The Development of a Mobile Instrumentation Data Acquisition System for Use in Cask Testing*

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Packagings for transporting radioactive materials are required to survive exposure to environments defined in Title 10 Code of Federal Regulations Part 71. Package designers investigate design and analysis problems through structural and thermal testing of various components or models, using instrumentation to measure physical responses. The acquisition of high quality data from instrumentation is an essential part of the testing activity. To provide this quality of data Sandia National Laboratories (SNL), under the sponsorship of the U.S. Department of Energy, is developing a mobile instrumentation data acquisition system dedicated for use in cask testing. This system is designed to acquire and analyze structural and thermal test data, and to provide leakage measurement capabilities.

The mobile instrumentation system (Figure 1) is housed in a 13.4m (44-ft) trailer transporter, which is self-contained with air conditioning, heating, and halon fire protection systems. External power from a commercial or motor generator source is line conditioned prior to distribution to the data acquisition equipment inside the trailer, and lightning protection is provided at the point where the measurement devices interface to the data acquisition equipment. This system is capable of performing data analyses and display of the acquired information within thirty minutes after an experiment. Data can be analyzed, using algorithms primarily developed by *Stearns and David (1988)*, with some or all of the following:

- o Filtering: Infinite impulse response (IIR): Butterworth, Bessel, Chebychev; Finite impulse response (FIR)
- o Frequency decomposition: Discrete Fourier transform (DFT), Inverse discrete Fourier transform (IDFT), fast Fourier transform (FFT), Inverse fast Fourier transform (IFFT), Power spectral density (PSD), Shock spectra

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- o Differentiation
- o Integration, Simpson method
- o Statistical analysis; least squares, standard deviations
- o Decimation
- o Interpolation; Linear, zero insertion

The processed data can be single or multichannel printed or plotted as well as permanently stored on optical media for quality assurance records retention. Additionally, portions or all the acquired or analyzed data can be transferred to 12.7mm (0.5 in) computer tape in ASCII format, readable by many agencies.

The structural test data acquisition system is capable of acquiring 72 channels of time domain data from any combination of piezoresistive measurement devices such as accelerometers, strain gages, strain-gaged bolts, and pressure transducers. The overall structural data bandwidth extends to 100 Khz, allowing linear recording of data up to that frequency. The thermal data acquisition system can acquire up to 200 channels of Type K thermocouple data, and record temperature and resistance measurements at intervals as short as 15 seconds. A helium mass spectrometer leak detector is also provided to perform leakage measurements.

The primary components in the structural test data acquisition system (Figure 2) include signal conditioner/amplifiers, a matrix switch, transient recorders, analog multiplexer/demultiplexer, and an analog tape machine. Diagnostic equipment such as digital oscilloscopes, digital multimeters, spectrum analyzer, function generator, and an arbitrary waveform system are used to demonstrate or verify system performance by either monitoring, inserting signals, or calibrating the data acquisition equipment. The thermal data acquisition system (Figure 3) consists of a thermal data acquisition and control unit along with a thermocouple simulator/calibrator. The central system processor is used for equipment control and the analysis and display of collected structural or thermal data.

The relationship and information flow between the components in the structural test data acquisition system is illustrated in Figure 2. Instrumentation measurement devices are connected to the data acquisition system at the trailer interface panel. Information or data from the measurement devices is then routed through a matrix switch, which is used to distribute data to the signal conditioner/amplifiers, transient recorders, and analog tape machine. The signal conditioner/amplifiers have a wide frequency response extending to 100Khz at 0.5dB and are designed to accommodate a variety of piezoresistive measurement devices. They contain an electrically-coupled computer-controlled solid state amplifier for general instrumentation applications. Outputs of the signal conditioners are routed through the matrix switch to the transient recorders and analog tape machine. The transient recorders are used as the primary data collectors and are capable of sampling data at rates from 20 samples per second to 1 million samples per second with full 12 bit resolution. Each of the 72 channels can store up to 2 million samples in battery backed-up memory. The 28-track wide-band tape recorder/reproducer, which has a broad frequency range extending to 4MHz, is used as a secondary data collection system. The multiplexer provides the capability of recording three data channels on a single tape track, using 24 of the 28 tape recorder tracks. In the event of a transient recorder failure the multiplexed data is demultiplexed and routed through the matrix switch for recording on transient recorder channels, thus returning the information on individual data channels.

Diagnostic signals can be inserted into the data paths by the matrix switch for monitoring or calibration purposes. A digital oscilloscope and multimeter are used to monitor these signals. Characterization of the frequency response of the signal conditioner/amplifiers is performed by the spectrum analyzer. The function generator is used to insert signals for calibration purposes into the signal conditioner/amplifiers, transient recorders, and analog tape machine via the matrix switch. The arbitrary waveform system contains a library of waveforms representative of cask drop and puncture test data that can be routed to the transient recorder and the analog tape machine. Recorded data signals are compared to the library definition of the waveform by the central system processor to verify system configuration and performance.

Figure 3 illustrates the flow of information in the thermal data acquisition system. Type K thermocouples are connected to the data acquisition system at the trailer interface panel. Information from the individual thermocouples is collected in a thermal data acquisition and control unit and subsequently transferred to the central system processor for display and analysis. The thermocouple simulator/calibrator is used to replicate varying temperature levels and to verify and calibrate the thermal data acquisition system.

The central system processor is a 32-bit super minicomputer rated at 14 million instructions per second (MIPS) using the AT&T System V UNIX (UNIX is a registered trademark of AT&T in the United States and other countries) operating system. This computer has 1.2 gigabytes of disk storage available to support data acquisition, control, and analysis. Several data transfer media are available including 6.4mm (0.25 in) and 12.7mm (0.5 in) tape, and optical disk. Collected and analyzed data is archived on an optical disk as part of the quality assurance records.

A universal time base for the data acquisition system is received from the NAVSTAR global positioning system (GPS) satellite. Precise time and frequency information is received and recorded allowing time interval evaluation of acquired data. Data acquisition event control is performed by a sequencer using the GPS time code reference. The sequencer provides starting and stopping signals to various equipment in the system as well as recording the time individual events occur. This time relationship is used to correlate acquired data to information from high-speed photography or other external measuring instruments.

The mobile instrumentation system also contains a portable helium mass spectrometer leak detector. The leak detector can be used to make field leakage measurements and has a sensitivity sufficient to measure leakage rates less than or equal to 10^{-7} std cm^3/s.

Quality assurance and documentation are also an important part of the mobile instrumentation system. The documentation package includes computer software documentation, system diagrams and procedures, equipment specifications, calibration records, and operating and maintenance manuals. Training will be provided to all operating personnel. Use of the diagnostic equipment will demonstrate and verify equipment prior to test data collection. A record of equipment parameters is produced, providing a computer-generated audit trail for quality assurance purposes.

The mobile instrumentation system is a self-contained unit that is capable of performing both test data acquisition and analysis. The system flexibility allows for the acquisition of data from any combination of piezoresistive measurement devices and thermocouples.

REFERENCES

Stearns, S.D., and David, R.A., Signal Processing Algorithms, 1988, Prentice Hall, Inc., Englewood Cliffs, New Jersey.

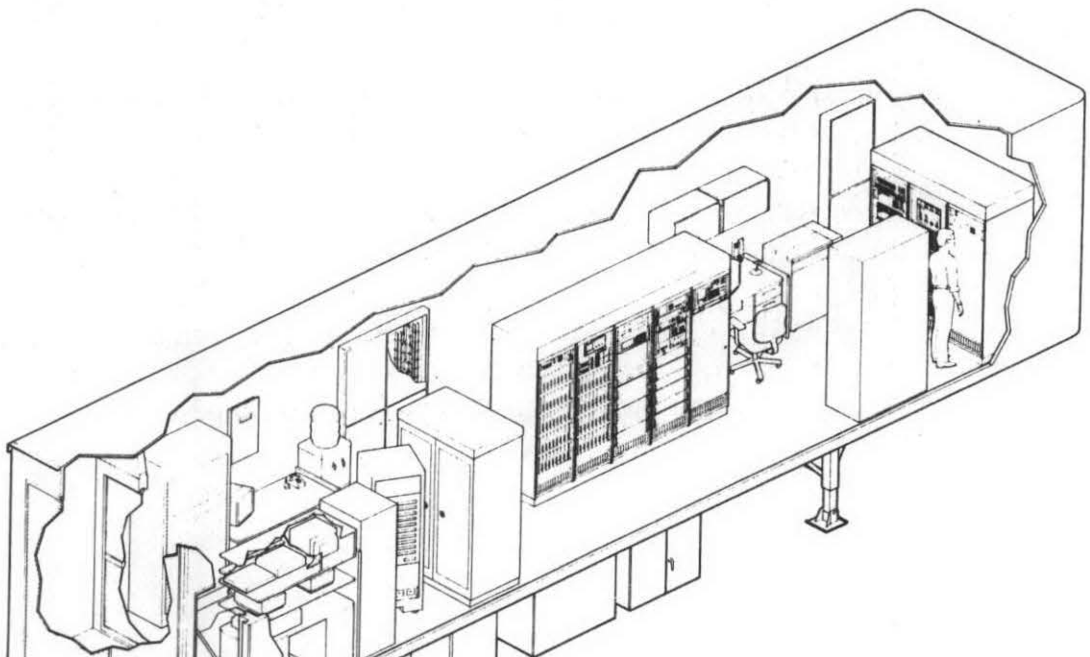

Figure 1. Mobile Instrumentation System

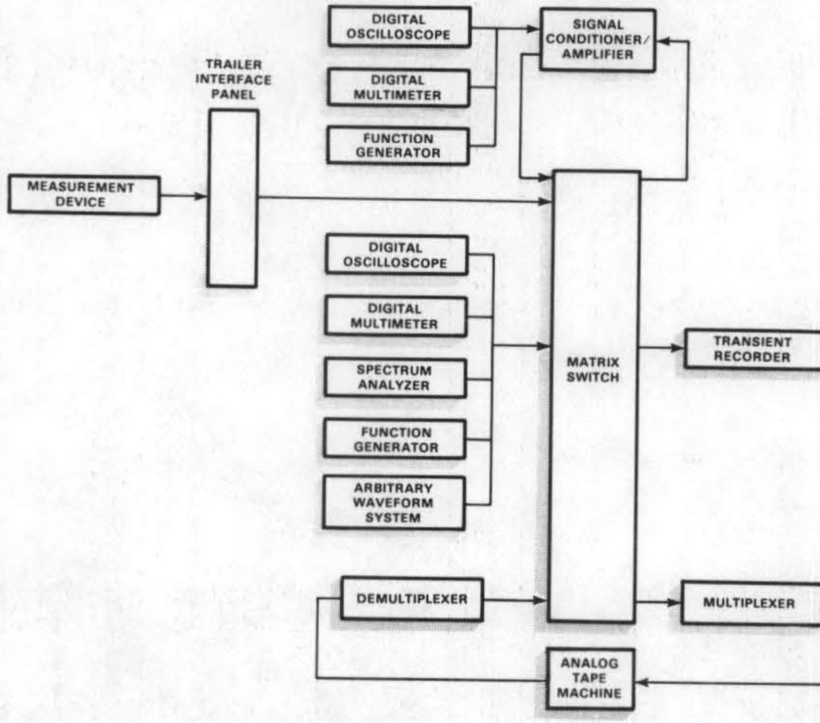

Figure 2. Structural Test Data Acquisition System

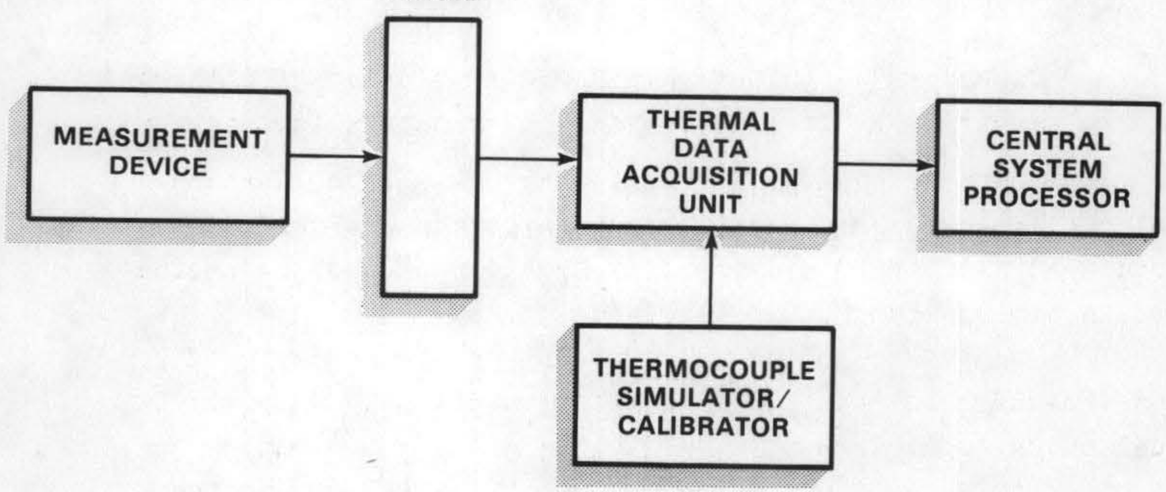

Figure 3. Thermal Data Acquisition System