

Crack Gauge EVOLUTION

Appalachian Region Technology Transfer

Patrick Matkozich
GeoSonics/Vibra-Tech, Inc.
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In The Beginning:

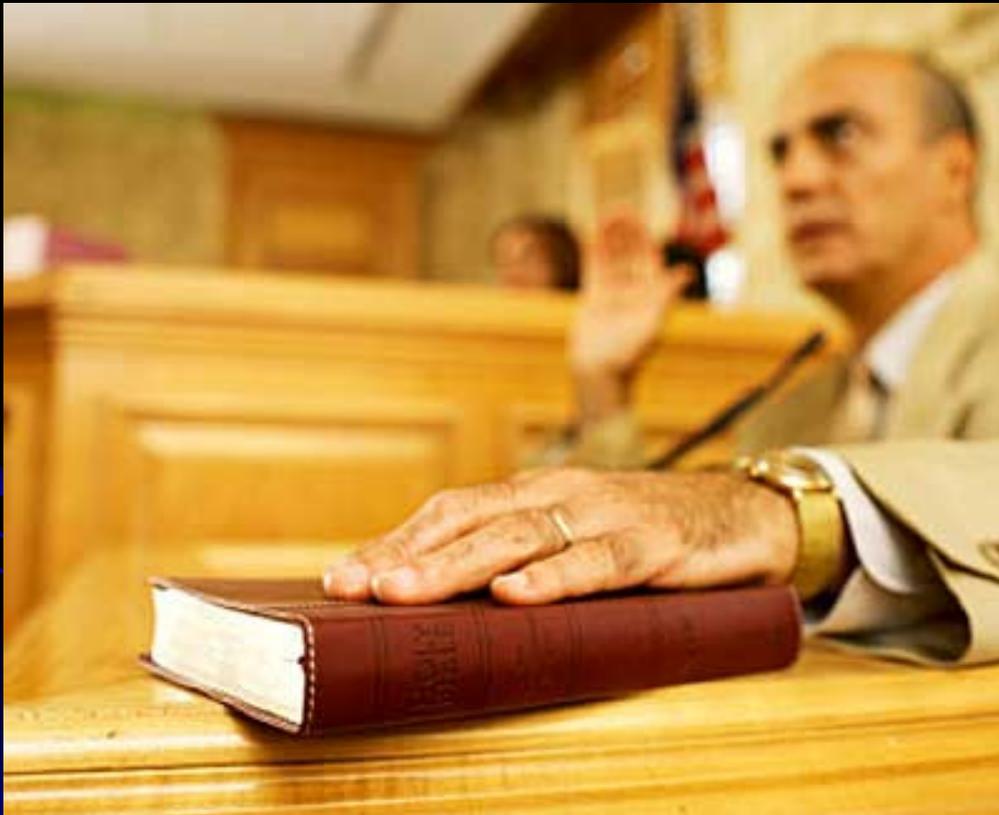


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"I know nothing about the subject,
but I'm happy to give you my expert opinion."

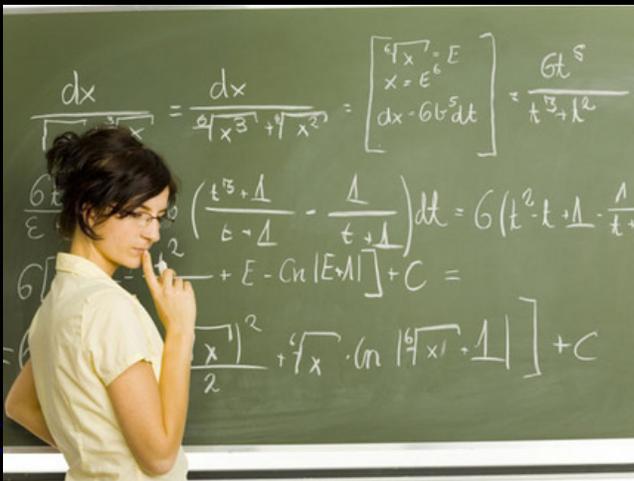
The End?



What We Know:

- Cracks in buildings experience daily and seasonal dimensional changes.
- They are primarily caused by environmental factors (T/RH)
- Human beings are generally unaware of these changes.
- Transient vibration spurs a natural link between these changes and blasting.

The Typical Tools:



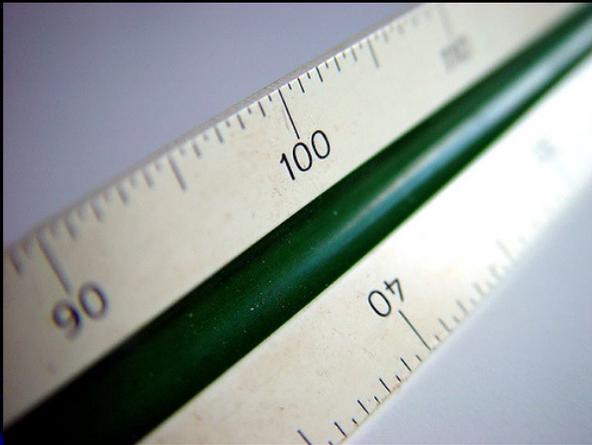
- Pre-blast surveys.
- Seismic readings and the USBM's Appendix B (Z-Curve).
- Standard vibration prediction formulae.

Inherent Problems:

- PBIs are only a picture in time.
- The science behind vibration limits and damage potential is often lost on homeowners.
- Data isn't always applicable in every case.



The Logical Next Step:



- Directly measure the defects in question.

Application Areas

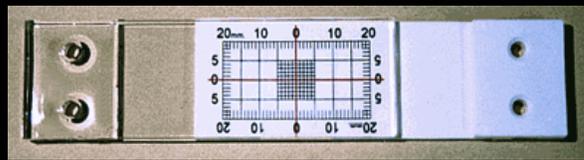
- Blasting Projects
- Pile Driving/Extraction
- Concern for Historic Structures
- Alarm Systems working with project specs.
- Going the extra mile with homeowners/operators/regulators etc.
- **Addressing Complaints**

What I've Seen:

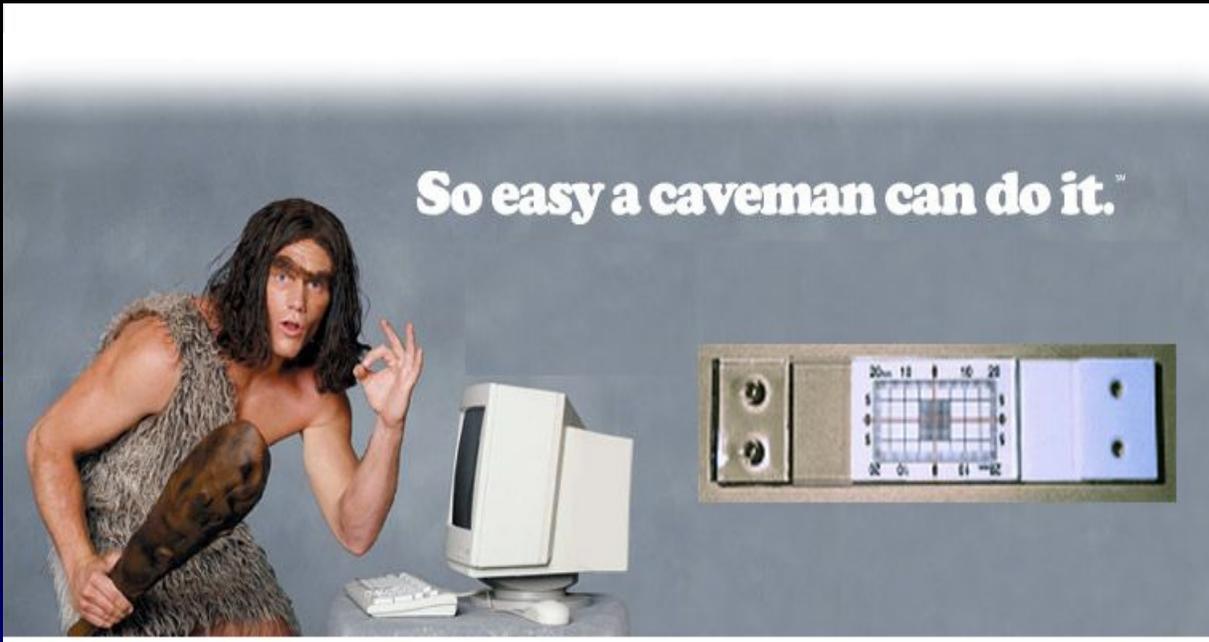
- Slow start to CG Acceptance.
- Technology has become user friendly.
- Software has been increasingly refined.
- Admission of data as evidence in court.
- Regulatory interest/acceptance has grown.

The Distant Past:

- Analog Gauges
- Oza Gauges
- Avonguard Gauges
- Paper Records



How Easy Was It?



Conventional Pros & Cons:

- Easy to install
- Easy to understand
- Cost Effective



- Limited Resolution (0.25-0.50 mm)
- Paper records : These are poor!!!
- Missing data points make this **dangerous**.

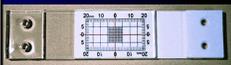
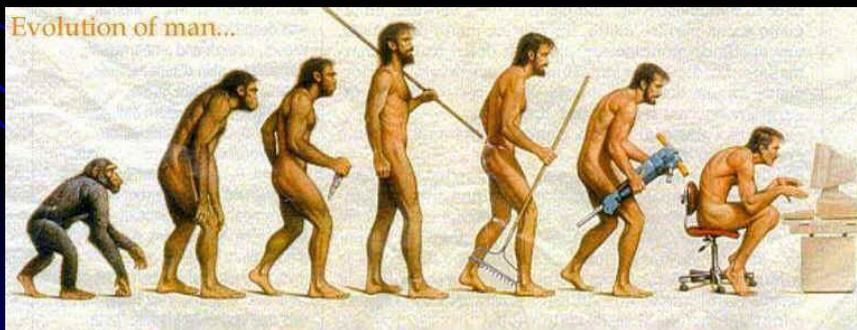
A Little More Recently:

- First digital CGs implemented ~2001.



The Evolution Begins:

- LVDT's – Linear Voltage Differential Transducers
- Temperature and Relative Humidity recorders
- Completely digital record
- Upgraded hardware nets better functionality
- Enhanced resolution – 0.004 of a 1000th of an inch.



Why Go Digital?

- Extremely accurate.
- Totally digital.
- No gaps in records.
- Movement is quantified.
- Still easy to understand.
- Data is highly versatile.
- Defendable in court!!!



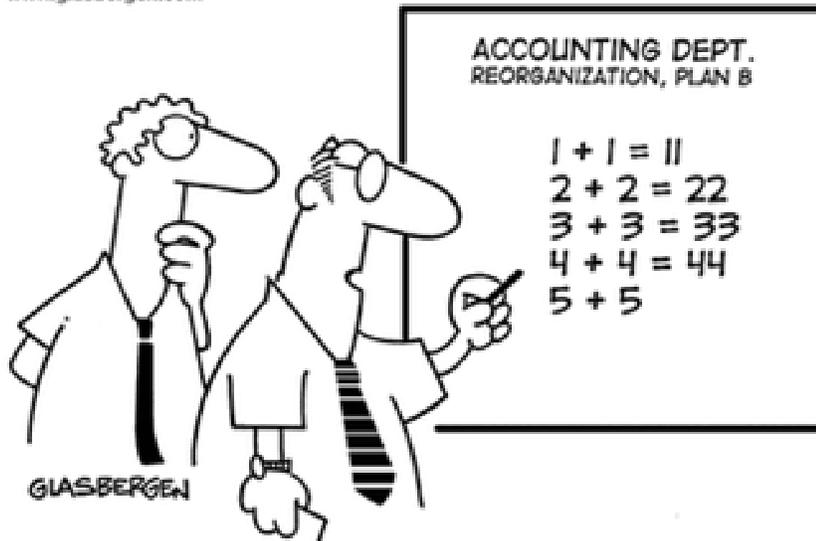
How They Work:

- LVDTs consist of a magnetized core and calibrated rod.
- Each component is fixed on either side of a defect.
- When movement occurs, the rod induces a change in current through the core.



The Evolution Continues:

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“For years, we’ve been playing by old rules and the results have been dismal. It’s time for a bold new direction!”

Analysis Evolution:

- Primary analysis conducted with Excel
- Earlier SW versions were hard to use
- Multiple histogram analysis made parsing the data much easier
- Temp and RH data was often hard to combine onto one dataset
- Usual parameters addressed:
 - Max to min
 - Max from activity
 - Dates and times of max and min
 - Windows around activity
 - Max environmental movement

Multiple Histogram Analysis

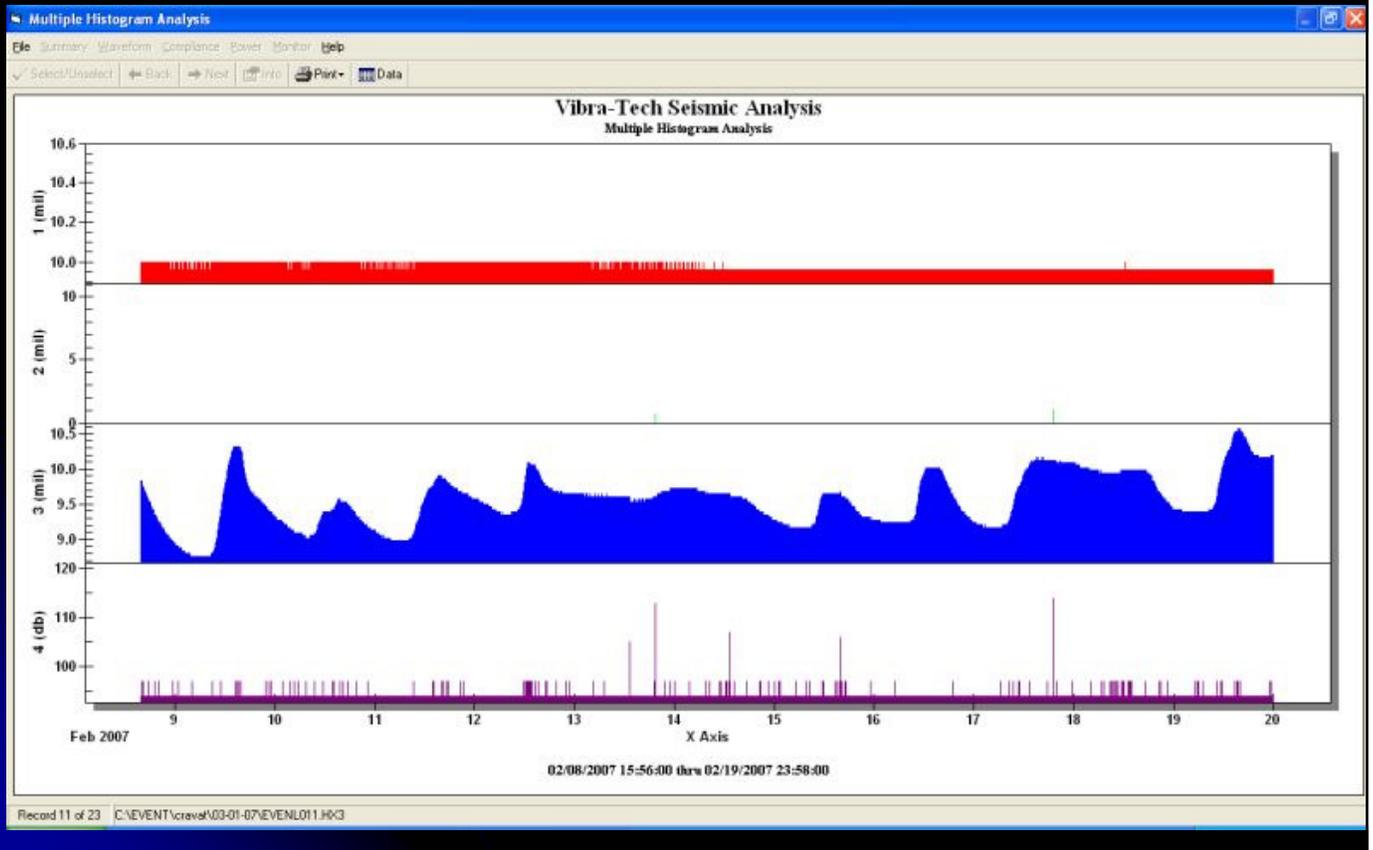
GeoSonics Inc. Seismic Analysis v6.3.37 Corporate

File Summary Waveform Compliance Power Monitor Tools Help

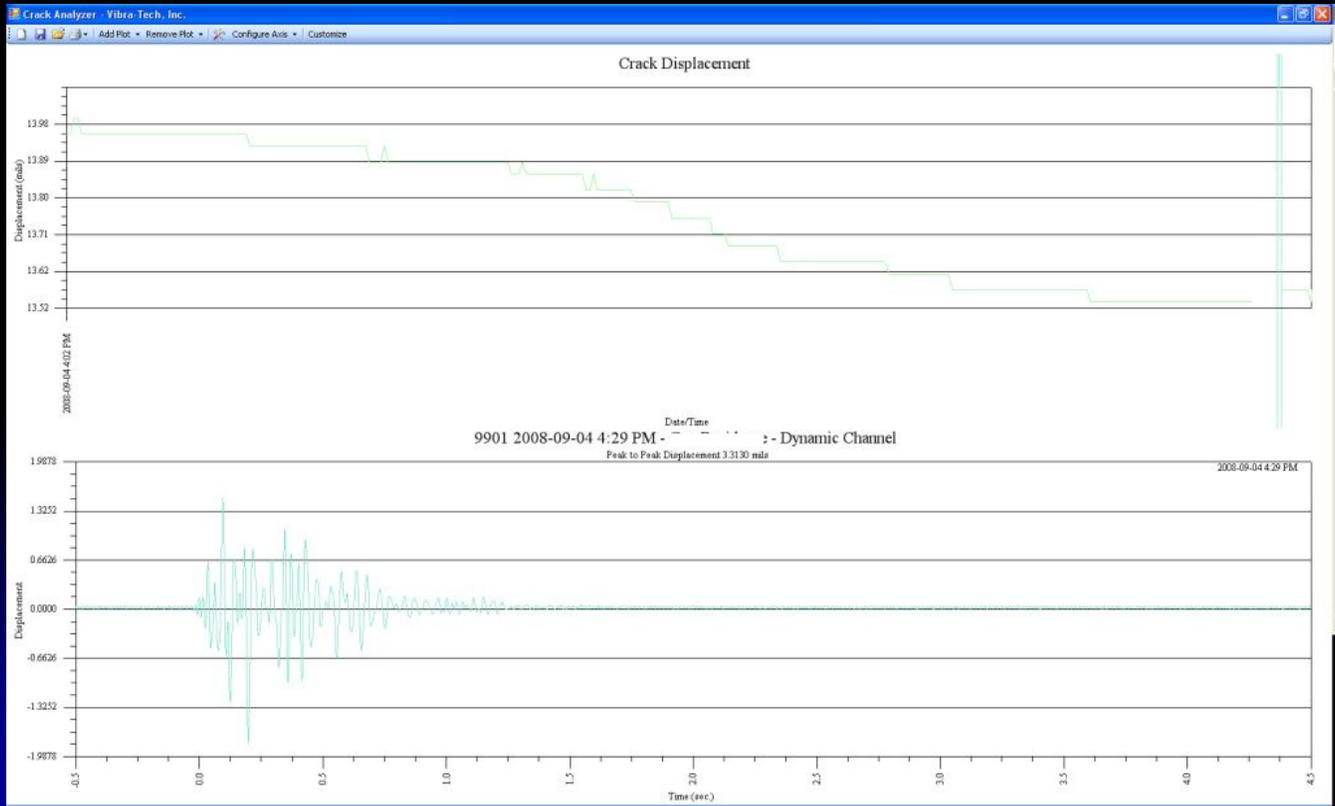
Select
 UnSelect
 Refresh
 Preferences
 View
 Print
 Data Mgt

#	Description	File Name	Ext.	Date	Time	Serial No.	Event No.	Seq. No.	L PPV	T PPV	V PPV	Resultant	S Peak	Client	
1	Non-Std Histogram	EVENL001	HX3	02/08/2007	15:56:00	9901	1		9.93	0.04	9.75	0.00	in/s	0.050	psi
2	Non-Std Histogram	EVENL002	HX3	02/09/2007	00:02:00	9901	2		9.93	0.07	8.89	0.00	in/s	0.050	psi
3	Non-Std Histogram	EVENL003	HX3	02/10/2007	00:02:00	9901	3		9.96	0.07	9.29	0.00	in/s	0.050	psi
4	Non-Std Histogram	EVENL004	HX3	02/11/2007	00:02:00	9901	4		9.93	0.04	9.07	0.00	in/s	0.050	psi
5	Non-Std Histogram	EVENL005	HX3	02/12/2007	00:02:00	9901	5		9.96	0.04	9.54	0.00	in/s	0.050	psi
6	Non-Std Histogram	EVENL006	HX3	02/13/2007	00:02:00	9901	6		9.93	0.68	9.61	0.00	in/s	0.271	psi
7	Non-Std Histogram	EVENL007	HX3	02/14/2007	00:02:00	9901	7		9.93	0.07	9.64	0.00	in/s	0.139	psi
8	Non-Std Histogram	EVENL008	HX3	02/15/2007	00:02:00	9901	8		9.93	0.07	9.21	0.00	in/s	0.136	psi
9	Non-Std Histogram	EVENL009	HX3	02/16/2007	00:02:00	9901	9		9.89	0.04	9.25	0.00	in/s	0.050	psi
10	Non-Std Histogram	EVENL010	HX3	02/17/2007	00:02:00	9901	10		9.93	1.07	9.21	0.00	in/s	0.321	psi
11	Non-Std Histogram	EVENL011	HX3	02/18/2007	00:02:00	9901	11		9.89	0.04	10.00	0.00	in/s	0.050	psi
12	Non-Std Histogram	EVENL012	HX3	02/19/2007	00:02:00	9901	12		9.89	0.04	9.39	0.00	in/s	0.050	psi
13	Non-Std Histogram	EVENL013	HX3	02/20/2007	00:02:00	9901	13		9.89	0.07	10.14	0.00	in/s	0.050	psi
14	Non-Std Histogram	EVENL014	HX3	02/21/2007	00:02:00	9901	14		9.89	0.07	9.86	0.00	in/s	0.050	psi
15	Non-Std Histogram	EVENL015	HX3	02/22/2007	00:02:00	9901	15		9.89	0.57	9.93	0.00	in/s	0.250	psi
16	Non-Std Histogram	EVENL016	HX3	02/23/2007	00:02:00	9901	16		9.89	0.04	9.75	0.00	in/s	0.050	psi
17	Non-Std Histogram	EVENL017	HX3	02/24/2007	00:02:00	9901	17		9.89	0.07	9.75	0.00	in/s	0.200	psi
18	Non-Std Histogram	EVENL018	HX3	02/25/2007	00:02:00	9901	18		9.82	0.21	9.71	0.00	in/s	0.200	psi
19	Non-Std Histogram	EVENL019	HX3	02/26/2007	00:02:00	9901	19		9.82	0.04	9.79	0.00	in/s	0.050	psi
20	Non-Std Histogram	EVENL020	HX3	02/27/2007	00:02:00	9901	20		9.86	0.04	9.68	0.00	in/s	0.050	psi
21	Non-Std Histogram	EVENL021	HX3	02/28/2007	00:02:00	9901	21		9.86	0.04	9.68	0.00	in/s	0.050	psi
22	Non-Std Histogram	EVENL022	HX3	03/01/2007	00:02:00	9901	22		9.86	0.04	9.79	0.00	in/s	0.050	psi

Multiple Histogram Analysis



Example Data:



Shanduka Coal
Middelburg District, South Africa

Englebrecht Residence
SN: 3467

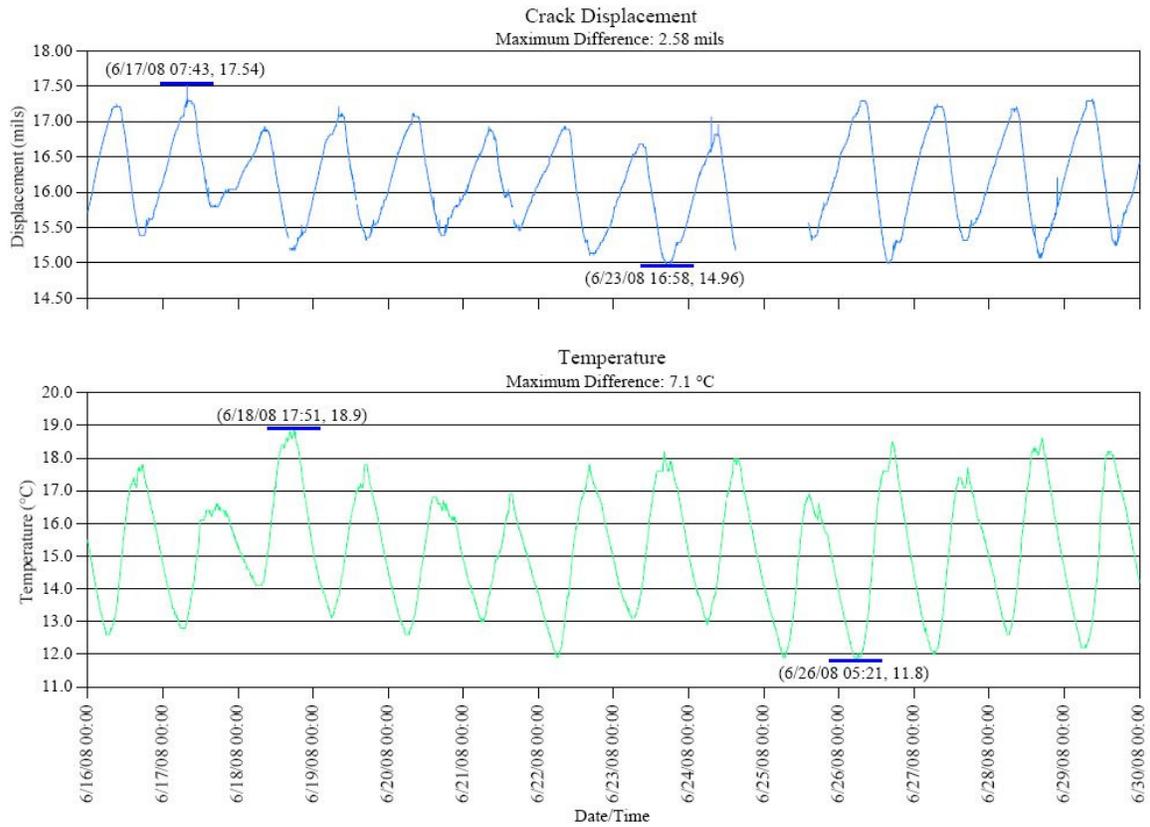


Figure 1

Shanduka Coal
Middelburg District, South Africa

Englebrecht Residence
SN: 3467

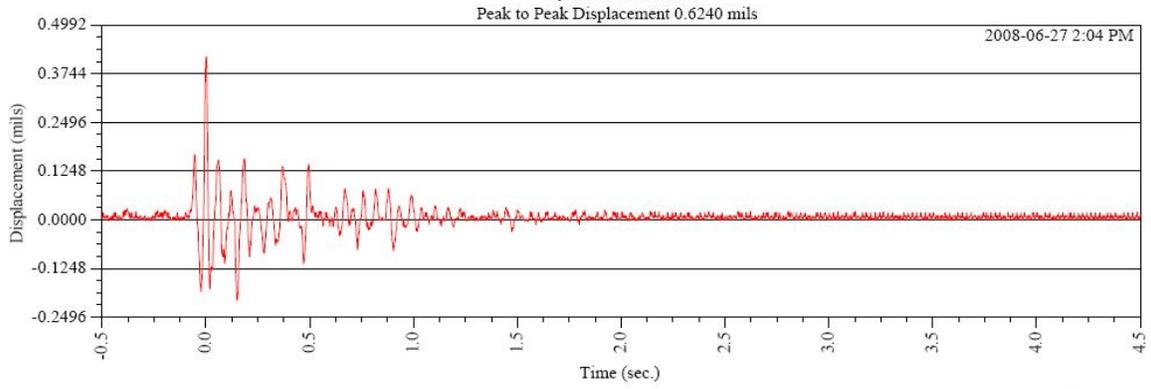
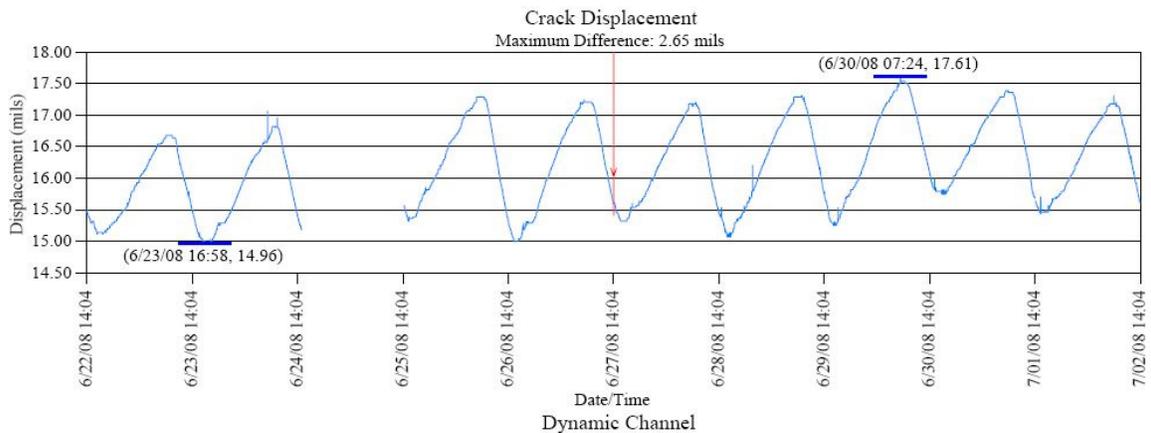


Figure 1

Gauge Types:



CG Setup:

- Two different types of Gauges.
- Type I gauges do not have built-in alarm systems or test boxes. These are externally connected.
- Type II gauges - have test box and alarm systems built in.

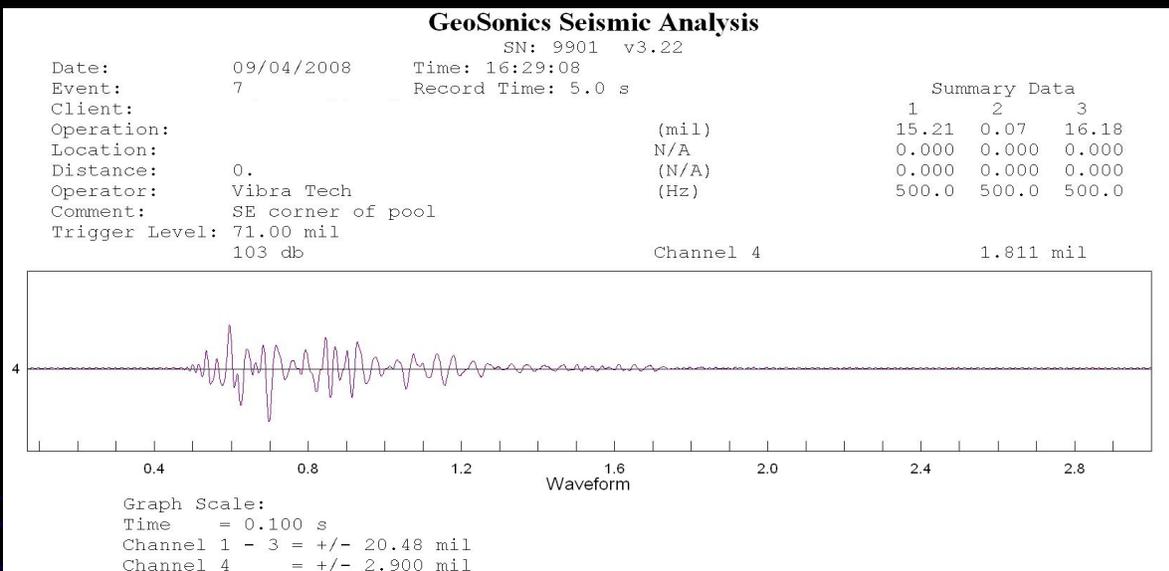


CG Setup:

- Cores and Rods go perpendicular across defects.
- Two sensor system does error checking by filtering out EMI.
- Rods must be free to move in the core and proper alignment is critical.



Hardware Evolution



- Addition of “Dual – Mode” allows both environmental data and time histories to be recorded simultaneously.
- Resolution jumps – 10X. Increases from 0.04 to 0.004 of a 1/1000th.

Darwin Would Be Proud:



Master Trigger Control:

- Master trigger control allows you to connect a crack gauge to a seismograph as an aux trigger source.
- Up to 5 slaves can be hooked to one MTC.



Master Trigger Control:



Master Trigger Control:



MTC – Optical Alarm Systems:



Optical Alarms: Details

- Connect any LC without an alarm port to a crack gauge.
- No worries about false events EMI.
- Easy correlation to a vibration event.
- Works independently of trigger level on unit.
- 1/1000th of a second response time!!!
- Optical Alarm Details



Case Study:

- Surface coal mine in Ohio
- PPV increasing as mine gets closer – up to 300'
- Homeowners complaining of damage since first blast
- Damage not documented in PBI



Details:

- Homeowners approached operator about alleged damage.
- Seismograph monitoring was conducted on the property since 1st blast.
- CG put in as a “last ditch effort”.



Details Continued:

- Monitoring conducted for all 59 blasts.
- Particle velocity's ranging from <0.02 to > 0.40 ips.
- No vibration exceeding the z-curve.



Details Continued:

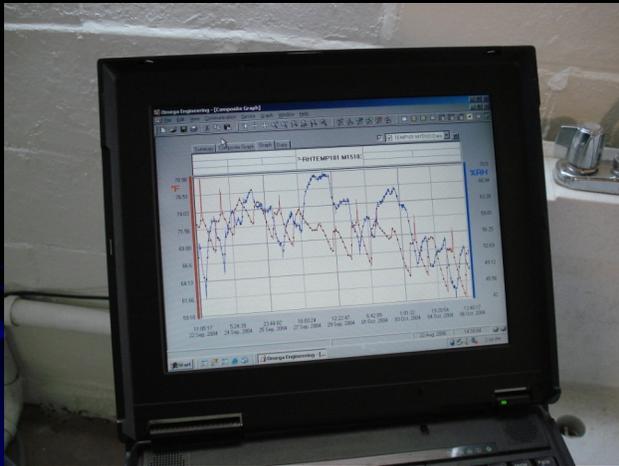
- Gauge in place for all but a handful of blasts.
- Monitoring conducted from August to February of following year – 6 months.
- Environmental monitoring conducted as well.



Final Installation:



Details Continued:



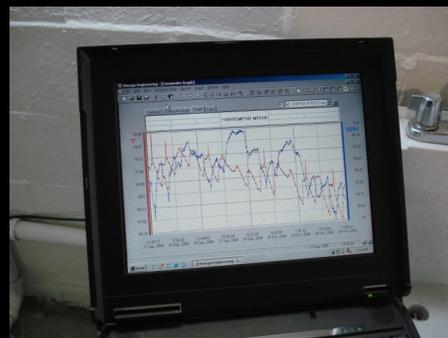
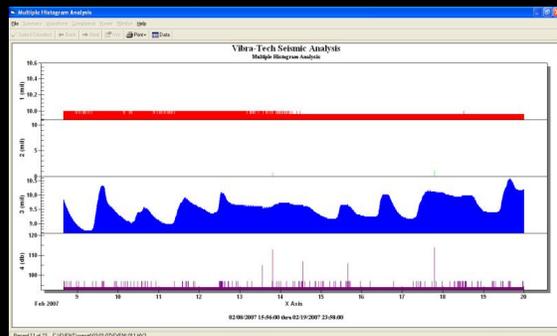
Interesting facts:

- Max crack opening occurred at installation.
- Crack steadily closed during the duration of study.
- Minimum crack opening occurred at the end of the study.
- 6 mil swing over the course of data collection.



Interesting Facts:

- Max movement attributable to blasting 0.11 of 1 mil...only 1/54 of environmental movement. (environmental mode only)
- Crack showed cyclical movement that directly corresponded to changes in temperature and relative humidity regardless of blast schedule



Benefits:

- Homeowner was able to grasp concept of crack gauge where seismic data alone was not effective.
- Mining co. able to continue their permit activity.
- Dismissal of damage claim....



Conclusion:

- Effective tool for our industry
- Many applications
- Useful and storable data
- Easy to understand concepts
- A great supplement to any monitoring program

