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REAL TIME ANALYSIS

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THE APPLICATION OF DIGITAL SIGNAL ANALYSIS TO THE ASSESSMENT OF RAILWAY VEHICLE RIDE:

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INTRODUCTION

This paper is a brief survey of the methods currently employed by British Railways Research & Development Division for the measurement of railway vehicle ride. In this context ride is loosely defined as the vibratory environment in the frequency range 0 - 50 Hz. Three areas of research are affected by these studies :- vehicle safety, passenger comfort and component integrity.

DEVELOPMENT OF DIGITAL ANALYSIS

Prior to the mid sixties all vehicle ride assessment was carried out either by manual analysis of time history records or by subjective feel of the ride. Manual analysis methods, though probably sufficient for low speed vehicles, were extremely wasteful of data since only a minute proportion of the time history could be used.

The first application of digital techniques was about 1965 and used data obtained by semi-automatic digitization of Ultra-Violet recordings. This work was restricted to Power Spectral Density and Proabability Density analysis and in conjunction with work on the measurement of track showed that useful results could be obtained. The main disadvantage was still the relatively small quantity of data which could be utilised in the analysis.

In order to increase the quantity and quality of data for analysis the mode of acquisition was changed to recording on analogue magnetic tape and then automatically digitizing the data on replay using a hard wired digitizer working directly to digital magnetic tape.

In order to scale the crude data, calibration signals are recorded on the analogue tapes at the start of each test and passed to the crude data digital tape. These values are then used by a pre-processing program which generates a new tape of scale and reformated data values ready for detailed analysis. This system of acquisition has been very successful and using data ob ained from various vehicle tests a considerable number of analysis programs have been developed, however the overall turn round time of data from test to analysis results can be quite long (a minimum of 2 days and often in excess of 5 days).

During prototype vehicle testing it is often necessary to see the results from one test or series of tests before proceeding. In order to provide the engineer with his results quickly so that testing time can be minimized an on-line system is being developed. This system consists of a small high-speed digital computer with an analog to digital converter into which up to 32 input signals can be multiplexed. In operation the system will provide a basic digital data acquisition facility direct onto magnetic tape and some forms of on-line analyses and in addition analysis programs will be available to perform most of the detailed analyses required on an immediate post test basis. Use of this system should cut the data turn round time to 30 minutes.

CURRENT TECHNIQUES

Most of our work falls in the general area of time series analysis and we find it convenient to divide the analysis into two sections quick look analyses and detailed analyses. Quick look analyses are those techniques which enable an assessment of the quality of the data to be made and in some cases a crude assessment of the influence of parameter changes on vehicle performance. Detailed analyses are intended to give a more complete understanding of the character of the data and the influence of parameter changes on vehicle performance.

In the area of quick look analysis the most freqnently employed technique is graphical presentation of short period data mean values and standard deviations against time (Fig.1.) These statistical parameters can be evaluated using either rectangular or exponential data windows but the rectangular window is usually used, since the plot produced is less distorted by long rise times. The main applications of this form of analysis is the selection of sections of the data for more detailed analysis. However there are direct uses and a typical application is the detection of unstable running of a vehicle which produces a gross increase in the standard deviation of data collected from lateral measurements.

A second form of analysis used for quick look and also as a final analysis is level exceedence counting. These counts are normally evaluated for a complete test but provision is made for obtaining cumulative counts at fixed time intervals. A direct application of this form of analysis is the assessment of damage risk for components or pay load due to excessive accelerations, forces etc.

To cater for the cases where either the quality of the data is in doubt or it is necessary to study the particular measured time histories, a program has been developed which produces a scaled graphical reconstruction of the original signal. The example Fig.2 is of an axlebox vertical acceleration and shows the responses to rail joints.

Before describing the more detailed forms of analysis employed some discussion of the assessment of data stationarity is appropriate. For most forms of random process analysis a minimum requirement is that the data should be weakly stationary i.e. the mean and standard deviation should be invariant with time. Our method of assessing this invariance is to visually select sections of data from the plots of mean and standard deviations. However we find that in many cases we have to accept a 20% variation of the standard deviation in order to obtain sufficient length of data to analyse. Such wide limits on stationarity are normally only accepted when there is prior knowledge of the st tionarity of the track irregularities which form the main input to railway vehicles.

The base for most of our detailed analysis is Power Spectral Density analysis which we compute by the method of 'Time Averaging of Short Modified Periodograms' as described by Welch (Ref 1). This analysis has been implemented on our IBM 370/145 computer using standard IBM software plus our own file handling routines to give a program which performs a typical analysis in less than 30 seconds central processor time. In addition to the basic P.S.D. analysis which can be output in either numeric or graphical form (Fig. 3) frequency dependent weighting can be applied and the spectra then integrated to give single figure assessment (e.g. weighted r.m.s.).

Probability Density analysis is also available and is used mainly in the areas of freight environment and component integrity. Results of this type of analysis are again available in numeric or graphical form Fig. 4. This type of analysis is also useful for confirming the statistical properties of data and hence the validity of other forms of analysis.

FUTURE DEVELOPMENT

These techniques have been in use for about two years with only minor changes. During this period much experience has been gained in their application to real vehicle situations. In some areas there is evidence that the methods may be inappropriate and a program of research, aimed at developing new techniques which will be more applicable to railway vehicle ride data, has been commenced.

Typical of the difficulties which this research is aimed at solving is the response to rail joints, which though occurring at regular intervals generate wheelset inputs of random amplitude.

As stated earlier a major disadvantage of using a main frame computer for signal analysis is the long time delay between tests and final results. Delays of this nature can create problems in development testing and to improve this situation we have developed an 'on-line' computer system. Software development for this system is aimed at providing the development engineer with simple analysis in real time and crude detailed analysis immediately after a test.

Real time processing available includes data logging to magnetic tape at rates up to 7000 samples/sec, level exceedence counting, continuous mean and standard deviation estimation using exponential averaging and other similar simple analyses. These simple analyses are often sufficient for an engineer to assess the influence of modifications and hence speed up the overall development program.

It is not intended to entirely replace main frame computer analysis by the use of the 'on-line' system but the main frame analysis will be relegated to a back-up roll for cases where a greater accuracy or detail is required.

CONCLUSION

Digital analysis has enabled us to increase the scope of our techniques but the main frame approach has the disadvantage of removing the interactive feel of analogue analysis techniques. It is hoped that the use of a mini computer operating in an 'on-line' system will enable us to recover the interactive feel without degrading the scope of our analysis too far.

REFERENCE 1, WELCH, P.D. 'The use of Fast Fourier Transform for the Estimation of Power Spectra: A met od based on Time averaging over Short, Modified Periodograms'
IEEE Trans. on Audio and Electroacoustics.
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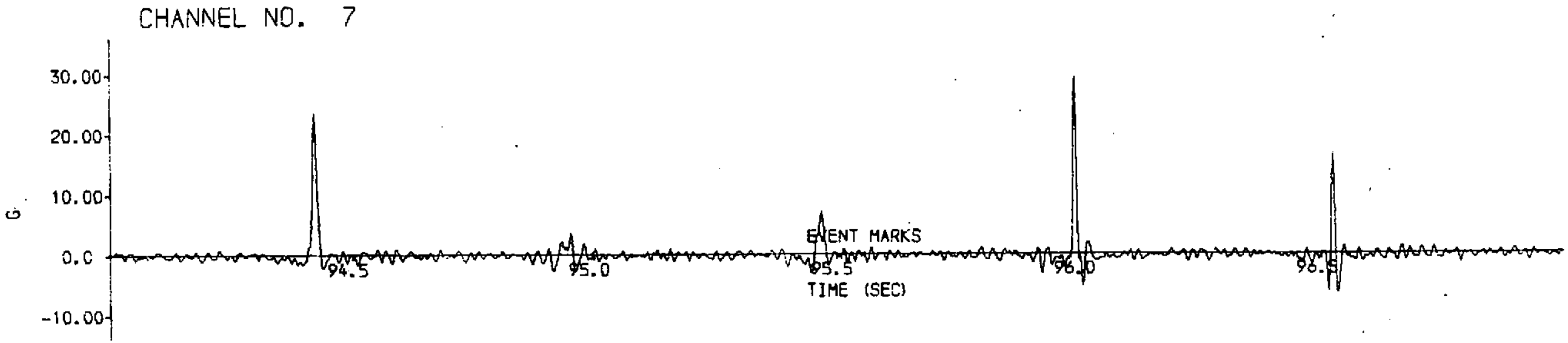

FIG 1 RECONSTRUCTION OF AXLE BOX VERTICAL ACCELERATION

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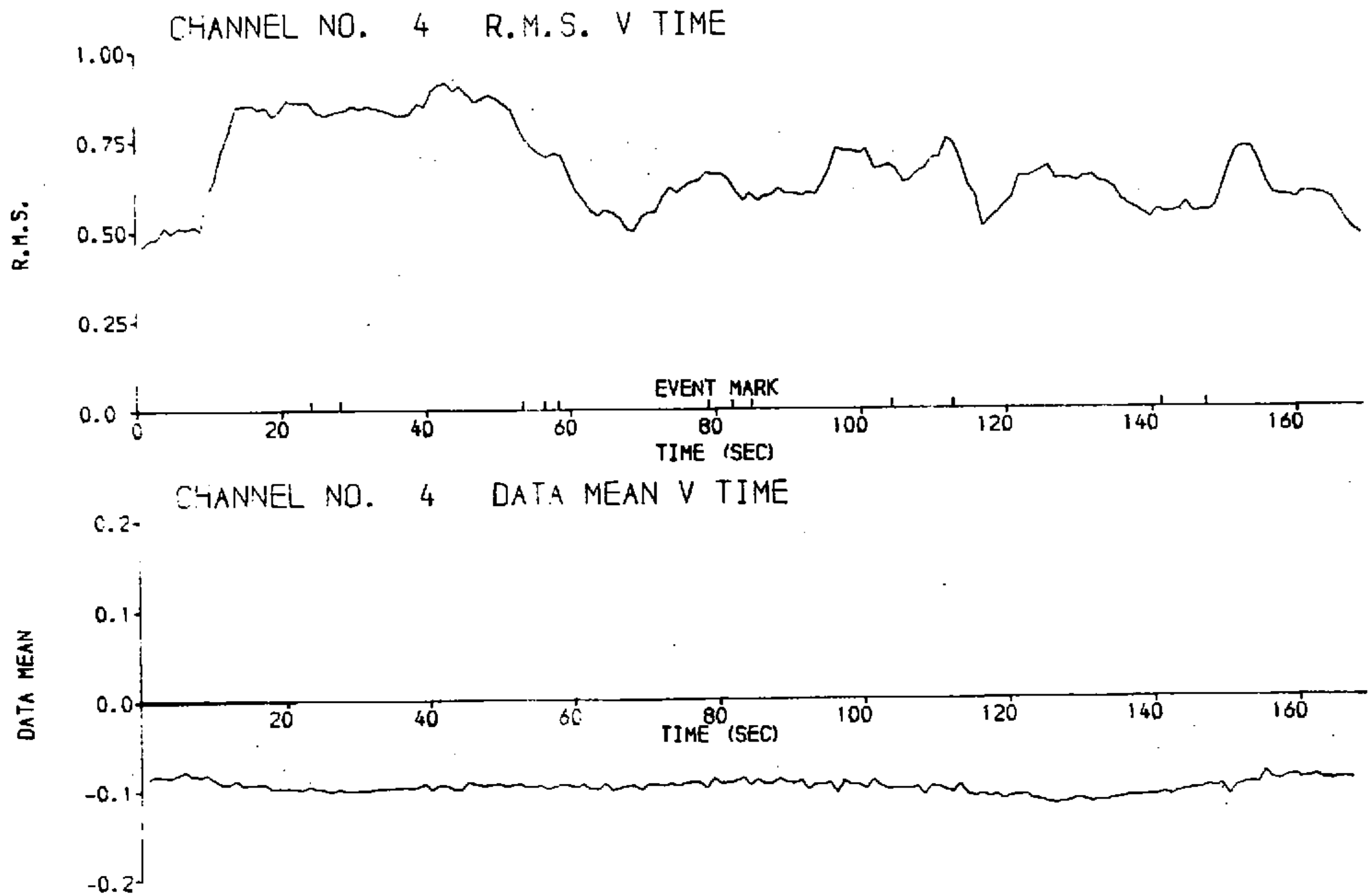

FIG 1 QUICK LOOK ANALYSIS OF BOGIE FRAME VERTICAL ACCELERATION

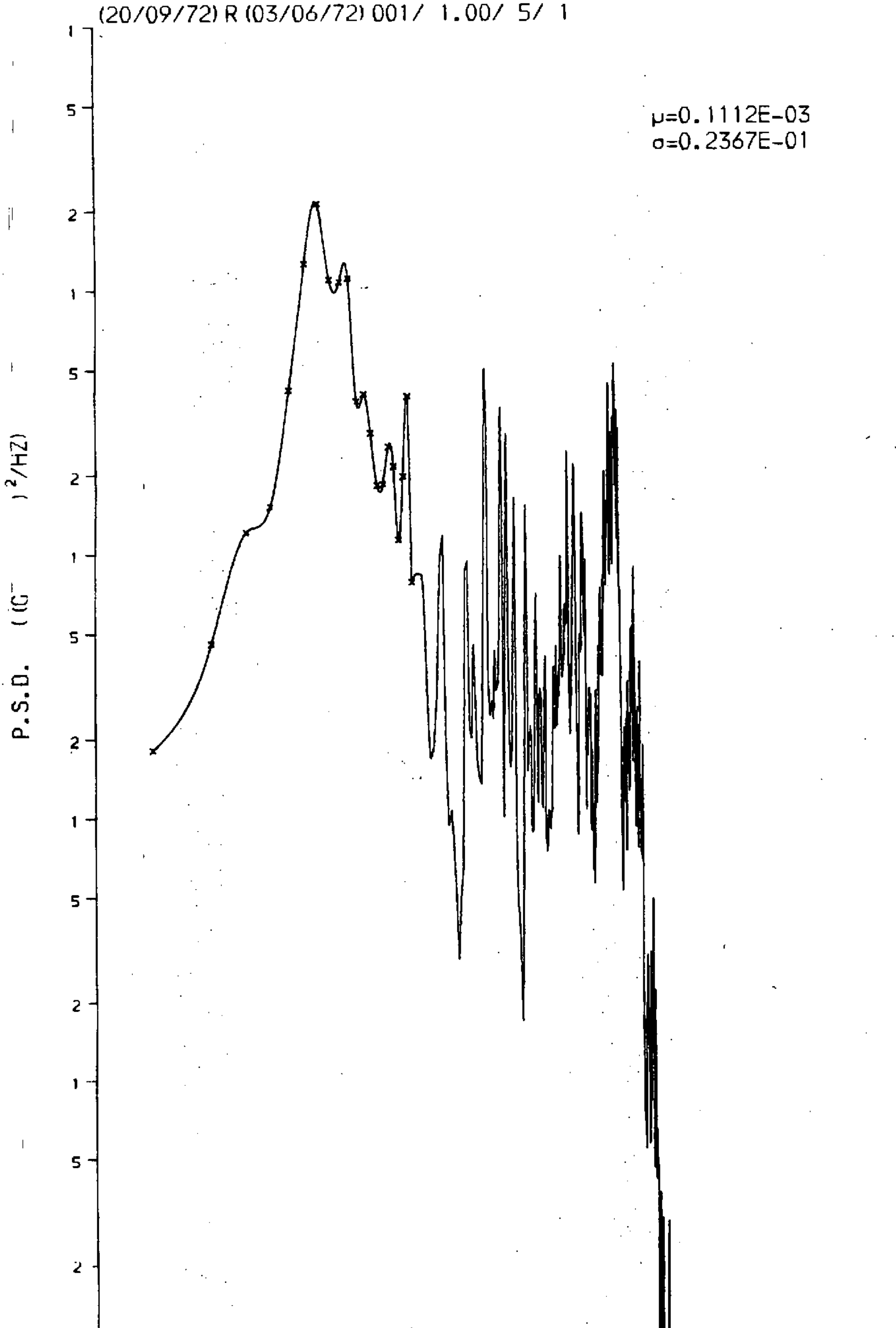

FIG 3 POWER SPECTRAL DENSITY OF COACH BODY VERTICAL ACCERATION

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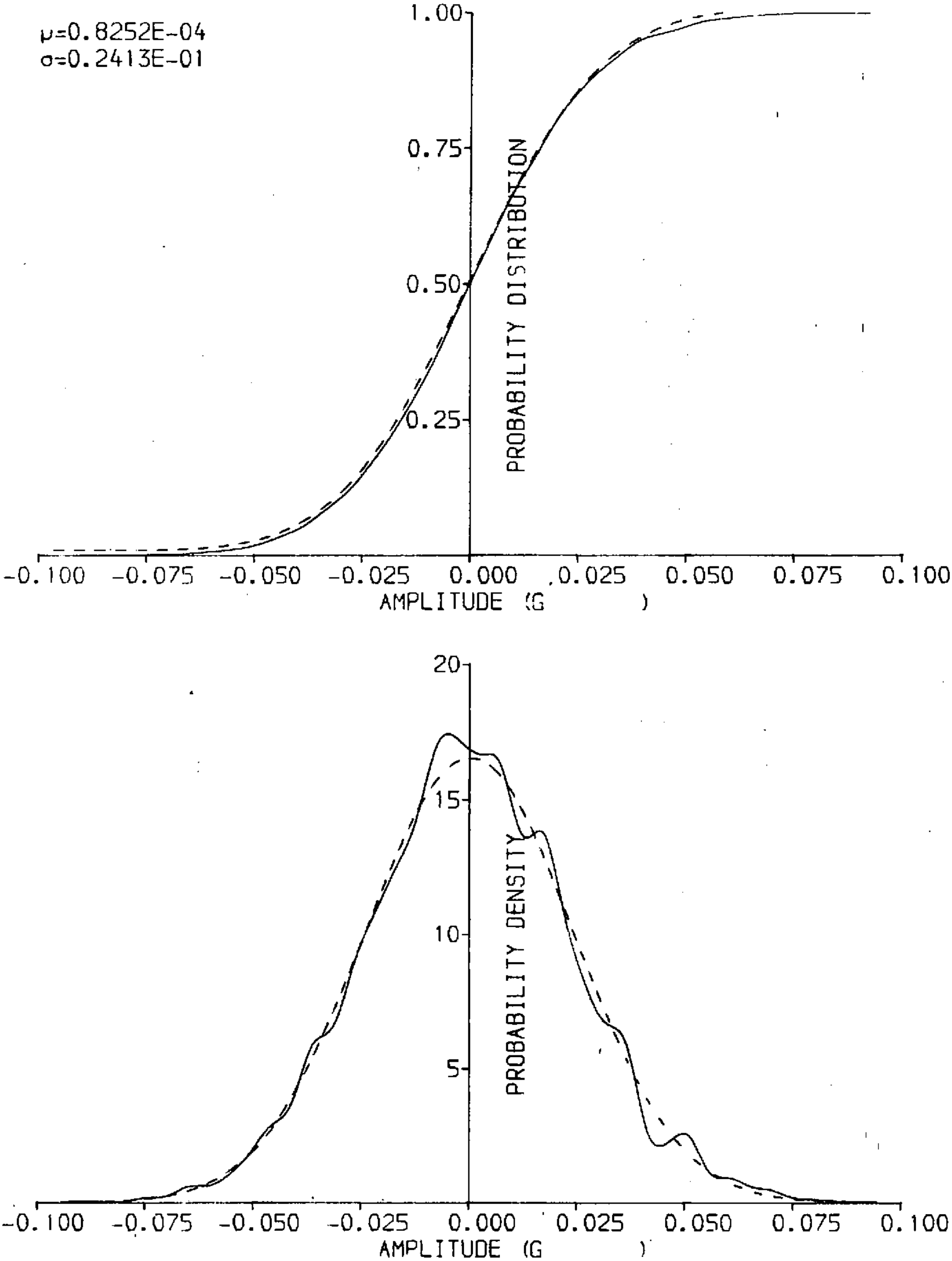

FIG 4 PROBABILITY DENSITY OF COACH BODY VERTICAL ACCELERATION