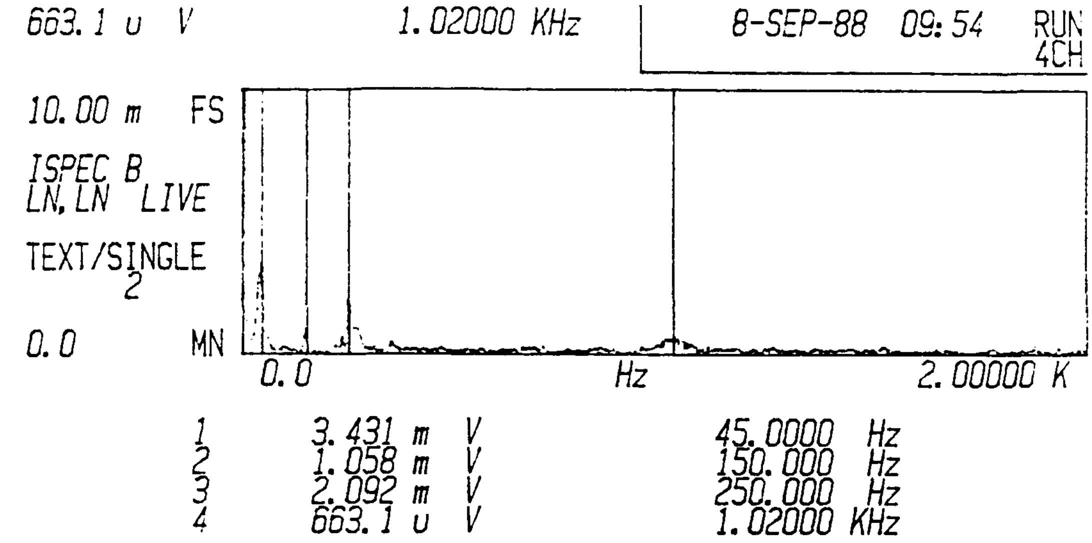


FIGURE 16. RESULT OF TEST ON 400 x 100 x 8mm FIBREGLASS SPECIMEN BONDED TO 350 x 75 x 3mm ALUMINIUM USING TWO COATS OF 3M RUBBER CONTACT ADHESIVE



3M SCOTCHMOUNT

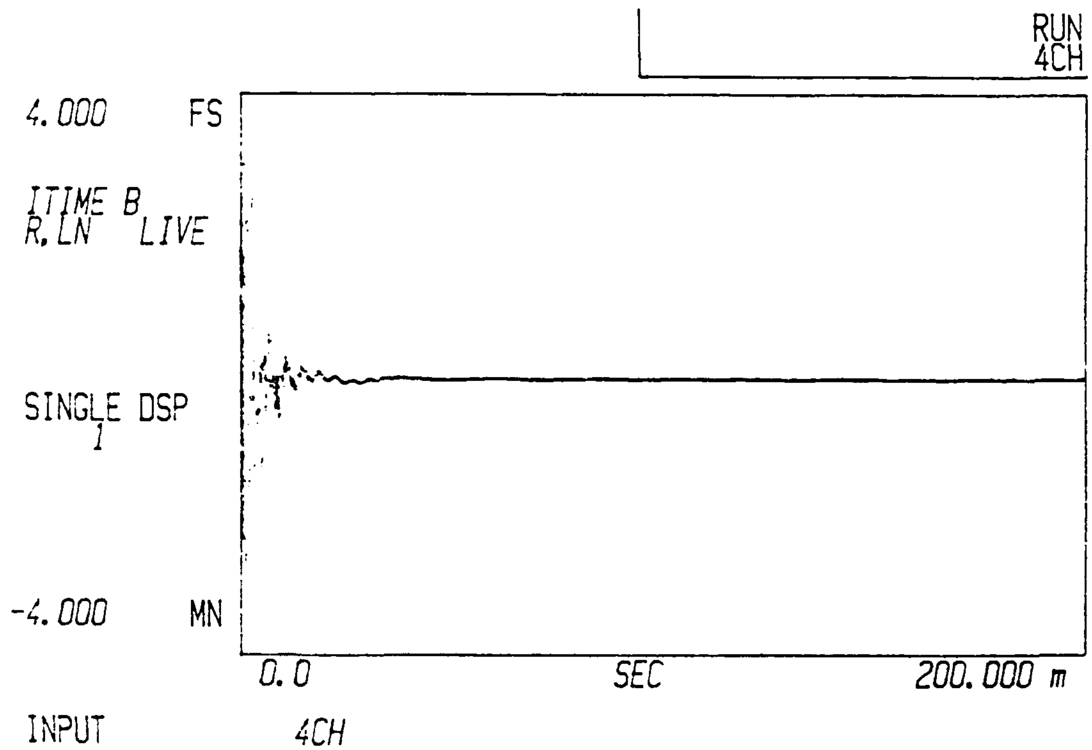


FIGURE 17. RESULT OF TEST ON 400 x 100 x 8mm FIBREGLASS SPECIMEN BONDED TO 350 x 75 x 3mm ALUMINIUM USING 3M "SCOTCHMOUNT" Y4965 ADHESIVE TAPE

FIGURE 18. EXPERIMENTAL CONSTRAINED LAYER DAMPING ON F/A-18 STABILATOR.

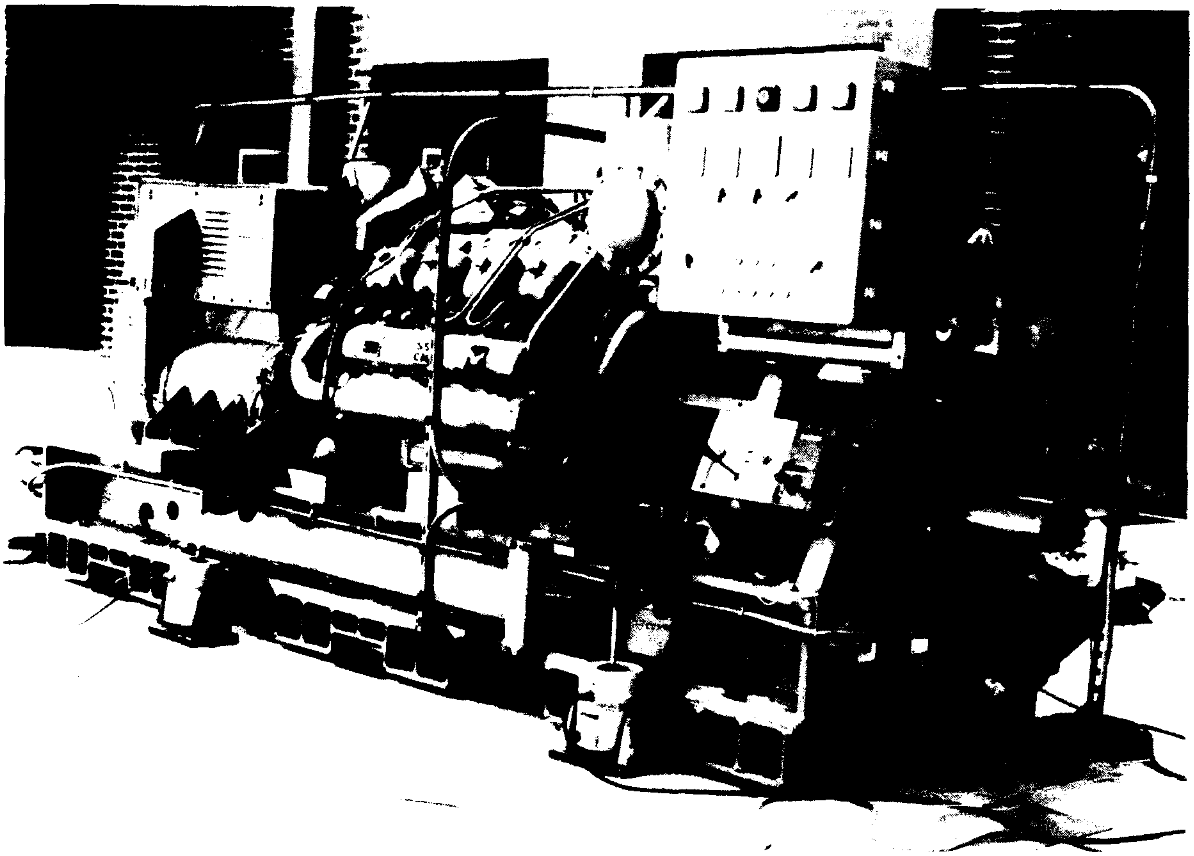


FIGURE 19. VIBRATION TEST ON A DIESEL GENERATOR SET WITH STEEL FABRICATED RAFT SUPPORTED ON 6 ISOLATION MOUNTS. TWO OF THE FOUR VIBRATION EXCITERS CAN BE SEEN.

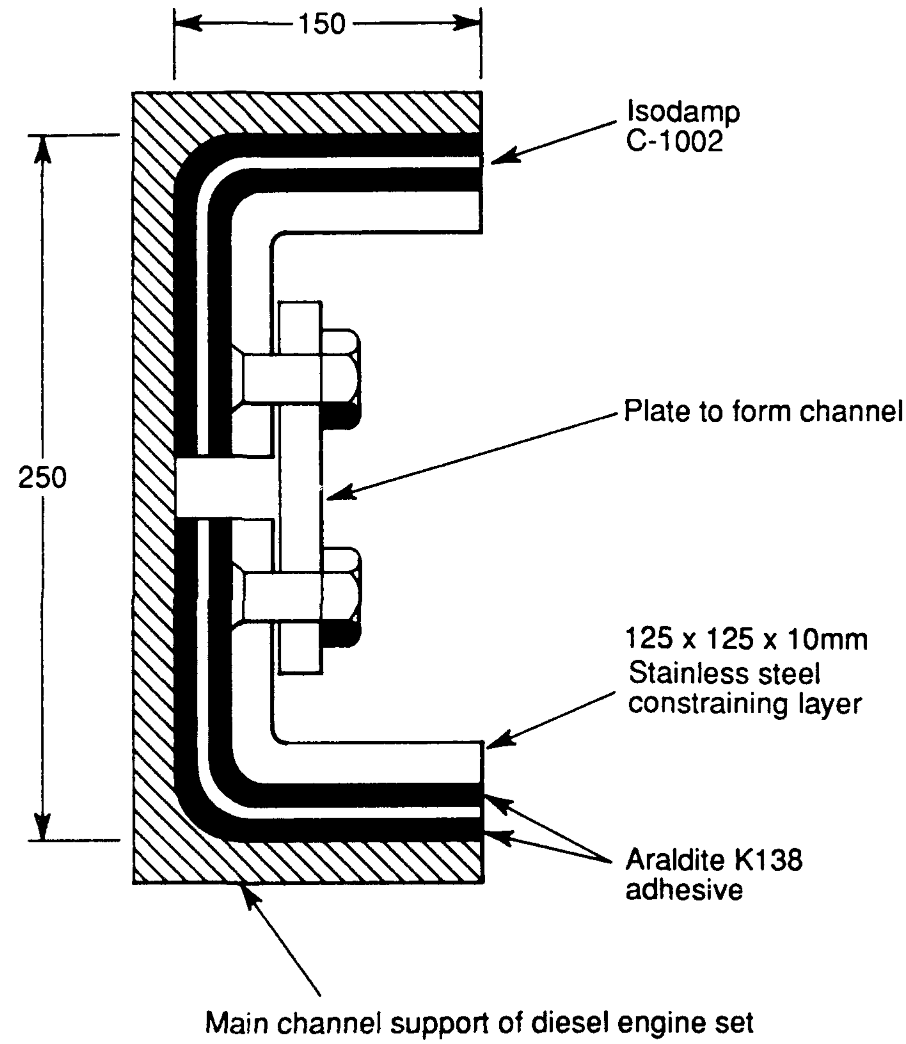


FIGURE 20. DETAIL OF INSTALLATION OF CONSTRAINED LAYER DAMPING ON DIESEL ENGINE/GENERATOR UNIT.

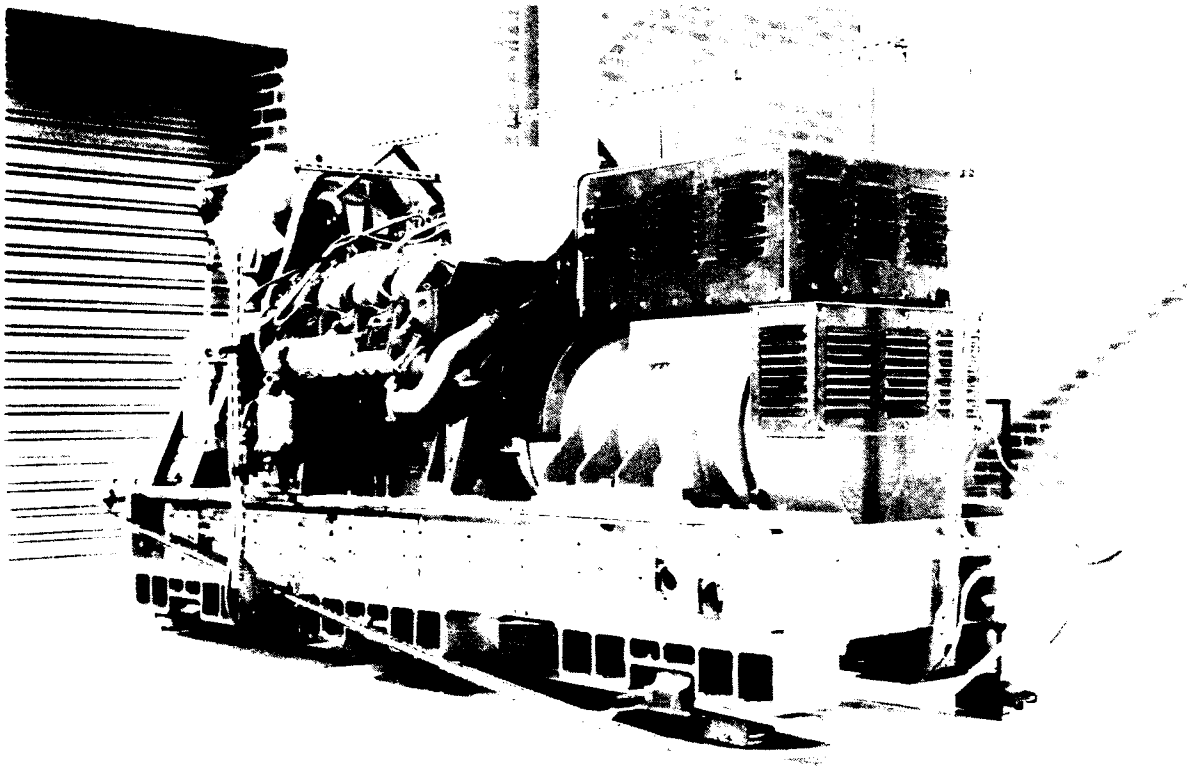
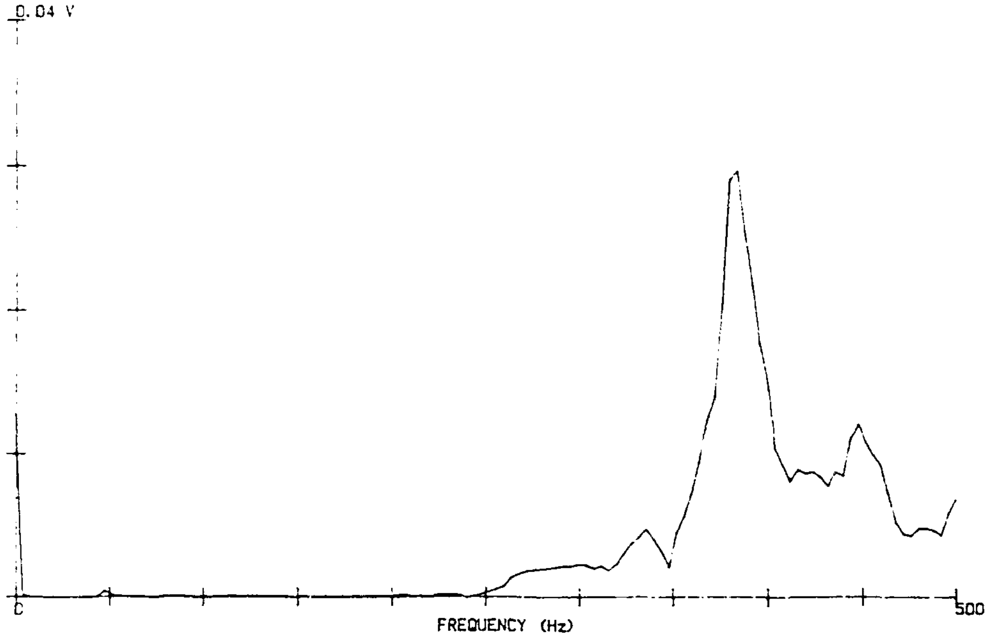
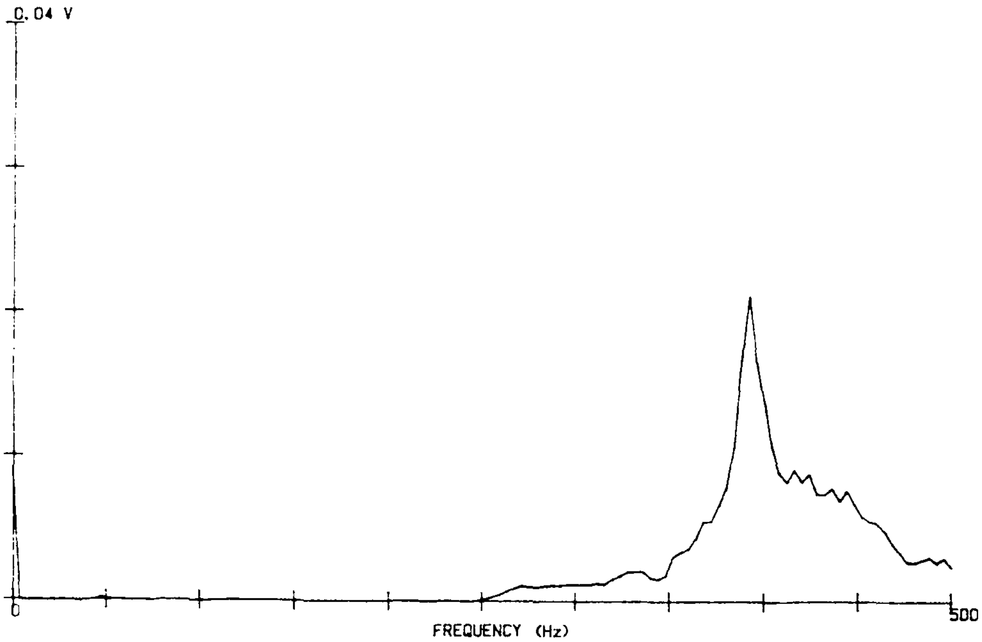


FIGURE 21. DIESEL SET WITH DAMPING INSTALLED IN MAIN CHANNELS



(a) before damping treatment

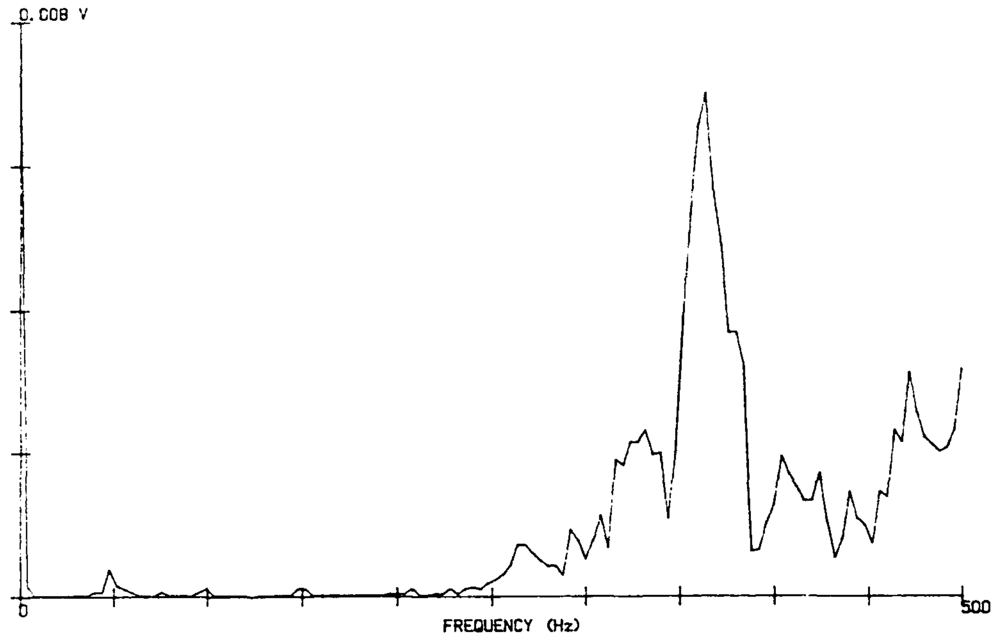
SHAKER No1 ACCEL. POS. No1 22/7/88



(b) after damping treatment

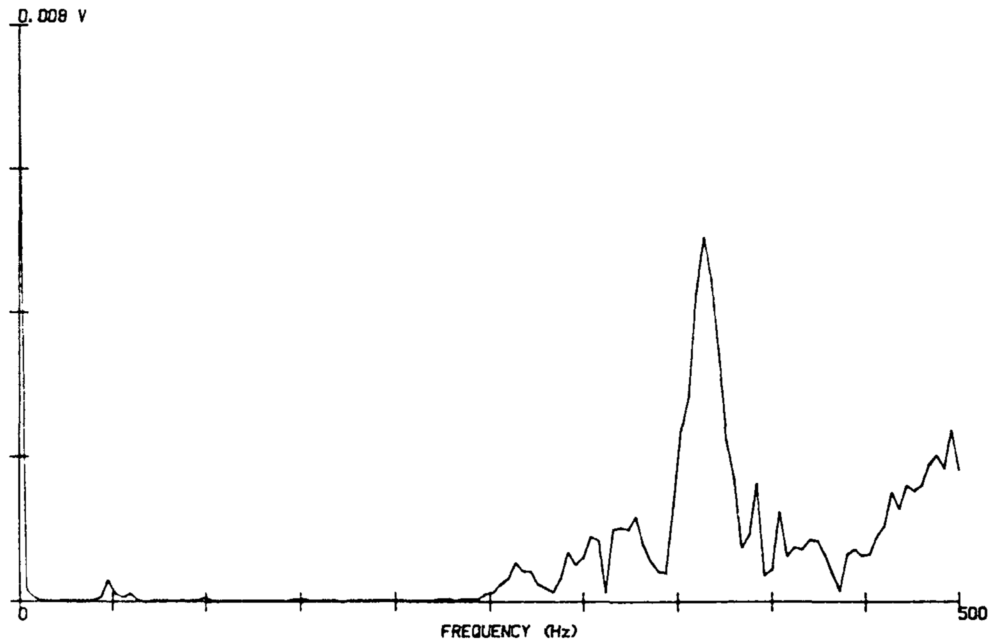
SHAKER No1 ACCEL. POS. No1 26/7/88

FIGURE 22. DIESEL SET - RESPONSE AT LOCATION 1 BEFORE (a) AND AFTER DAMPING TREATMENT (b)



(a) before damping treatment

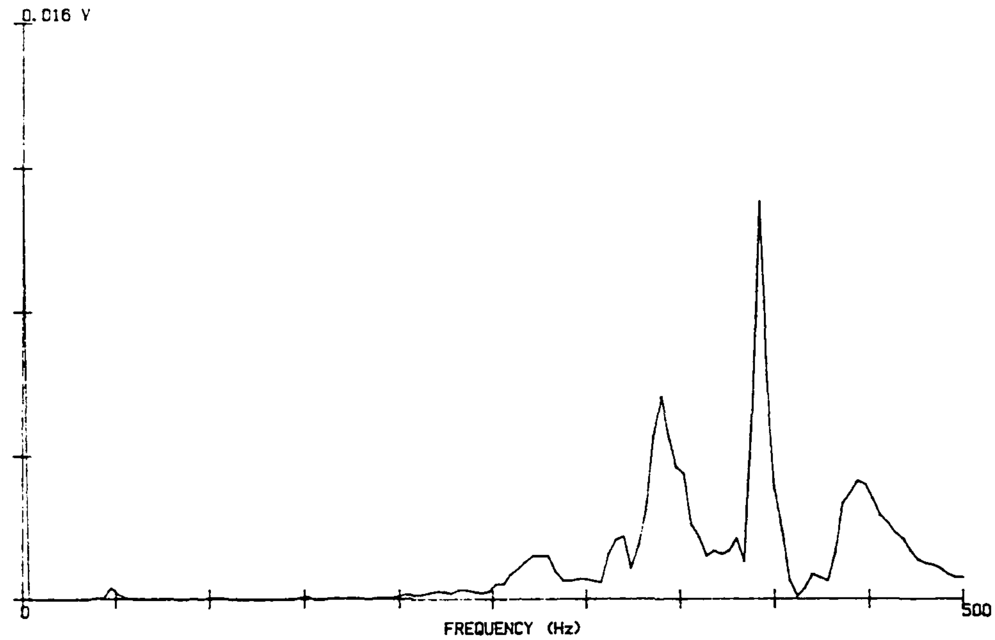
SHAKER No2 ACCEL. POS. No1 22/7/88



(b) after damping treatment

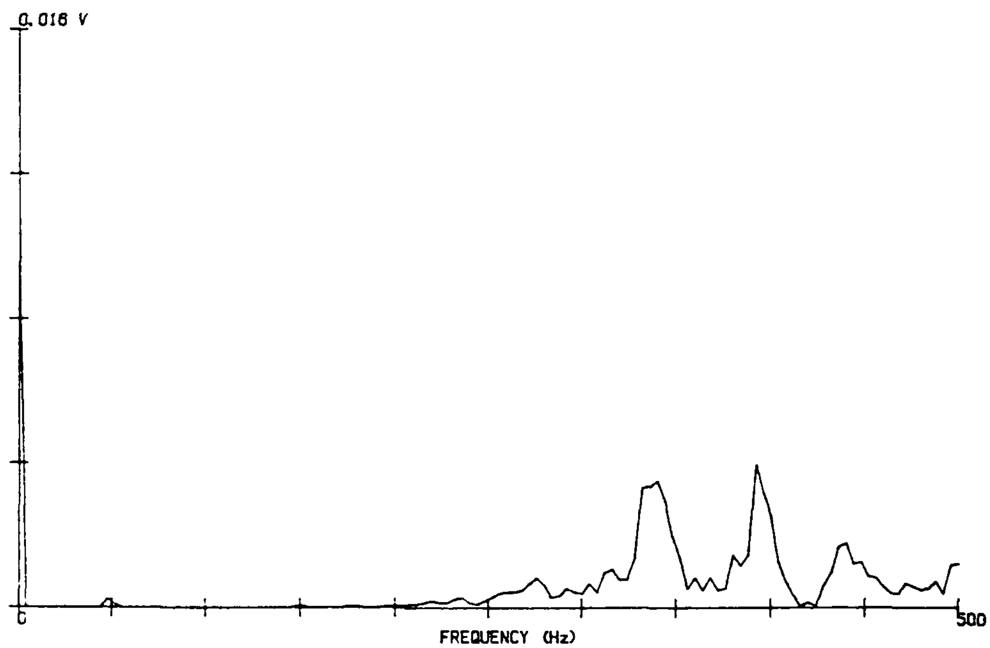
SHAKER No2 ACCEL. POS. No1 26/7/88

FIGURE 23. DIESEL SET - RESPONSE TO SHAKER NO 2 AT LOCATION 1 BEFORE AND AFTER DAMPING TREATMENT



(a) before damping treatment

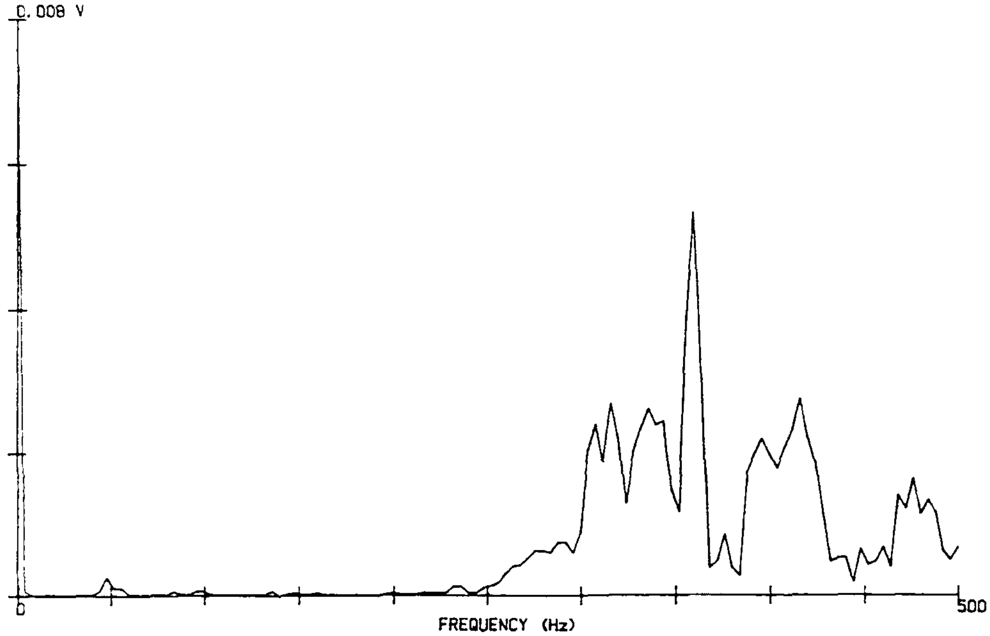
SHAKER No3 ACCEL. POS. No1 22/7/88



(b) after damping treatment

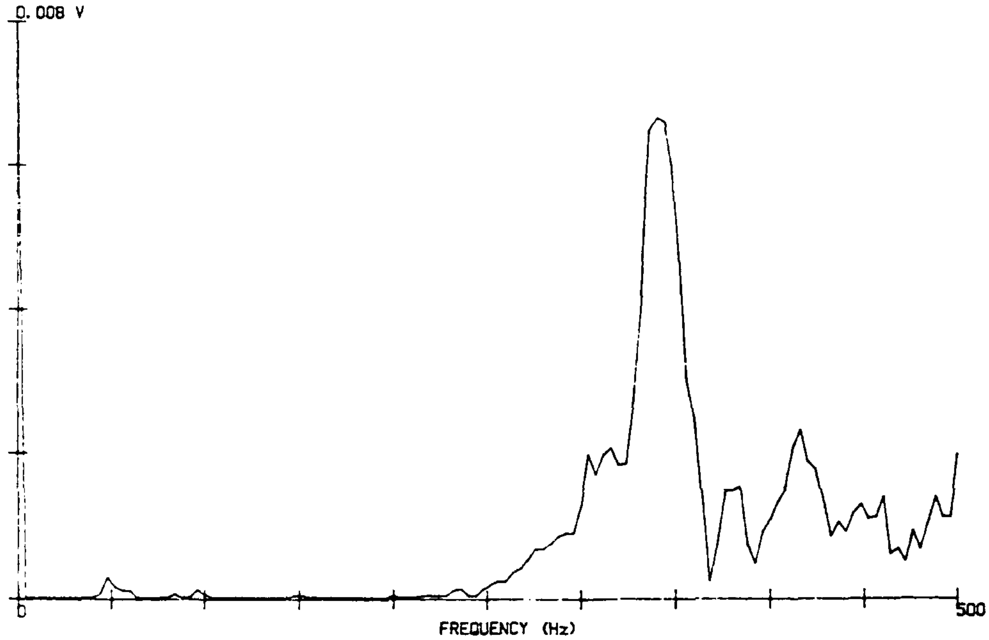
SHAKER No3 ACCEL. POS. No1 26/7/88

FIGURE 24. DIESEL SET RESPONSE TO SHAKER NO 3 AT LOCATION 1 BEFORE AND AFTER DAMPING TREATMENT



(a) before damping treatment

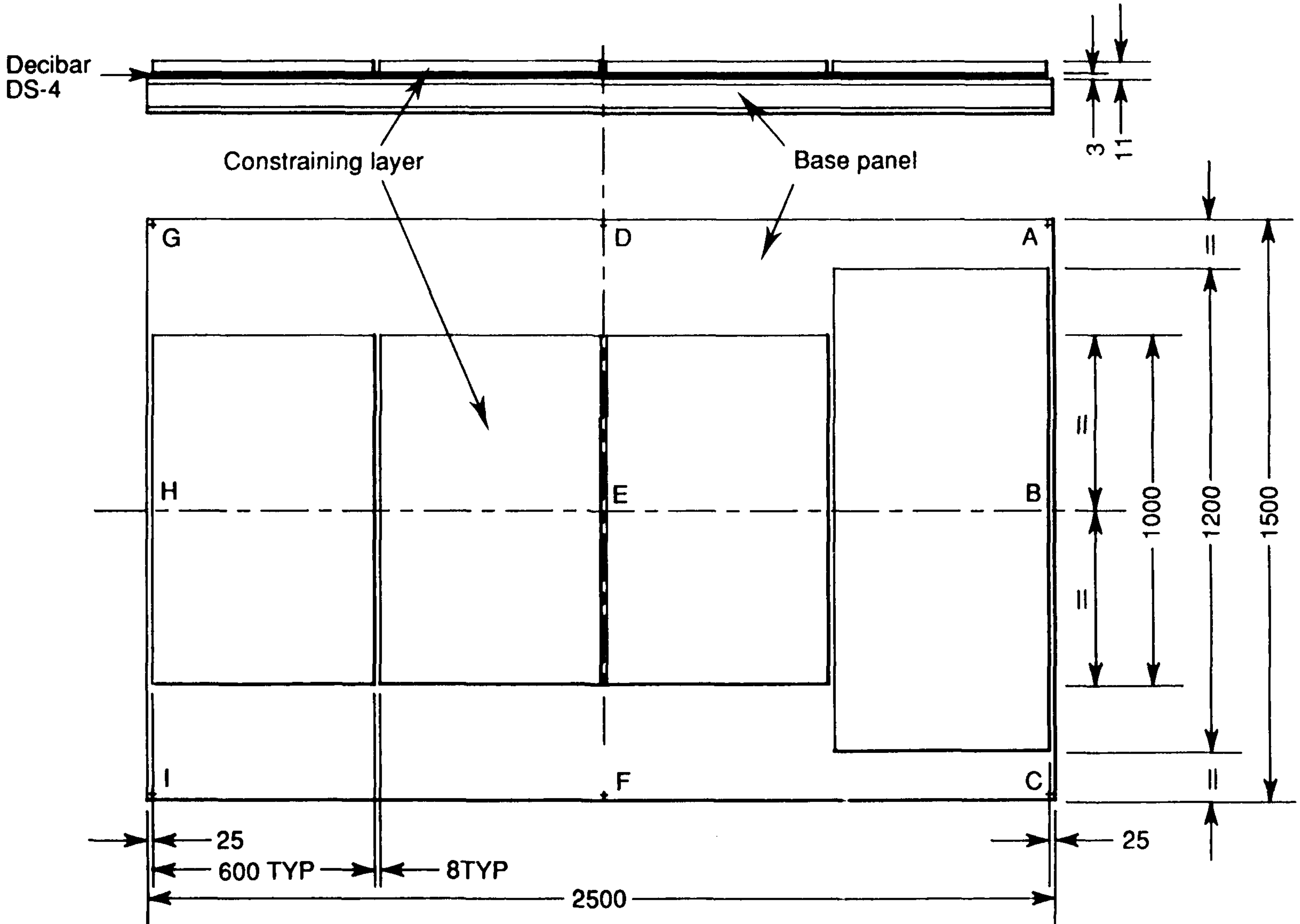
SHAKER No4 ACCEL. POS. No4 22/7/88



(b) after damping treatment

SHAKER No4 ACCEL. POS. No4 26/7/88

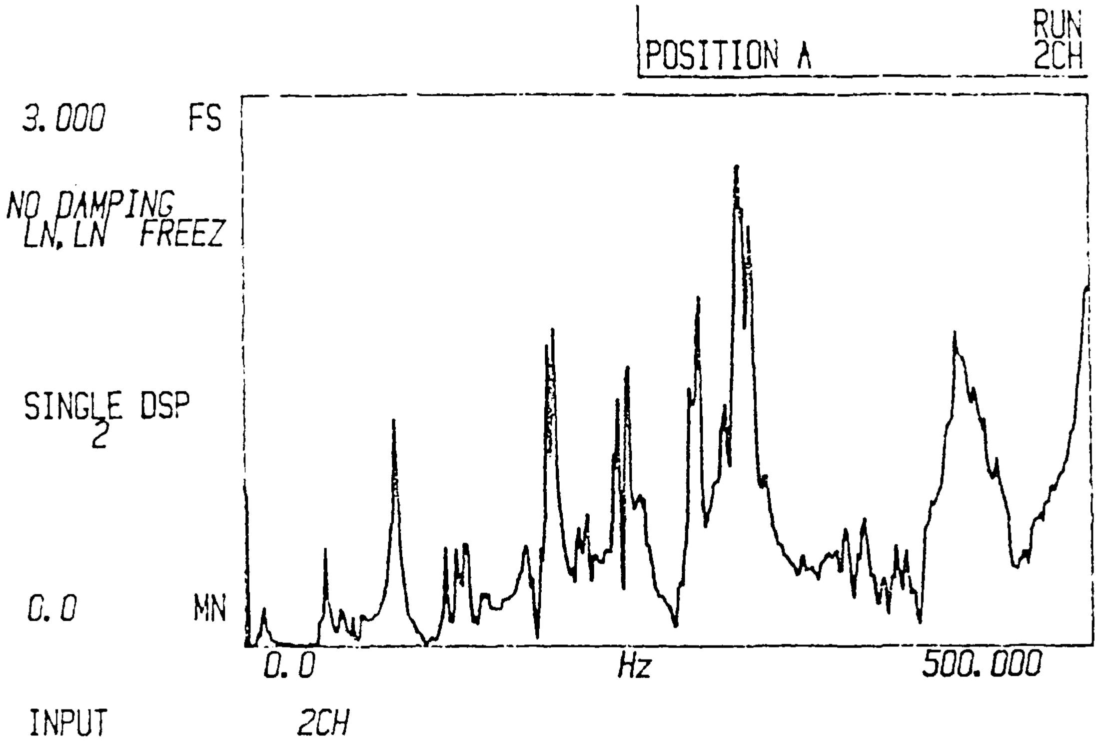
FIGURE 25. DIESEL SET - RESPONSE TO SHAKER NO 4 AT LOCATION 4 BEFORE AND AFTER DAMPING TREATMENT



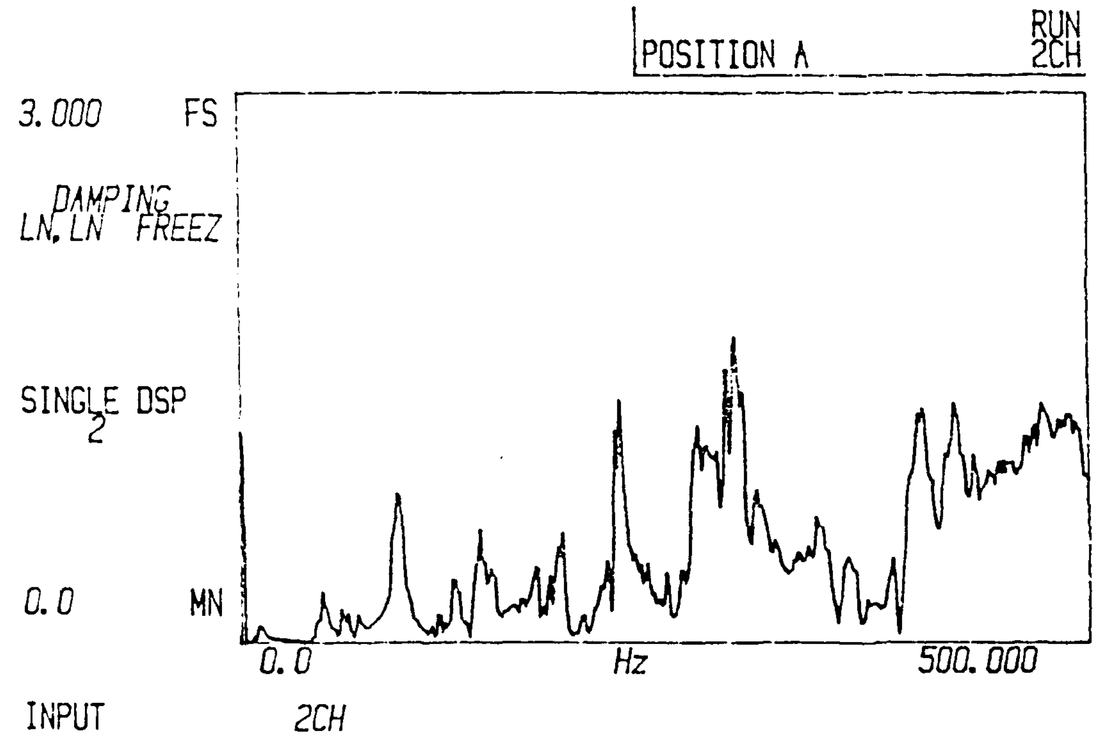
Note: All dimensions in millimeters

FIGURE 26. LAYOUT FOR DAMPING EXPERIMENTS ON LARGE SANDWICH PANEL

FIGURE 27. FOAM SANDWICH PANELS SET UP FOR DAMPING EXPERIMENTS

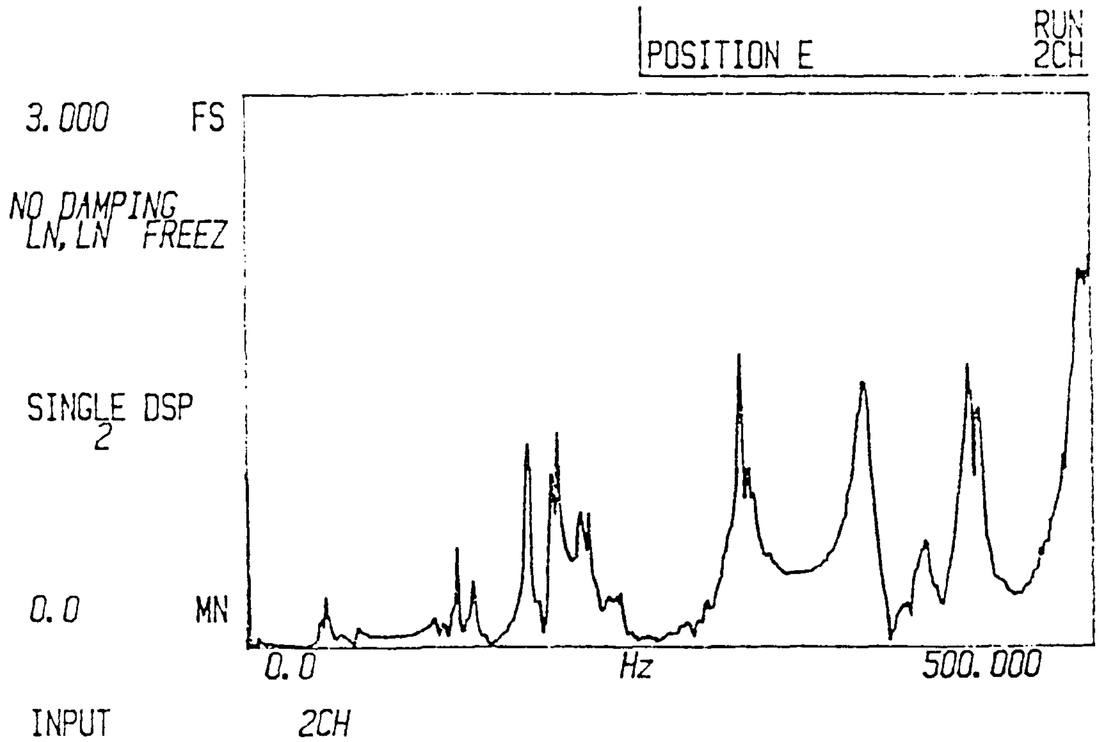


(a) No damping treatment

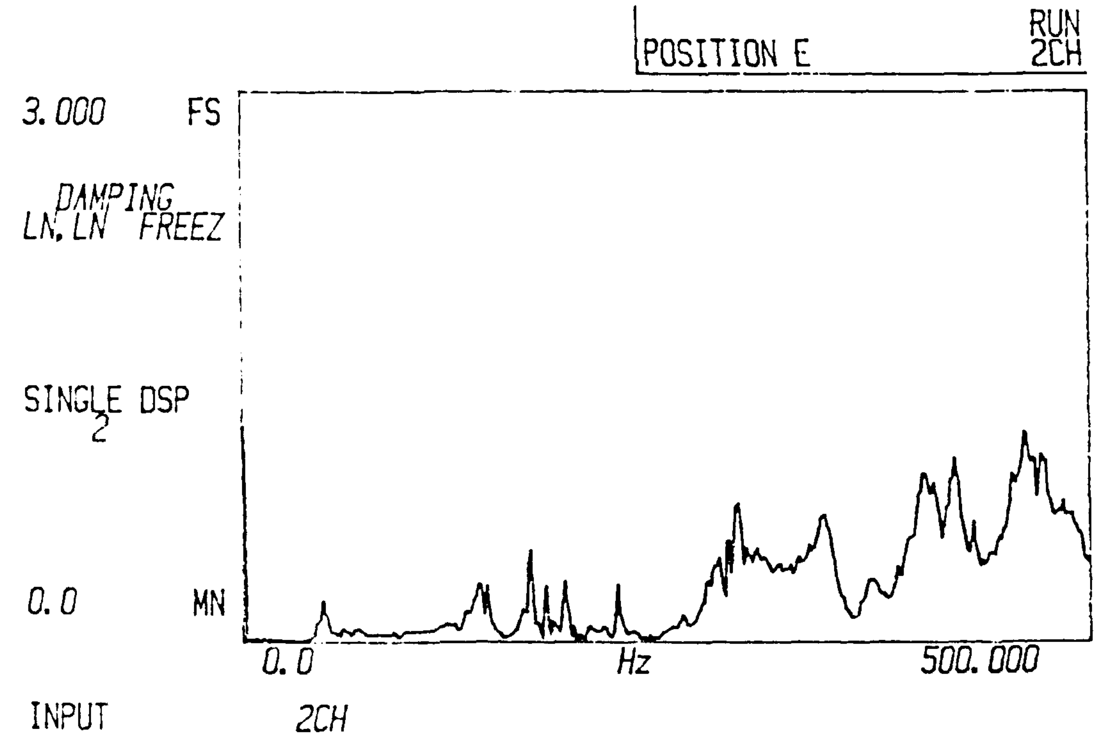


(b) damping treatment applied

FIGURE 28. EFFECT OF DAMPING ON LARGE GRP PANEL RESPONSE AT POSITION "A" TO RANDOM VIBRATION



(a) No damping treatment



(b) damping treatment applied

FIGURE 29. EFFECT OF DAMPING ON LARGE GRP PANEL RESPONSE AT POSITION "E" TO RANDOM VIBRATION

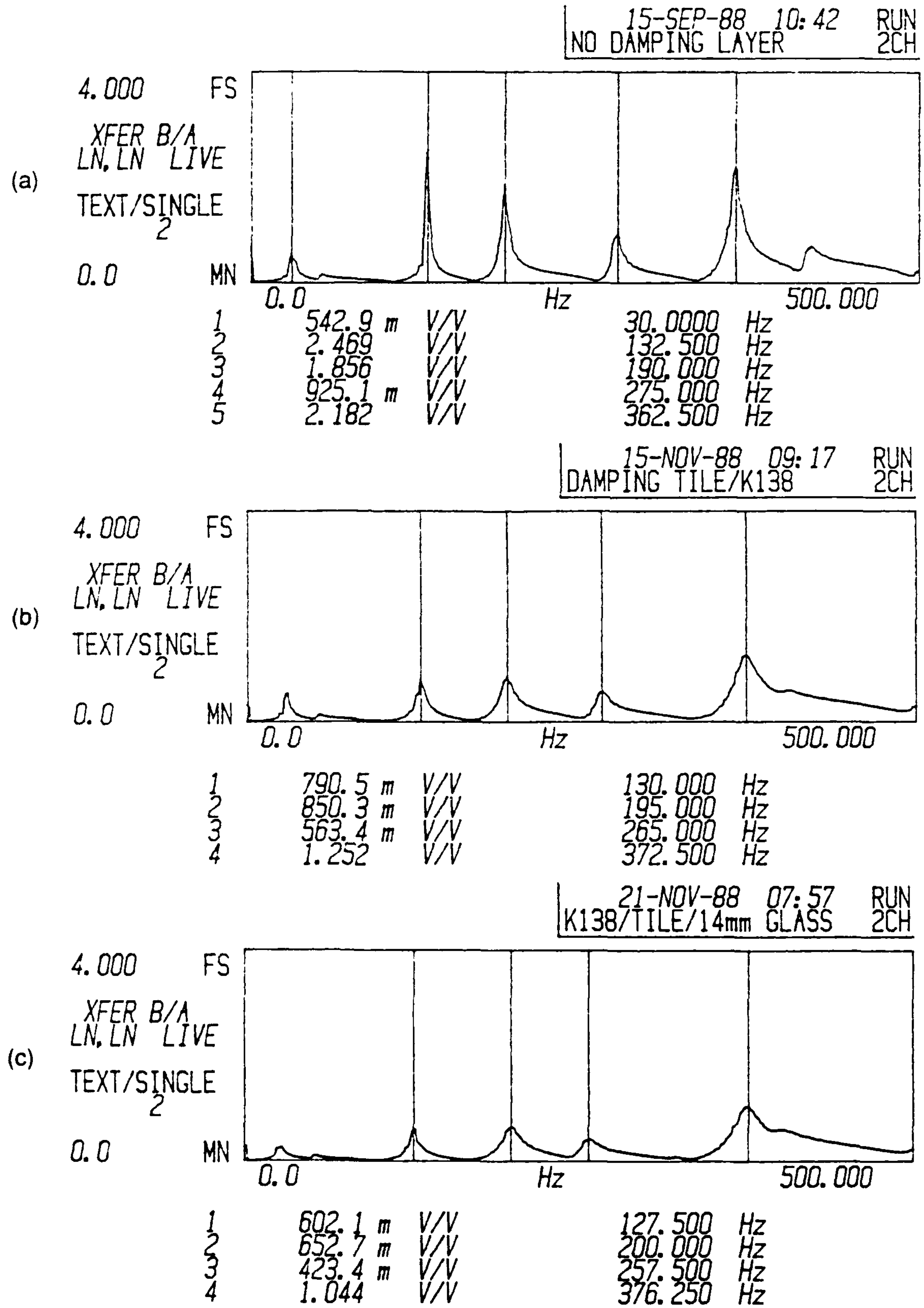
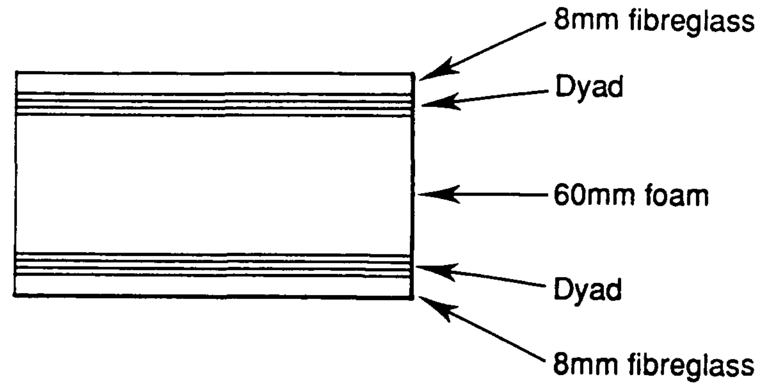
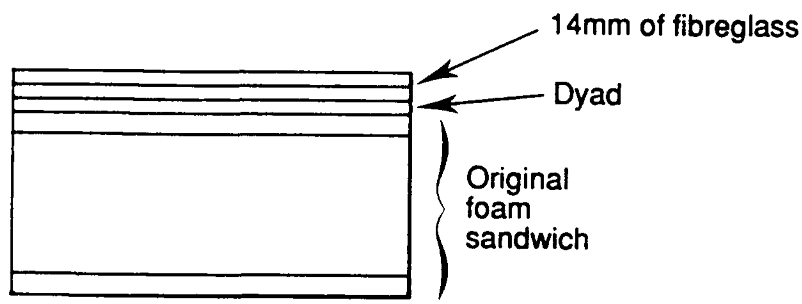


FIGURE 30. TESTS ON FIBREGLASS/FOAM PANEL 1500 x 300 x 75mm
(a) BARE PANEL
(b) WITH EAR SHIP DAMPING TILES
(c) WITH EAR SHIP DAMPING TILES + 14mm FIBREGLASS

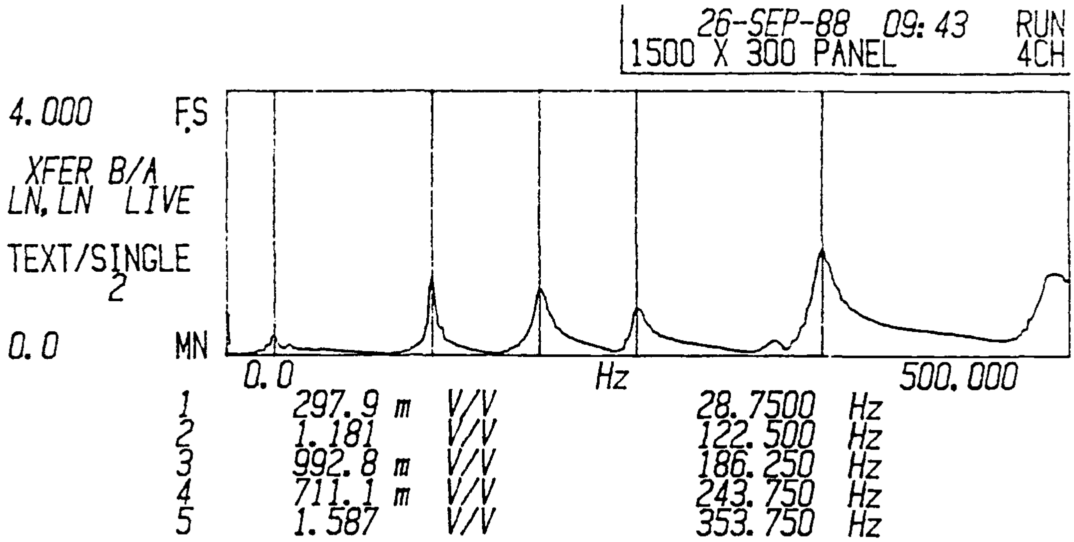


(a) Construction of modified foam/sandwich panel to include damping layer

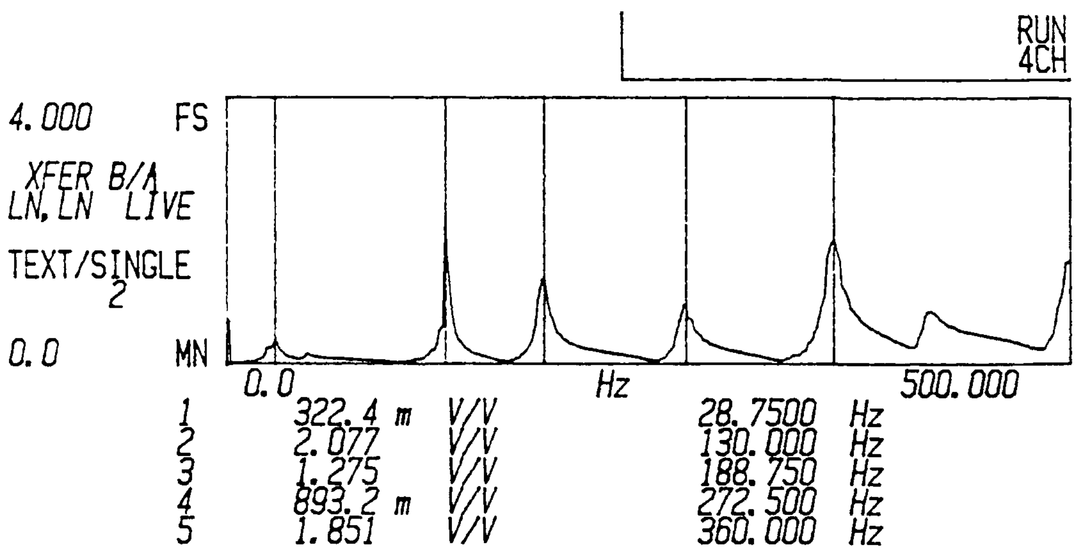


(b) Construction of constrained layer damping using dyad and 14mm fibreglass as an external addition

FIGURE 31. USE OF DYAD (a) INTERNALLY AND (b) EXTERNALLY ON A FIBREGLASS/FOAM SANDWICH PANEL



(a) Test on panel with external DYAD and 14mm fibreglass bonded using 3M RUBBER ADHESIVE



(b) Test on panel with internal DYAD bonded using Araldite K138 adhesive

FIGURE 32. RESULTS OF TESTS ON FIBREGLASS/FOAM PANELS DESCRIBED IN FIGURE 31

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16. ABSTRACT
Interest has recently been renewed by the Aeronautical Research Laboratory in the use of constrained layer damping for passive vibration reduction. This report describes the authors' experiences in applying the techniques to a variety of practical problems.

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