Digital Daze

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This article provides some insight into the trials and tribulations of manufacturing digital seismographs in the early days of that particular technology.

Prior to the late ‘70s or early ‘80s, virtually all blast vibration recording was done with analog devices that either printed directly onto film or onto magnetic tape. The film could then be developed and analyzed, but the magnetic tape usually had to be sent to a consulting group who would then transcribe the data and provide a report. These services were fairly expensive and several companies made a very good living doing this. They also had no particular desire to see devices hit the market that would allow the end user to derive his own data, but it was inevitable that this would eventually occur. They had to change their ways, or watch their business go down the drain. In addition, a couple of manufacturers of analog devices refused to expend the effort and expense necessary to develop digital seismographs and they have since moved on to other fields or have disappeared altogether.

In the anecdotes that follow, manufacturer’s names are not mentioned for reasons that are obvious. Suffice it to say that the development of the digital seismograph did not occur without some problems. Mistakes will be made and a certain number of problems are bound to crop up when advances in technology are being made. Bear in mind that I utilized units from different manufacturers back in those days so don’t assume anything about a particular brand of instrument being discussed.

One of the very early devices I had would appear to be monitoring properly, waiting for an event to occur, but in actuality would be fast asleep. You could have blasted the geophone off the end of the cable and it wouldn’t trigger.   This fault was obviously addressed rather quickly by the manufacturer.

Two opposing manufacturers promoted different printing technologies. One favored a pen plotter, while the other used a thermal printer. In actuality, neither was very good. The plotter had many moving parts that would accumulate dirt in the field and could quit working. You really had to keep them clean. The pens could also gum up or run out of ink if you weren’t paying attention.   The thermal printer was simpler, but its resolution was pretty bleak and the resulting records would fade into unreadable strips of paper fairly rapidly. The solution was to make copies of them before they faded too badly. Some sort of semi-permanent storage medium was needed and was eventually developed.   Printers have improved over time.

One manufacturer used infrared emitters and sensors to control the paper take up. When I opened an instrument's lid in daylight, the paper drove through the printer uncontrollably. This was traced to overly sensitive components, resulting in that particular manufacturer instituting a “California Sunshine” test as a quality control measure on outgoing instruments. Ingenuity is not without its trials and tribulations.

Other technical issues existed with some units. One manufacturer's seismograph would not monitor for more than six or seven hours without the batteries going dead. (Not recording, mind you, just waiting for an event to occur.) Another instrument operated on 8 volts. Just try to find an 8 volt battery. This one used 6v and 2v batteries in series. Thankfully, that was changed in their next series of units.

One of the earliest units calculated true vector sum and printed it. This was a great help because you no longer had to scan the entire record to find the vector sum (square of each individual channel in a given instant, then add them together and extract the square root of the total). The problem with the initial run of this early machine, however, was that the true vector sum printed on the record often fell below the reading of the highest individual channel, a situation that is not technically possible. The vector sum will be equal to the highest channel, but only if the other two channels are indicating zero. If any data appears on either of the other channels, the vector sum must rise accordingly. With no means of turning vector sum off, there were a few embarrassing moments until the error in the internal software was corrected.

Having sufficient internal memory in those days was also a particular problem. As some indication of what was required, consider that in order to meet an upper frequency response of 250 hertz, the accepted standard, one had to record at 1000 samples per second per channel. It is universally conventional to have a sampling rate that is at least four times the highest frequency that is anticipated. For research work, ten times the highest frequency is more often utilized. Lower sampling rates could possibly allow a short spike to slip through undetected. This is commonly referred to as the "picket fence" effect. (For clarity purposes, it should be noted that in binary work we are dealing in numbers such as 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, etc., so instead of 1000 we were actually recording at a sampling rate of 1024 samples per second. The difference between 1000 and 1024 may not amount to much, but I wanted to be accurate so that you more knowledgeable folks wouldn't take me to task over it.) When you consider that there are three channels of motion and one channel of airblast, you are looking at 4096 samples per second of recording. That doesn't include the memory required for all of the other peripheral stuff. Today a few gigabytes of storage can be had for not too many dollars, but back then even a megabyte was unheard of. Various methods of dealing with memory issues were tried, but the method used in one seismograph was particularly fraught with problems. This instrument would record quite well at 1024 samples per second per channel for events of a few seconds, but when one needed to record an extended event, such as in tunnel blasting where the event could exceed anywhere from 6 to 12 seconds, the unit had insufficient memory to store all the data. This manufacturer's solution was to slow the internal clock rate down so that the entire event could be stored. Unfortunately, it was then only sampling at approximately 512 or 341 samples per second, depending upon whether they halved the rate or cut it by two thirds. This had the effect of dropping the upper frequency response to approximately 125 hertz or 85 hertz, which didn't meet the standard. The manufacturer's product specification data didn't properly disclose this shortcoming, and many users of this instrument never even realized it was happening.

The problem would usually only rear its ugly head when a particularly high frequency was recorded at these reduced rates, resulting in aliasing when the data was digitally processed. Aliasing occurs when a recorded sample is at a frequency that exceeds about half the sampling rate. It usually shows up as a high frequency waveform (that is usually correct) superimposed over a low frequency waveform (that is the incorrect aliased wave). To their credit, at least one manufacturer (not of the above unit) incorporated an anti-aliasing filter to remove any frequency that came through high enough to be a problem at 1024 samples/sec.

By and large, digital seismograph manufacturers have succeeded in developing high quality instruments that are capable of recording just about anything we can throw at them. It wouldn't be fair to those manufacturers to disclose their early foibles though, without also mentioning some of the rather humorous situations that the users managed to get themselves into and also to pass along some other possibly interesting anecdotes. Again, no mention of names in order to protect the innocent. (Or maybe guilty. Do you recognize yourself in this article?)

Most digital seismographs conduct an internal check of their sensors, usually when first turned on and then again after an event is recorded. One customer called to complain that his unit would not pass the sensor check when turned on or when he manually forced a check. I knew that his office was in a very shaky travel trailer and so I questioned him as to the placement of the sensors. The geophone block was on the ground outside the trailer, so location wasn't a problem. When I asked him to verify that the cable was securely fastened, his response was, "What cable?" I don't know how he thought the test data was going to be conducted to the instrument. Maybe through the ether....

I also rented units to a company working along the Alaskan Pipeline at Atigun Pass. Winters there were so cold that the units had to be kept in the cab of a truck or they wouldn't function. They needed 250 foot long geophone cables to keep the truck a sufficient distance from the shot. These cables invariably came back in pieces, once in as many as 17 pieces. I'm not sure that the cable manufacturer from whom I was buying my bulk cable wasn't using recycled beach balls and plastic lawn furniture for his feedstocks of insulating material and sheathing..... Eventually I found a source for high quality cable that wouldn't get brittle and break, but by then the Atigun Pass job was finished. By the way, geophone anchoring up there at Atigun Pass was a piece of cake. Pour a little warm water on the ground, place the geophone on it and in a few seconds it was secure.

I had another client who just couldn't train his employees to respect the equipment. He purchased some seismographs from me and almost immediately they started coming back in for repairs. Without fail, the wiring where it entered the geophone block was badly mangled and the strain-relief was broken. Investigation revealed that his operators would spike the geophone block, but when it was time to move to another location, they yanked it out of the ground by the cable and hauled it away, ….possibly with knuckles dragging on the ground.....

This same client called me at home one evening complaining that the readings apparently were being corrupted in most of his units. He felt the velocity readings (in in/sec) that he obtained in the field appeared to be legitimate, but when they downloaded the data to the computer in the office, the data somehow got “corrupted” and was now incorrect. He was calling from the field office and I asked him to open the files on the computer. I also asked what the units were. He responded, “What do you mean?” I indicated, “The small letters after the velocity readings.” “mm/sec” he said.... Oops. Things got a lot better after he changed the units on the computer from metric to imperial to match those in the instruments. (Come to think of it, I wonder why he never realized that all the data in the computer was “corrupted” by a factor of 25.4? That surely should have been a clue.)

There have been several instances where the robustness of seismographs have been tested severely and they usually came through with flying colors. In one very sad case, I delivered a rental instrument to Needles, California and trained the pipeline blasting superintendent in its use. I didn’t hear anything from them for about a month. Then one day I got a call from his office and the complaint was made that the plotter wasn’t printing correctly. In questioning the caller, I learned that the fellow I trained had the unit with him when his pickup was broadsided by a train at a grade crossing. Unfortunately, he didn’t survive the accident. The seismograph was thrown out of the truck bed and through the sagebrush and was eventually retrieved. I sent a replacement unit and when the damaged one came back, all that was wrong was that the plotter had been jarred from its mountings. I re-mounted it, tested everything and it was good to go.

In another instance, a customer’s seismograph fell out of the back of a truck at highway speeds. Other than cleaning up some cosmetic damage, replacing a badly bent battery hold-down bracket and verifying accuracy, it was placed back in service.

This same customer had a unit that was buried in blasted rock from a shot. It kept on recording for most of the event, at least until the rock severed the geophone and microphone cables. The data up to that point was still in memory and was usable. My customer couldn’t be blamed for the unfortunate placement of the instrument either. It was inside a house and the muck came smashing through a wall! (No, my customer was NOT the one doing the blasting. Just doing the recording.) Again, the unit was just fine after the cables were replaced and it was tested.

You may wonder how these instruments could take this kind of abuse and still work. Actually it’s rather simple. There are very few moving parts in a digital seismograph. The sensors are mechanical but are enclosed in a robust geophone block. They usually survive rather well. The printing or plotting mechanism is usually the only other moving part and they do get beat up and need replacing occasionally. The rest of the important parts are solid state devices that can withstand quite a bit of abuse (unless of course, they are torn apart too). My hat’s off to the manufacturers of our modern instruments. Good job, guys.