SAND95-0192C
CONF-951203--9

The Collection and Analysis of Transient Test Data Using the Mobile Instrumentation Data Acquisition System (MIDAS)*

RECEIVED
DEC 27 1995
OSTI

W. L. Uncapher and M. Arviso

Transportation Systems Department
Sandia National Laboratories**
Albuquerque, NM 87185

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Packages designed to transport radioactive materials are required to survive exposure to environments defined in Title 10, Code of Federal Regulations, Part 71 (NRC 1994). Cask designers can investigate package designs through structural and thermal testing of full-scale packages, components, or representative models. The acquisition of reliable response data from instrumentation measurement devices is an essential part of this testing activity. Sandia National Laboratories, under the sponsorship of the U.S. Department of Energy (DOE), has developed the Mobile Instrumentation Data Acquisition System (MIDAS) dedicated to the collection and processing of structural and thermal data from regulatory tests.

The self-contained MIDAS facility, housed in a 13.2-m (44-ft) trailer transporter, collects and processes structural and thermal data (Figure 1). The structural data acquisition system collects and processes up to 72 channels of time domain data from any combination of piezoresistive or voltage-based measurement devices. These measurement devices include accelerometers, strain gages, strain-gaged bolts, pressure transducers, linear variable differential transformers, or other voltage-type measurement devices. The thermal data acquisition system collects and processes up to 200 channels of type K thermocouple data. Thermal data can be acquired in concert with structural data, allowing flexibility in the number and types of information collected for a specific test program.

Primary components in the structural data acquisition system are the central computing system, the signal conditioner/amplifiers, the signal switching system, and the high-speed transient analog-to-digital recorders. Figure 2 shows the general relationship and the information flow between the components in the structural data acquisition system. Diagnostic equipment is used to verify and demonstrate system performance by either monitoring, inserting voltage signals, or verifying component or system performance. Instrumentation measurement devices are connected to the data collection system at the trailer interface panel. The measurement electrical signals are transferred from the measuring device to the data collection system using conventional shielded instrumentation cable. These data are then routed through a matrix switch that distributes voltage signals to the signal conditioner/amplifiers and high-speed transient recorder systems. The signal

* This work was performed at Sandia National Laboratories, Albuquerque, New Mexico, for the U.S. Department of Energy under Contract DE-AC04-94AL85000.

** A U.S. Department of Energy facility.

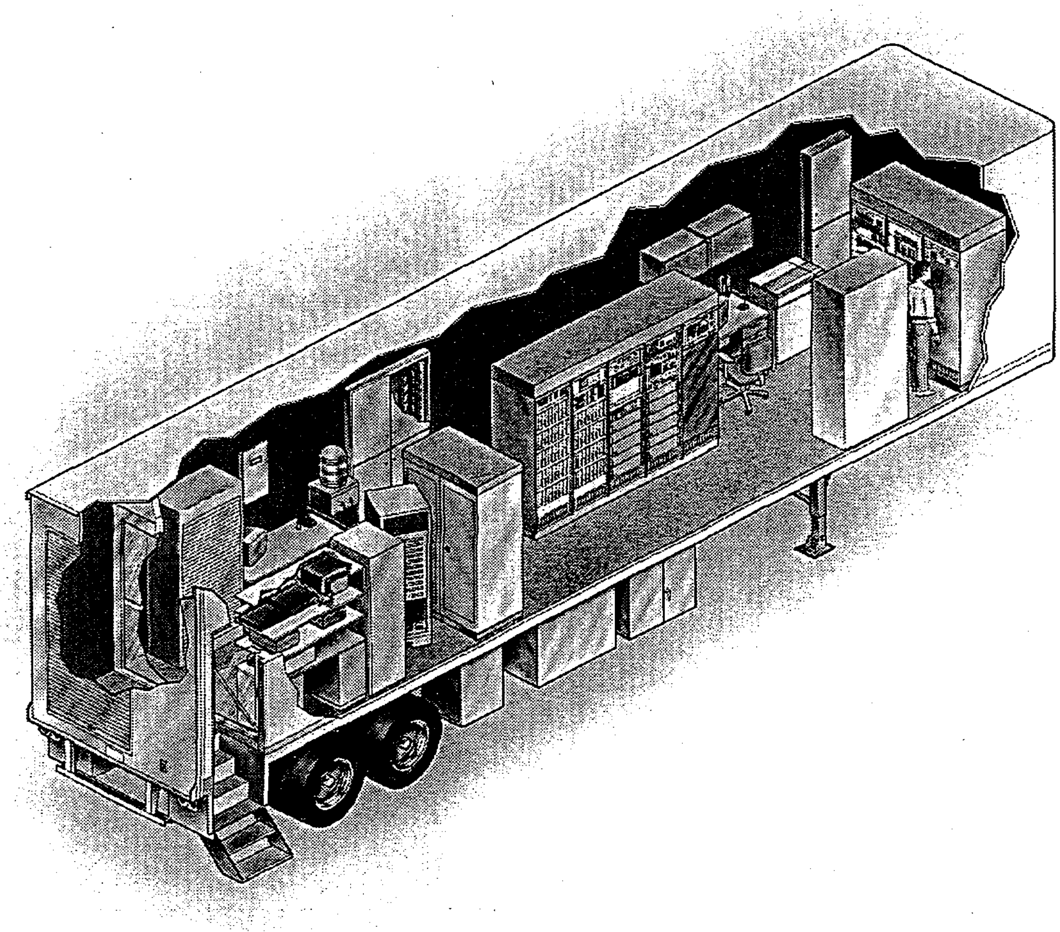

Figure 1. Mobile Instrumentation Data Acquisition System (MIDAS)

conditioner/amplifiers have a wide frequency response extending to 100 kHz at 0.5 dB and accommodate various piezoresistive and voltage-based measurement devices. The output of the signal conditioner/amplifiers is routed through the matrix switch to the primary and secondary high-speed transient recorder systems. The transient recorder systems collect, convert, and store the measurement data. The data are converted from analog to digital information using analog-to-digital converters in the high-speed transient recorder systems. The primary high-speed transient recorder system samples data at rates from 100,000 samples per second to 1 million samples per second with full 12-bit resolution. Each of the 72 channels in this system can store up to 2 million samples in battery-protected memory. The secondary high-speed transient recorder system is capable of sampling data at similar rates, from 100,000 samples per second to 1 million samples per second with full 14-bit resolution. Each of the 72 channels in this system can store up to 12 million samples in battery-protected memory. The large storage capability of the secondary recording system allows collection and storage of data with bandwidths comparable to analog tape technology.

The structural data acquisition system contains diagnostic equipment to determine both component and system performance. Diagnostic signals from this equipment can be inserted into the data paths through the matrix switch for monitoring, verification, and

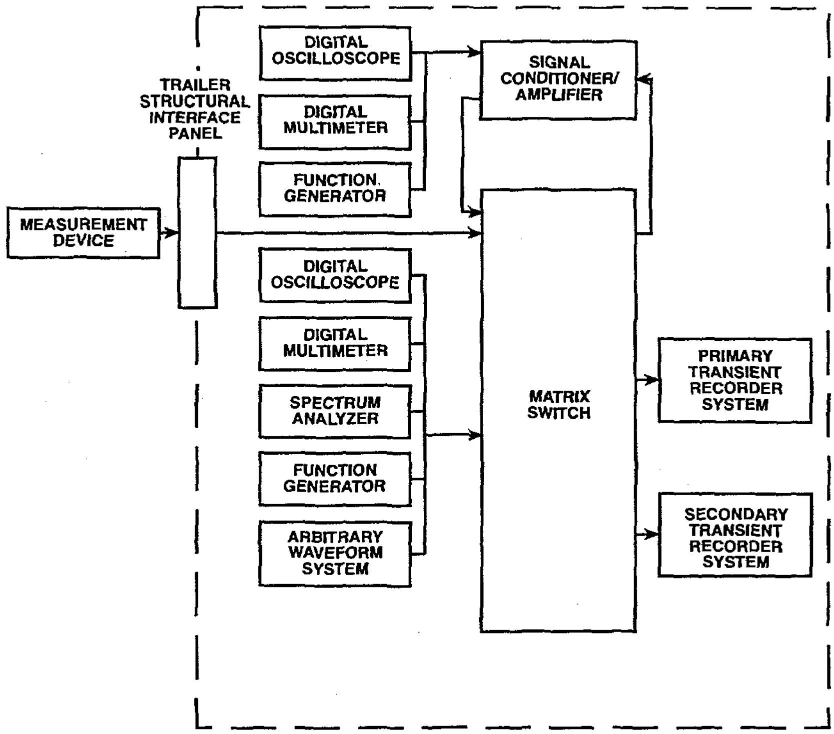

Figure 2. Structural Data Acquisition System

calibration of components or the entire data collection system. The digital oscilloscope and multimeters are used as monitoring devices for these signals. Characterization of the frequency response of the signal conditioner/amplifiers is performed by a spectrum analyzer. Characterization of the phase response of the signal conditioner/amplifiers is performed using a network analyzer. In conjunction with the frequency response information, these data provide an accurate measure of the performance of the signal conditioner/amplifiers. The function generator is used as a voltage signal source to insert signals that verify the amplitude levels and determine the amplitude performance of the signal conditioner/amplifiers and high-speed transient recorder systems. The arbitrary waveform system provides a unique approach to verify the performance of the data collection system. The system contains a library of waveforms representative of transient cask drop and puncture test data. These data can be routed through the data collection components and collected and stored in the high-speed transient recorder systems. The recorded information is retrieved and compared to the library definition of the waveform definition on a point-by-point basis by the central computing system to verify the configuration and performance of the data collection system. This diagnostic tool provides system-level verification for the characterization of the data collection components in the structural data acquisition system.

Primary components in the thermal data acquisition system include the central computing system, the thermal data acquisition and control system, and a thermocouple simulator/ calibrator. Figure 3 shows these components and the information flow. Type K thermocouples are connected to the thermal data acquisition system at the trailer thermal interface panel. Information from the individual temperature-sensing devices is collected in a thermal data acquisition and control unit and transferred to the central computing system for display and analysis. The electrical signals are transmitted from the temperature-measuring device to the data collection system using conventional thermocouple instrumentation cable. The thermocouple simulator/calibrator replicates voltage signals from varying temperature levels and verifies the performance of the thermal data acquisition system.

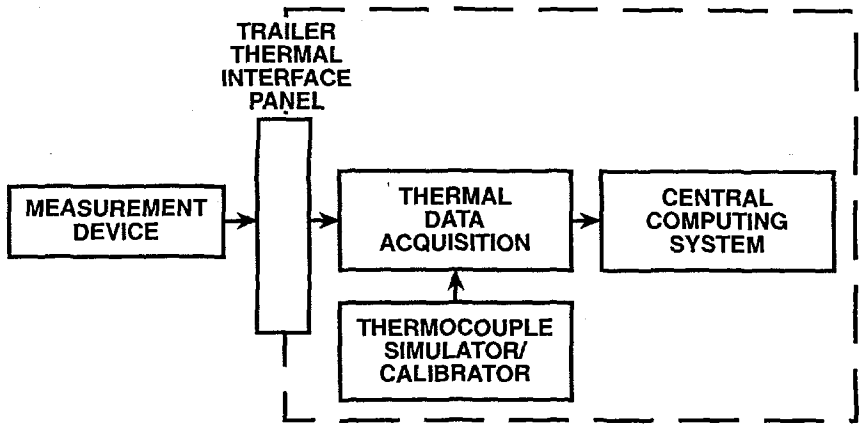

Figure 3. Thermal Data Acquisition System

The central computing system in MIDAS is a combination of three 32-bit minicomputers networked together using the AT&T System V UNIX® operating system. (UNIX is a registered trademark of AT&T in the United States and other countries.) Each computational platform serves specific functions in the system. One super minicomputer, rated at 22 million instructions per second, controls the structural and thermal data collection equipment. A second computer, rated at the same performance specifications, archives the collected data on high-capacity optical media. The total capacity of the optical storage device exceeds 20 gigabytes of information. All the experimental data collected by MIDAS is available for analysis and comparison using this high capacity storage system. This second computer also serves as the hard-copy print manager for both data collection and analysis. The main system processor, rated at 150 million instructions per second, performs all the data analysis and graphics associated with the data collection system.

After collection, the experimental data are transferred to the main system processor for analysis. A comprehensive software package for analysis and plotting (known as KAPP) was developed to perform digital signal processing of both transient structural and thermal data. This software provides a suite of signal-processing functions common to evaluation of experimental data. These functions use documented algorithms primarily developed by Stearns and David (1988). The analysis package uses a graphical interface that simplifies the software operation. The window-based software uses a mouse-driven means of producing data analysis functional paths and easily allows changes to these paths and reexecution of the data sets. Both time and frequency domain data can be processed and presented in engineering units. The analysis package contains options to output these data in single- or multiple-plot formats, in both black-and-white or color. The software was designed to operate in a workstation environment running the UNIX® operating system. KAPP can display both raw (unprocessed) voltage-based data from measurement devices and processed data. Figure 4 provides an example of acquired acceleration data analyzed using KAPP. The plotting package in conjunction with the data analysis package can display up to 12 million data samples from a single measurement device. The analysis package has options for infinite impulse response (IIR) and finite impulse response (FIR) filters. These filters remove unwanted frequencies in the measurement data. The filters are implemented in low-pass, high-pass, bandpass, and bandstop configurations. The IIR filters can be configured as Butterworth, Chebyshev I and II, or Bessel designs. Figure 5 illustrates the roll-off characteristics of a 1000-Hz, IIR, Butterworth, low-pass filter design. Figure 6 shows the acceleration data presented in Figure 4 filtered using this Butterworth filter design. The FIR filters can be implemented as rectangular, tapered rectangular, triangular, Hanning, Hamming, and Blackman designs. Frequency decomposition implemented in the software includes both discrete Fourier Transform and fast Fourier Transform (FFT). Figure 7 is the FFT of the structural acceleration data shown in Figure 4. Figure 8 illustrates a windowed FFT plot of the data shown in Figure 7. Other functions implemented in the analysis package include integration, displacement, force, force/displacement, velocity, averaging, and windowing. Common arithmetic functions are also provided to complement the analysis package. This data processing and analysis package provides a powerful tool to analyze, display, and plot data collected from testing of hazardous and radioactive material packages.

Quality assurance (QA), an important part of MIDAS, includes computer software documentation, system diagrams and procedures, equipment specifications, calibration records, and operating and maintenance documentation. Training is provided to all operating personnel. Additional operational documentation includes the logging of all diagnostic testing parameters in an "audit trail" traceable to the uniquely defined test. These audit trails become part of the permanent QA record that is archived with the collected data for each experiment. MIDAS has been developed and documented in accordance with a QA program meeting current regulatory drivers to ensure accurate and reliable response measurements.

MIDAS has been used to support certification, design verification, and benchmark testing for the DOE Environmental Restoration and Waste Management, Transportation Management Division, and Naval Reactors Division, and the U.S. Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards. The system has also been used to collect and process test data for the U.S. Army and the Defense Nuclear Agency. The unique mobile capabilities of the system were successfully demonstrated when it was transported to Germany to support an international cask-certification testing program sponsored by the DOE and the German government.

REFERENCES

Stearns, S.D., and David, R.A. *Signal Processing Algorithms,* Prentice Hall, Inc., Englewood Cliffs, NJ (1988).

NRC (U.S. Nuclear Regulatory Commission), U.S. Code of Federal Regulations, Title 10, Part 71.71, *Normal Conditions of Transport,* and Part 71.73, *Hypothetical Accident Conditions,* U.S. Government Printing Office, Washington, DC (1994).

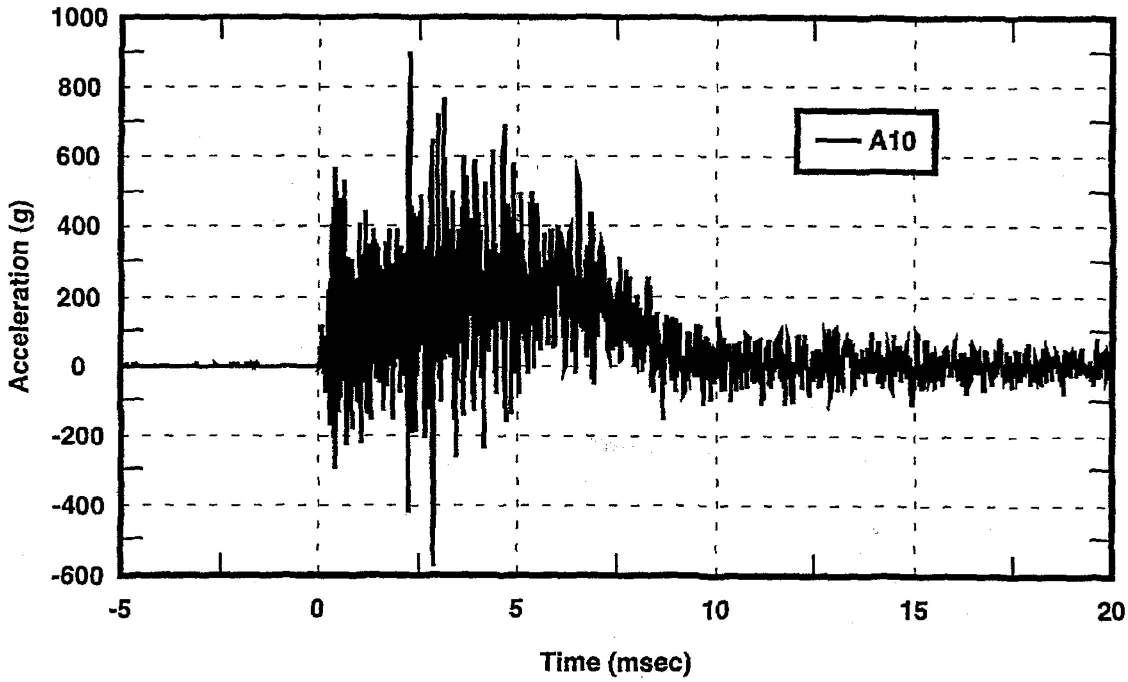

Figure 4. Raw (Unprocessed) Acceleration Data

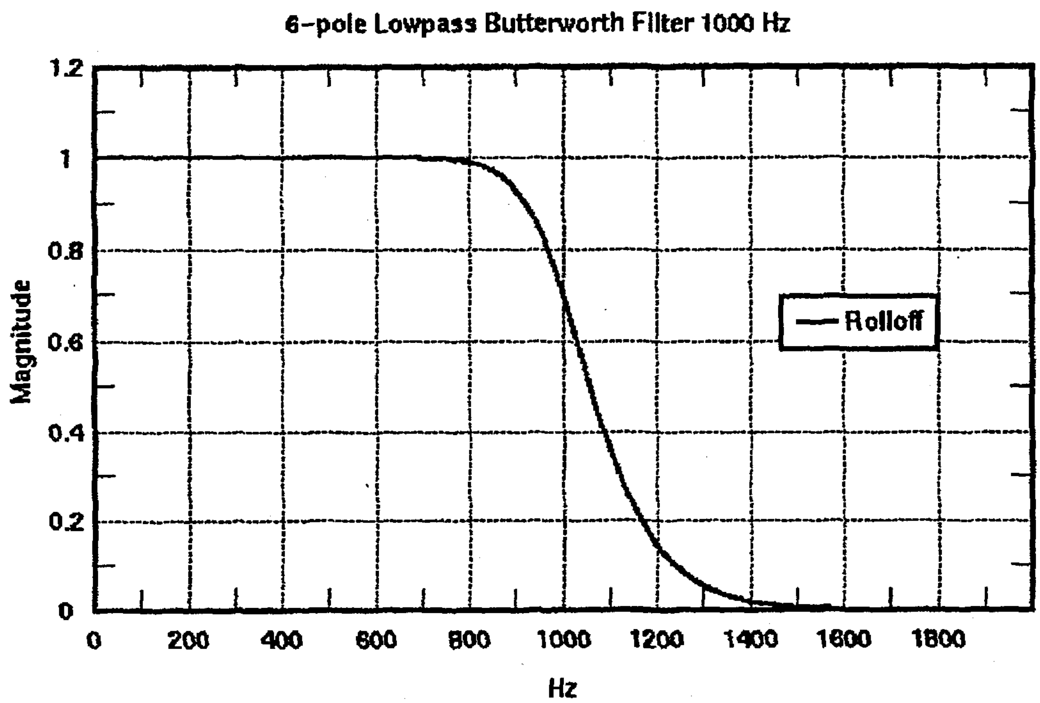

Figure 5. 1000-Hz, Infinite Impulse Response, Butterworth, Low-Pass Filter Roll-Off Characteristics

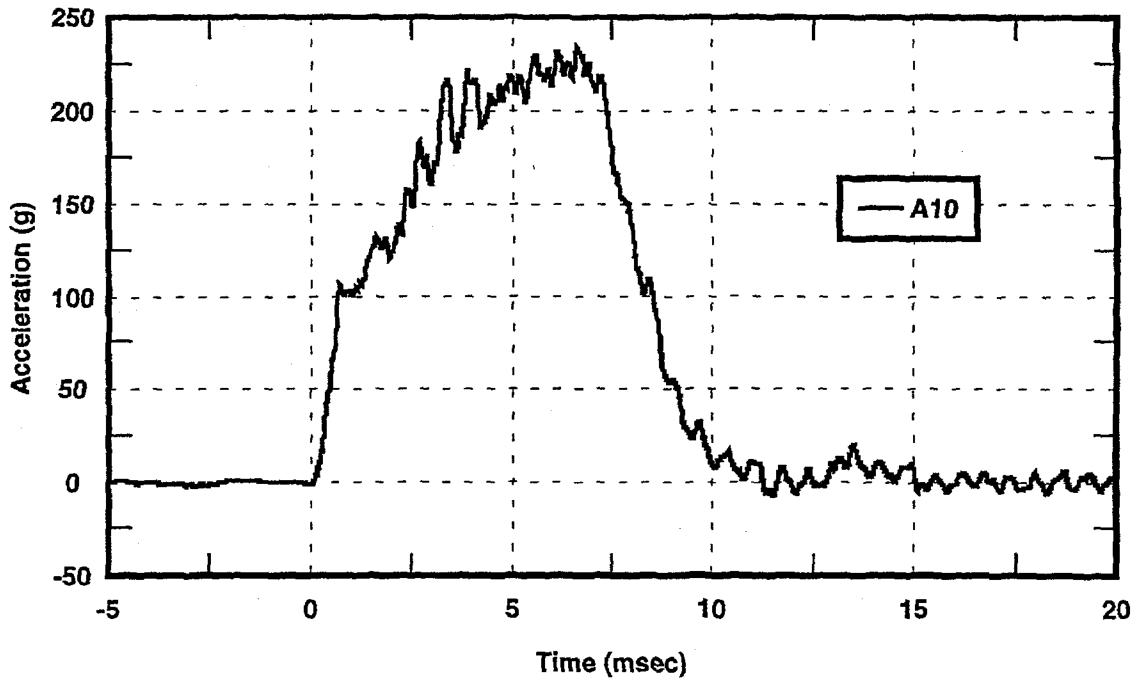

Figure 6. Accelerometer Data Filtered at 1000 Hz

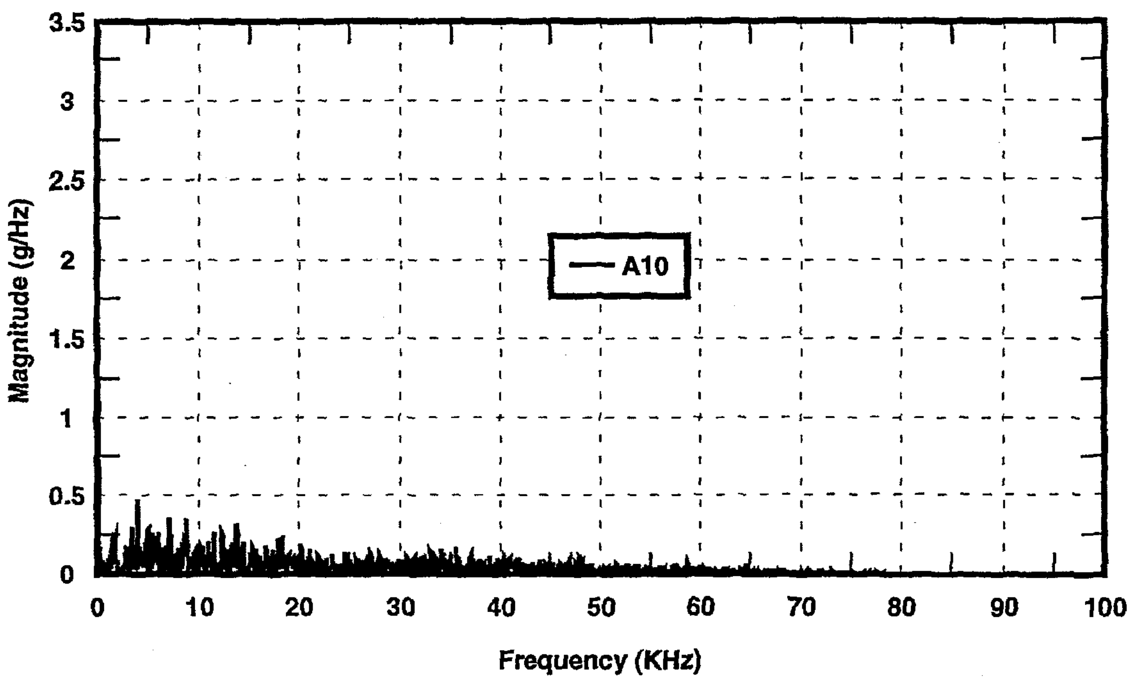

Figure 7. Fast Fourier Transform of Accelerometer Data

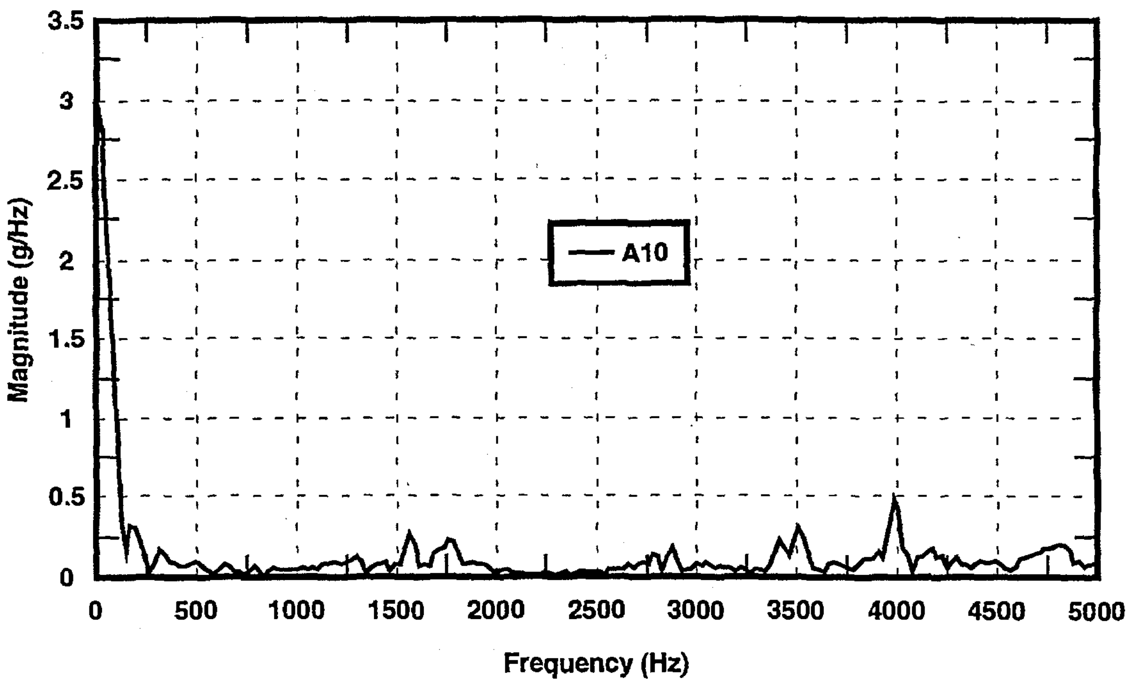

Figure 8. Windowed Fast Fourier Transform of Accelerometer Data