

# **The Use of Telemetry in Heavy Equipment Testing at Caterpillar Inc.**

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## **ABSTRACT**

Caterpillar has for many years used telemetry as a key component in the data acquisition and analysis systems used to test and develop heavy equipment. The testing of construction and mining equipment at Caterpillar presents several unique challenges, such as the operating environment of the test machine, the large number of models in the product line, the need to change test machines on a daily basis, and the need to test machines at job sites throughout North America. These challenges have resulted in the development of telemetry, data acquisition and data analysis systems that have been highly customized to meet all of our requirements for construction equipment testing. This paper describes the past history of telemetry use at Caterpillar, from early FM/FM systems to our current PC/Unix based PCM/FM system, the criteria used to develop these systems, and how our current telemetry system is being used today to help develop and test product.

## **KEY WORDS**

Telemetry, Instrument Vans

## **INTRODUCTION**

Caterpillar began using telemetry systems in the mid 1960's, primarily as a tool to reduce the risk of serious accidents in the testing of construction and mining equipment. Prior to the use of telemetry, test data was collected in mobile instrument vans that were connected by an umbilical cable carrying all of the data signals from the test machine. This umbilical cable was fairly short, about 50 feet, therefore the van was required to very closely follow large machines operating at high speeds. A roll-over accident with a van in 1963 provided the impetus to develop a functional telemetry system.

## **TELEMETRY & INSTRUMENT VAN HISTORY**

Caterpillar's first telemetry system was a six channel system that fed data to an analog strip chart recorder. This system was equipped with Bridge Controlled Oscillators (BCO's) connected directly to a strain gage bridge circuit. The BCO's were eventually replaced with Voltage Controlled Oscillators (VCO's), and in 1971 the system was upgraded to 12 channel capacity. All of the telemetry system components, (VCO's, discriminators, transmitters and receivers) for this first system were purchased, but the signal conditioning and packaging was all developed in-house at Caterpillar. In mid 1970's the signal conditioning was redesigned and upgraded, again in-house, and used with the existing telemetry components. This new signal conditioning came to be known as Type II conditioning, and is still in limited use. These first telemetry systems were used with analog strip chart recorders.

The first use of computers with telemetry at Caterpillar was in 1968, when analog computers were installed in the instrument vans. The first digital computer system used with telemetry was developed in the late 1970's, and was based on the DEC PDP-11 computer. The PDP-11 computer system was mounted in new instrument vans and was used with 12 channels of the Type II signal conditioning and an FM/FM telemetry system. All software for the system was developed by Caterpillar. The next major upgrade to the telemetry systems came in the early 1980's when the channel capacity was increased to 16 channels in a single package. This system utilized the same Type II conditioning and Caterpillar packaging, but with purchased telemetry system components. This was an FM/FM type of system, utilizing 16 VCO's and an FM transmitter mounted on the test machine and an FM receiver and 16 discriminators mounted in the instrument van. The telemetry transmitters all operated in the 216 to 220 MHz band. A total of ten 16 channel telemetry systems were built for use a Caterpillar Proving Grounds and field locations.

The next system upgrade occurred in the mid 1980's when the PDP-11 computers were replaced with Hewlett Packard HP-1000 computers. This computer system was installed in the existing instrument vans and was capable of digitizing 32 input channels. The system utilized two of the 16 channel telemetry systems with dual transmitters and receivers for each van to obtain the 32 data channels. The HP-1000 computer was also able to run a special version of our Caterpillar designed, VAX based data analysis software, which provided limited data analysis capability in the van. This system has proved to be very productive and reliable, and is still in limited use today.

Caterpillar's first Pulse Code Modulation (PCM) telemetry system was purchased as a turn-key system in 1989. The system was supplied with 128 channels of signal conditioning and a large truck housed all of the telemetry receiving and ground station hardware. This system represented a departure from our previous systems in that it was purchased essentially as a turn-key system. The system software was customized by the telemetry system provider and Caterpillar to meet our testing requirements.

Caterpillar's current telemetry system was developed in the early 1990's, and consists of purchased signal conditioning/PCM encoding hardware and a PC-based decom system. The PC is networked to a Unix workstation to provide full data analysis capability within the instrument van. For further information about our current telemetry system please refer to references 1 and 2. Refer to Figure 1 for a timeline of telemetry development at Caterpillar.

Caterpillar has also developed a very compact, battery powered signal conditioning and telemetry system that is mounted on a steel track shoe. This system is used to measure input load and stress data on an individual steel track shoe on steel tracked tractors. The first generation system consisted of 12 channels of signal conditioning, an FM/FM telemetry system, and a 250mW transmitter. The data was relayed from the track telemetry system into the instrument van with a 5 W repeater transmitter. The second generation track telemetry system is a 24 channel PCM/FM system. The data is again relayed through a repeater and into the instrument van. The instrument van is capable of receiving and decommutating two PCM input streams, one from the track telemetry unit and a second from a PCM encoder mounted on the main frame of the test machine.

## **TELEMETRY SYSTEM DESIGN CRITERIA**

It has been our experience that the testing of construction and mining equipment at Caterpillar has several requirements that may not be present in typical aerospace applications--the market for which most of the telemetry equipment and systems currently available have been developed. One of the major differences is the large number of different machines that need to be tested. The Caterpillar product line consists of over 20 major product lines and over 300 different machine models-- and the telemetry and instrument van systems test the entire product line. The large number of test machines and the limited number of transducers, telemetry systems and vans available require that the signal conditioning equipment and software be easily and quickly switched from one test to another. It is not economically feasible to have dedicated transducers and data

acquisition systems for every individual test machine. An instrument van based at the Peoria Proving Ground will typically run tests on 3 to 4 different machines during any given week.

Another requirement for our telemetry and data acquisition systems is the need to measure test data at customer job sites throughout North America. The range of applications in which Caterpillar equipment needs to operate in is very large, and it is not possible to duplicate all of these conditions at a proving ground. Job sites can range from large mines, to forestry logging applications, and to road construction.

The design requirements for Caterpillar's newest generation of instrument vans took into account the entire instrument van system. It is necessary to consider the telemetry, computers, and van chassis as a complete system, in which all three sub-systems must be upgraded in parallel. The basic design criteria were:

- All telemetry and computer equipment housed in a mobile instrument van
- Utilize Pulse Code Modulation (PCM) telemetry
- Provide full data analysis and reduction capability in the van
- Retain reliability and ease of use of previous van systems
- Control costs & provide high value

One of the key design requirements was to provide full data reduction and analysis capability in the instrument van. The objective was to provide the test engineer with computer hardware and software that is identical to what is available in the office. This allows full analysis of the data to be done before moving to a different job site or ending the test prematurely. Controlling the cost on the instrument van and telemetry systems was critical, and also one of the largest challenges in this project. The goal was to build several new instrument van systems, therefore it was crucial that the cost for an individual system be kept as low as possible.

Why does Caterpillar need to use telemetry to test machines? This question is frequently asked, both internally and from people outside the company. The primary reasons Caterpillar uses telemetry based data acquisition systems are:

- Safety--no need to be close to large operating equipment.
- Severe machine operating environment--the signal conditioning and PCM encoding equipment is specifically designed to operate in high vibration and shock conditions.
- High data channel capacity
- High data acquisition rate capability
- Ability to acquire large data files--limited only by hard disk capacity in the instrument van.
- Ability to monitor the test machine and instrumentation during a test

A second question that is frequently asked is why does Caterpillar install telemetry and data acquisition systems in instrument vans, rather than shipping all the test equipment to test sites in shipping containers. The primary reason is that the instrument vans are self-contained and self-sufficient--they provide AC power, heat and air conditioning while carrying all of the transducers, cables, analysis computers, and miscellaneous support equipment required to run a test at a customer's job site. The vans also provide shelter and a work platform in inclement weather.

## **APPLICATIONS**

Caterpillar's instrument vans and telemetry system are used to measure and analyze data. We take data on all of the major systems on our machines, including structural, hydraulic, control, electronic, powertrain and cooling systems. A wide variety of transducers are used to take the measurements. The data is used to:

- Verify machine performance
- Troubleshoot problems
- Measure input loads for computer models
- Calibrate and correlate computer models

The instrument vans are an integral part of integrating the design and test phases of new product development at Caterpillar. The vans are able to gather input and load data for computer models, and then are also able to test the actual prototype machines to verify and correlate the computer models. The vans are also a very powerful tool to trouble shoot individual performance problems on prototype and current production machines.

Currently, there are 12 instrument van type telemetry systems in operation--7 at the Peoria Proving Ground, 1 at the Tucson Proving Ground and 4 at Caterpillar's Ono Proving Ground in Japan. In addition to running tests at the 3 proving grounds, two of the vans based in Peoria do full-time field testing at customer job sites throughout North America. In the 10 years since our first field van became operational, we have run tests in nearly all the contiguous 48 states and 3 Canadian provinces. A portable version of the instrument van system has also been developed which can be used on overseas tests where it is not feasible to ship an entire instrument van. This package is usually used without telemetry (because of the difficulty in obtaining operating licenses in foreign countries) and has limited data analysis capability.

## **CONCLUSION**

Telemetry has, and will continue to be an integral part of the data acquisition systems that are used to test construction and mining equipment at Caterpillar. Telemetry provides the ability to remain a safe distance away from the operating equipment, the ability to monitor the test machine during the test, and has the data channel and data rate capacity to support our testing requirements.

## **REFERENCES**

1. Jury, Owen T. "The Design of Telemetry Acquisition and Analysis Vans for Testing Construction and Mining Equipment" ITC 1997 Conference Proceedings.
2. Tate, Jeffery J. "Automating Signal conditioner Setup through Integration with Sensor Information" ITC 1997 Conference Proceedings.