REVIEW
I BLASTING AND ATTENUATION STUDIES BY PROF. AIMONE-MARTIN
II PROPOSED ORDINANCE 15.33: BLASTING REGULATIONS

Prepared by C H Dowding
20 August 2005

I
REVIEW OF BLASTING AND ATTENUATION STUDIES BY PROFESSOR AIMONE-MARTIN

MY CONCLUSIONS & OBSERVATIONS FOLLOWING REVIEW OF THE AIMONE-MARTIN REPORT

I have reviewed Professor Aimone's Blasting Attenuation & Structure Response Study and have reached the following conclusions related to the nature of the study. This short report will not repeat Professor Aimone's conclusions, with which I agree.

1) The city of Henderson received one of the most complete reports of blasting effects that I have reviewed. The some 70 page report is founded upon some 145 pages of Appendices. Some 25 blasts were monitored with an average of 6 or more seismographs, which involved more than 150 seismological measurements, and nearly 1000 time histories.
2) Vibration monitors deployed to measure ground motions and air overpressures are standard models employed regularly in the blasting industry. Procedures employed to install these instruments are standard.
3) Reported conclusions were based upon measured house and crack responses, which are normally only obtained in research studies. These research grade measurements facilitated estimates of blast vibration induced strains in the structures that could be compared to those necessary to crack various construction materials.
4) Crack responses to blasting and air overpressure excitation were compared to those induced by changes in weather (temperature and humidity), and were found to be far less than those induced naturally. These low blast responses have been confirmed by my own research as well as that by others.
5) Measurements of crack response to high wind velocities confirm long standing – but experimentally not verified for blasting– observations of the stresses and deformations induced in structures by wind. The importance of wind stresses is confirmed by hurricane and tornado induced damage.
6) While the instruments and sensors employed in the crack study are newly developed, several firms are in the process of commercializing other similar instruments.
7) Micro-inch crack sensors are the same sensors that I employ in my research.
8) Procedures and computations employed Procedures and computations employed in this study follow those recommended in my book Construction Vibrations.

9) Reported measurements show that blast induced effects – that meet vibration controls -- are smaller than those induced by nature and thus can have no proximate effect.

10) That fact that neighbors are concerned by blasting is not unusual. An entire book on the subject – The Effects of Vibrations and Environmental Forces -- has been written by L. Oriard, one of the "Deans" of blast design and forensic investigation.

ADDITIONAL INFORMATION REQUESTED AND RECEIVED

These conclusions not withstanding, there were several additional pieces of information that I requested of Professor Aimone-Martin. She has supplied answers to all of these questions and information and summaries of our exchange are attached in the Appendix.

1)_ Long term and dynamic responses of the null crack sensors are supplied in the appendix. The null sensors are employed to verify that measured crack responses are caused by crack widening and narrowing and not that of the sensor itself. This information confirms the proper functioning of the instruments measuring crack responses

2) Variation in calibration signals of the vibration monitors is explained in the appendix. Specifically, the appendix explains the manner in which the calibration signals are employed to increase the accuracy of the reported response. These calibration signals are part of the in-depth provisions for validating measurements of blast vibration monitors that have grown over the more than 5 decades of the development of these instruments.

3) Sample rates of 512 samples per second were chosen to ensure recording of long time histories should they have occurred. This sample rate ensures that digital sampling is 95% accurate at 51 Hz and 91% at 73 Hz

4) Photographs and/or drawings of the instrumented crack locations relative to the instrumented corners and mid walls were provided. These are the missing Figures 2 and 3 of the report, which should be added to the version on Henderson's web site.

5) The source of equation 8) was provided as described in the appended materials.

BIASES

It is important for readers to know that Professor Aimone was a student of mine and that we collaborate extensively. We have taught classes and have written papers together. I explained this relationship to Mr Zalaoras before I was retained, and we agreed to go forward. It is also important to know that blast vibration monitoring involves a small community of experts, and thus it is natural for Professor Aimone to be professionally related.

Finally, while I was not the first to use micro-inch sensors to measure crack response, I am probably one of the greatest proponents of their use. Thus it should not be surprising that I whole heartedly approve of their use in these situations. They allow measured comparisons to be made between noisy blast induced and quiet environmentally induced crack response that is helpful to differentiate human from structural response. Their use is becoming increasingly important in monitoring historic structures and court mandated measurement. For example I have employed micro-inch sensors on historic structures in Washington, DC and those involved in court determined limits.

II
REVIEW OF THE PROPOSED ORDINANCE 15.33

I have reviewed the proposed chapter 15.33 of the Henderson Municipal Code. My comments are divided into two sections: Municipal Oversight and Prevention of Cracking.

Municipal Oversight My comments regarding oversight regulations are divided into two groups: Issues of logic and Issues of an editorial nature.

In general the plan is well written, defined and thought out. The idea of a special inspector for proximate blasting is an excellent approach to reduce the burden on the Fire Department. However there remains a great deal of burden on the Fire Marshall for an issue that does not involve fire. Ultimately Henderson may wish to consider administering this out of the City Engineers office, which may be more used to monitoring building permit issues.

Issues of Logic

Pg 3: 100 feet: It is defined in two conflicting frames of reference. First it is blasting within 100 ft of a structure (I assume of a structure not owned by the person about to blast). Then it is defined as property owners within 100 ft. Which was the desired point of reference, the structure or the property line?

Pg 4 and 8: Citations: There seems to be only one form of interdiction: revocation of the permit. Henderson may wish to consider an order to cease drilling as the first step for, minor infractions like late filing, missing notification of 1 out of 20 neighbors, etc.

Pg 5: Blast Site and Fly Rock: Normally fly rock is limited to falling within the "permit area" as described in 130.06 on Pg 11. As currently written on Pg 5, it cannot fall more than 50 ft from the blast. Thus a developer blasting in the middle of a large parcel of land cannot enjoy the benefit of that property. Even page 11 is contradictory for large parcels of land.

Pg 5: "public improvement" listed as a critical bound on page 5 but not elsewhere (eg Pg 10 130.04, a). Given my feeling about the robustness of concrete flatware, does Henderson wish to apply its limits to "sidewalks"?

Pg 12: a. 5) On windy days and near traffic it may be necessary to set the trigger level at 0.05 ips. Why not specify a range?

Pg 13: 130:07 c) Add a requirement that the seismograph and blast reports be combined by producing plots of PPV v. distance and PPV v. scaled distance as well as dB of air overpressure v. scaled distance that contain a point for each blast. This plot will provide a living document of the off-site effects and induce greater coordination between the blaster and seismologist.

Pg 15: # of seismographs. Page 15 140.05 is vague and without limit and conflicts with the more specific guidance supplied in 130.02

Editorial Issues:

Pg 5 and 7: Blaster has different licensing requirements/options under Blaster (5) and 15.33.10.02, para 2.

Pg 8, last para: The contractor is given a deadline to respond. Would not symmetry require a statement about timely reinstatement by the Fire Department of the suspension, if the contractor rectified the situation immediately?

Pg 9: Blast Scheduling, 2: This wording could be interpreted to mean that the contractor can only request blast times one at a time. Could a contractor request to blast M, W & F in advance?

Pg 14: 140. 03 & 04. Structures should be those owned by others through out.

Pg 16: The Y, Vertical Axis, of Figure 2 should read SQRT of Weight (lbs$^{1/2}$)

Pg 20: 150.02 a) 3. "scaled photographs" is not consistent with the definition of preblast survey "visual record"

Pg 21: 150.03 1st para: independent special inspector. Is this in addition to the "company responsible for preparing the seismological report" on pg 15, 140.05, 3.

Prevention of Cracking. The proposed limits to blast induced ground motion and air overpressures in 15.33 are overly conservative and without scientific foundation even if they are meant to prevent cosmetic cracking of even the weakest of wall coverings such as gypsum drywall. Concrete masonry units, brickwork, and concrete flatware are even more vibration resistant. The ground motion limits should follow the USBM guidelines as described in RI 8507 and NFPA 495 to have a scientific foundation. The air overpressure limits are also conservative and should follow the limits as set forth in NFPA 495. Even these limits for allowable air overpressure are not founded upon observed cracking. Professor Aimone-Martin's measured crack response to wind demonstrates that environmental effects can exert large stresses on residential structures.

While it is within the right of any self governing body to constitutionally limit any activity it deems undesirable, it is incorrect to interpret these proposed limitations to relate in any way to the onset of even cosmetic cracking of interior wall covering.

Furthermore these ground motion limits are applied to utilities, which have been shown to be more than 10 times more robust than residential wall coverings. The conservatism of this regulation is without scientific foundation.

Any of my comments or lack thereof with regard to Municipal Oversight above can not be interpreted to contravene the above opinion relative to the overly conservative setting of vibration and air overpressure limits.

III RESUME

1. I am currently a Professor of Civil and Environmental Engineering at Northwestern University in Evanston, Illinois. I have held this position since 1986. Prior to that, I was an Associate Professor of Civil Engineering at Northwestern University from 1976 through 1986. Prior to that, I was an Assistant Professor of Civil Engineering from 1972 through 1976 at the Massachusetts Institute of Technology.

2. I obtained a Bachelor of Science degree in Civil Engineering from the University of Colorado at Boulder in 1967. I obtained my Master of Science degree from the University of Illinois at Urbana in 1968 and obtained my Ph.D. from the same institution in 1971.

3. I am a Registered Professional Engineer in the State of Colorado. I am a member of the American Society of Civil Engineers, where I was the Chairman of Rock Mechanics Committee from 1984 through 1991 and I also was on the Publications Committee from 1986 through 1990. I am also a member of the American Institute of Mining Engineers, the International Society for Soil Mechanics and Foundation Engineering, the Society of Explosive Engineers, the International Society of Rock Mechanics (where I was the Chairman of the Committee on Ground Vibration Monitoring), and the American Rock Mechanics Association. I was on the U.S. National Rock Mechanics Committee of the National Research Council (1983-1988), the Chairman of the 25th U.S. Rock Mechanics Symposium (1982 through 1984), the Committee for Rock Mechanics Research Requirements, and the Co-chairman, Fracture Pattern Mapping (1978-1981).

4. My recent honors and awards include the following: (a) Named Sigma Xi 2003-2004 Distinguished Lecturer (2003); (b) Received the Distinguished Engineering Alumni Award for Education from the University of Colorado at Boulder (2003); (c) Elected to the Board of Directors of the International Society of Explosive Engineers (2002); and (d) Editorial Board of the Journal of Rock Mechanics and Rock Engineering. (e) Board of Directors of the American Rock Mechanics Association (2000).

5. Classes I have taught at Northwestern University within the last 3 or 4 academic years include: Air Photo Interpretation; Underground Construction; Engineering Properties of Soils; Rock Mechanics; Soil Dynamics and Geotechnical Engineering seminars.

6. My principal fields of research interest include rock mechanics (blasting, dynamic response, etc.), soil mechanics (exploration decisions, foundation engineering), and construction (vibrations, computer graphics, digital data acquisition and analysis).

7. I have been involved in many major consulting projects over the years which concerned blasting, vibration, slope stability, settlement or ground motion including, but not limited to the following: (a) Vulcan Materials Co., 1999-2000, Blast Response of Rock Slope; (b) Argonne National Laboratory, Illinois, 1997-1999, Blast Response of High Energy Physics Instruments; (c) IBM, White-Plains, NY, 1998-1999, Impact of Microvibrations on Research Instructions; (d) Fina Oil Co., 1996-1998, Vibroseis Ground Motion; PBQ, Newark, New Jersey, 1996-1997, Blasting Considerations for Urban Rail Tunnel; (e) Birmingham Water Board, 1996, Exploration and Blast Hole Drilling; (f) CIGNA Insurance Co., 1994, Blast Damage of Adjacent Rock; (g) Shell Pipeline Co., 1993, Blast Vibration Response of Pipelines; (h) Leviton Construction Co., Dayton OH, 1989-90, Pile Driving Vibrations; (i) Turner Construction Co., New York City, NY, 1989-1989, Urban Blast Vibration Monitoring; (j) Sargent and Lundy, Chicago, 1985-1888, Dynamic Slope Stability; (k) and Minnesota Department of Transportation, 1983, Blasting Response of Historic Buildings; Peabody Coal Co., Kentucky, 1981-1989, Blast Induced Subsidence and Indiana, 1986-1989, Strain Monitoring.

8. I was part of the team that developed the U.S. Bureau of Mines safe blasting criteria (from which the Office of Surface Mining's criteria was developed). The research resulting in that standard took place over more than a decade. Many homes were observed (pre- and post-blasting). They were old and new, distressed and not, one and two story, etc. I was present and participated in some of the tests.

9. I have authored two books regarding construction vibrations entitled "Blast Vibration Monitoring and Control" (Prentice Hall Saddle River, N.J., 1985, 297 pages) and "Construction Vibrations," Prentice-Hall, Saddle River, N.J., 1996, 620 pages), and was a coauthor of two peer reviewed reports for the US Bureau of Mines: RI 8507, Structure Response and Damage Produced by Ground Vibration from Surface Mining, 1980 (received the Applied Research award from the US National Rock Mechanics Committee of the National Research Council); and RI 8896, Effects of Repeated Blasting on a Wood Frame House, 1984.

10. I have written over Fifty (50) articles, 5 book chapters, and conducted approximately ten (10) externally funded research studies and countless seminars (world-wide) concerning construction vibrations air-blast effects and/or other seismic (dynamic) phenomenon.

IV)

SUGGESTED MINOR EDITING OF THE AIMONE-MARTIN CONCLUSIONS

The following are suggested changes to the conclusions in the Aimone-Martin Report. They are minor relative to the overall conclusions, and were inserted for completeness. The first list is from the Structure Response report and the second group is from the Attenuation Study

RESPONSE

- All ground vibration data recorded during this study fell well within the safe blasting criteria defined by the U.S. Bureau of Mines in 1980 and widely used in the U.S. rock blasting industry. This safe criteria is based on over 40 years of research and crack observations and has been scientifically supported since 1980 by experts in the field of structure response to rock blasting. There has been no scientific data to date that disputes this criteria.

- Horizontal peak ground (particle) velocities (PPV) recorded at the structures were very low, ranging from 0.025 inches per second (ips) to 0.075 ips, Except for the anomalous motion on 3/23. The peak ground and FFT frequencies ranged from 3.3 Hertz (Hz) to 42.6 Hz, with lower frequencies associated with the lower PPVs, which occurred at the larger distances

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- For most blasts, the airblast did not contribute to structure vibrations within either dwelling as illustrated in upper corner and mid-wall velocity time histories. During this study, airblast averaged 105.5 dB for the Bighorn dwelling and 104 dB at High Mesa. Peak airblast frequencies were above 11 Hz and energy was not coupled within the walls at this low amplitude.

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- Velocity time histories of upper corners and mid-walls for the two structures did not exhibit any unusual characteristics. Both structures responded as expected and within the range of structure responses for similar construction dwellings.

- Blasting over the time period of this study did not provide sufficient energy to allow a simple computation of structure damping and natural frequency, except in the case of the blast on 3/23/05 at 2:47 pm for the structure on Bighorn. Structure natural frequency and damping were computed to be 9 Hz and 5.4%, respectively, and well within the normal range for all structure types.

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- Based on the low ground vibrations and the absence of airblast, it was not possible to compute amplification factors (AF) comparing time-correlated maximum structure responses to ground vibrations for blasts, except for the blast on 3/23/05 at 2:47 pm at the structure on Bighorn. AF values for the R and T components for this blast were 2.3 and 1.2, respectively, and are well within the expected range. For all other blasts there was insufficient blast-generated energy to compute AF.

- The maximum in-plane tensile and mid-wall bending strains calculated for the structure on Bighorn were 27.8 and 9.4 micro-strains, respectively. For the dwelling on High Mesa, the maximum in-plane tensile and mid-wall bending strains calculated were 5.78 and 4.33 micro-strains, respectively.

- The range of failure strains in the gypsum core of drywall is 300 to 500 micro-strains while in polymeric fiber reinforced stuccos, failure strains are in excess of 1,000 microstrains. Therefore, strains computed from structure motions from blasting during this study were far below those that could possibly cause cracking in walls.

- Peak dynamic crack displacements during blasting ranged from 45.6 to 243.5 micro-inch for the horizontal crack on the southeast wall of the structure on Bighorn for ground motions up to 0.45 ips. Peak crack displacement for the diagonal crack on the northeast wall in the structure at High Mesa ranged from 42.6 to 113.6 micro-inch for ground motions up to 0.045 ips.

- The largest measured changes in the width of the cracks as influenced by variations in temperature and humidity over a 12-hour (half-day) cycle were 6844 and 4583 microinch for the structures at High Mesa and Bighorn, respectively. Over the project duration of 764 hours (31 days), overall crack width changes were 8212 and 5403 micro-inch for the structures at High Mesa and Bighorn, respectively. Thus, environmentally-driven crack width changes were 72 and 22 times greater than the zero-to-peak dynamic motions during blasting for the High Mesa and Bighorn structures. Environmental changes have a far greater influence on cracks movements compared with blasting.

- Crack displacements during construction activity (rock impacting, backhoe, vibratory rollers) adjacent to the structure on Bighorn were similar in magnitude to those recorded during blasting with the exception of the anomalous blast on 3/23/05 at 2:47 pm. Hence, close-in construction and typical blasting activities vibrations have the same influence on structure response as measured by existing crack motions.

- The largest crack displacements measured at the Bighorn residence during a wind storm on 3/22/05 and 3/23/05 were 252.8 and 277.4 micro-inch, respectively. The corresponding wind speeds computed from measured peak air pressures were 31 and 34 mph.
  Weather data for Henderson available on the Internet indicated wind gusts measuring up to 40.3 mph. Therefore, high winds during storms in Henderson can produce crack responses greater than those produced by ground vibrations near the regulatory limit of 0.5 ips.

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- Blast vibration influence on changes in crack widths were negligible compared with the influence of climate and compared with those produced by high winds. Large weather induced changes in crack widths are the greatest contributing factor to crack extension and widening over time. Hence, blasting is unlikely to be the source of stucco cracking compared with other daily environmental and weather.

ATTENUATION

Airblast is affected to some degree by the direction of wind and the elevation of the blast site. Airblast levels at blast site elevations above 2580 ft. measured 10% higher than airblastlevels recorded below 2418 ft. Blasts generally were located at the higher elevations.

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- Blasting and vibration monitoring and control methods currently employed are state-of art and represent best practices available in the rock blasting industry.

- Historical vibration records from VCE (prior to 2/25/05, or the commencement of these studies) showed vibration levels slightly higher than those recorded by both VCE and AMA from 2/25/05 to 4/14/05, given a constant distance and explosive charge weight. However all historical data for ground motions were within regulatory limits.
This may indicate that more control on blasting was exercised since that inceptions of scientific studies and elevated oversight by the City.

- Post-blast record keeping of blasting and vibrations information was somewhat deficient
in key data upon commencement of this study and greatly improved over the following 3 months. As a result, blasters were more aware of off-site impacts and responded with improved control measures.

- The best-fit equation (50-percentile) for data recorded during this study was
$_{50\,.\,1}6\ .\ 121\ _{-}= SD\ PPV$
with a correlation, R$_2$, of 0.93. This fit is very close to the fit obtained by Siskind, et al. (1980) during U.S. Bureau of Mines structure response research. The 100% confidence line was given as
$_{49\,.\,1}290\ _{-}= SD\ PPV$

- There are minor yet measurable influences of terrain that appear
to enhance averages of the ground vibrations in directions that align with ridge lines from the blast sites; however, the maxima of all three directions fall on the same upper bound.

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The attenuation or decrease in vibration amplitudes with distance in different directions is not statistically significant and does not warrant special regulatory consideration.

V
APPENDED NEW MATERIALS

X-Original-To: dowding@casbah.it.northwestern.edu
Delivered-To: dowding@casbah.it.northwestern.edu
X-Sender: cathya@sdc.org (Unverified)
X-Mailer: QUALCOMM Windows Eudora Version 5.2.0.9
Date: Sat, 06 Aug 2005 13:44:56 -0600
To: janedowding@yahoo.com
From: Cathy Aimone-Martin <cathy@aimonemartin.com>
Subject: items for Henderson review 0 more data to follow
Cc: c-dowding@northwestern.edu
X-Virus-Scanned: ClamAV version 0.86.2, clamav-milter version 0.86 on virgo.sdc.org

X-Virus-Status: Clean

Chuck:
I am answering the issues you want to address in your review herein. If I have missed anything, please indicate in writing. These issues are

1. calibration of seismographs (see file *calibration date.doc*)

2. problems with S2 sensors/seismograph 2279 in the structure at Big Horn (see files *one.jpg, Big Horn.xls*)
The one.jpg file is a screen capture of the seismograph report showing the cals for the shot on
3/16/05 at 13:52,

Most definitely the unit 2279 was inadvertently set on 1X gain (lowest velocity resolution is 0.01 ips) while the gain for the sensors were manufactured at 2X (lowest detected is 0.005 ips). Generally when this type of gain "mis-match" occurs with a traditional tri-axial geophone, the readings will shown two times larger than normal and the R, V, and T components will cal at ~ 1.0 ips rather than ~0.5 ips (or a 100% greater cal).

NOTE the airblast is not included in this as the gain is constant and will not be affected;
it always cals at ~1.0 units regardless of any gain mis-match to the transducers.

In this case, when using a tri-axial geophone, we simply divide the peak value reported and values for all time histories by 2 to obtain the adjusted (corrected) amplitudes (the same holds true for displacements).

However, for some reason the single-axis transducers show a cal at 50% greater rather than a 100% greater with the same gain mis-match. In other words, instead of a 0.5 ips cal, they show at 0.75 ips cal. Now if you look at the variation in the data (I took a random check though a few shots) I found the range to be 0.74 to 0.84 ips while it theory it should vary about 0.75 ips .

What I always do in these cases is to adjust the peaks reported and the time histories by a factor
equal to the following (using the data for 3/16)

	peak reported	cal	adjustment factor	reported in report (see spreadsheet)
R	0.22	0.8	0.625 = 0.5/0.8	0.136
V*	0.51	0.81	0.617	0.319
T	0.13	0.79	0.633	0.08

I most likely used a constant average factor for convenience

The V channel is connected to the mid-wall and reported under the mid-wall row in the excel spreadsheets

When I noted this a few years ago (during the OSM project when we learned to modify gains with Larry's DOS program) he indicated that ratioing the data by the cal assuming that the cals should read a perfect 0.5 ips, which they rarely do, is perfectly OK to find the approximated true amplitude values.

I make the gain errors infrequently but it happens I make the same type of corrections. I own a large number of 40 ips and 80 ips sensors I place close-in to shots and bury than behind the last row to obtain deep ground motions near the back break zones

This is a perfectly acceptable technique to find peaks when gain mis-matches occur, as agreed upon by the manufacturer of the seismographs.

3. Null gages response (see files *NULL COMPARISON.xls*, *Hcrack_dyn3_16b.xls*, *Wcrack_dyn3_16a.xls*)

Null gages responses were ignored after the effects of the null gage for the stucco cracks were found to be insignificant relative to the crack data alone. (No crack/null gages were placed where the sun could hit them at any time of the day.)

This was the case for static, long-term responses (shown in *NULL COMPARISON.xls*) and for dynamic, blast-induced responses (*Hcrack_dyn3_16b.xls* for house at High Mesa and *Wcrack_dyn3_16a.xls* for house at Big Horn as examples).

The null data was reduced and compared with the crack data for the early downloads. Subsequent data was downloaded but never converted and evaluated after the data up to the second download showed this insignificance. The additional time involved to include this data was not warranted for this level of non-academic study.

Please review the data for the selected files attached to observe the errors introduced by taking only the crack data and not subtracting the null data.

****

Are there any other outstanding issues that I can provide the data for?

Cathy

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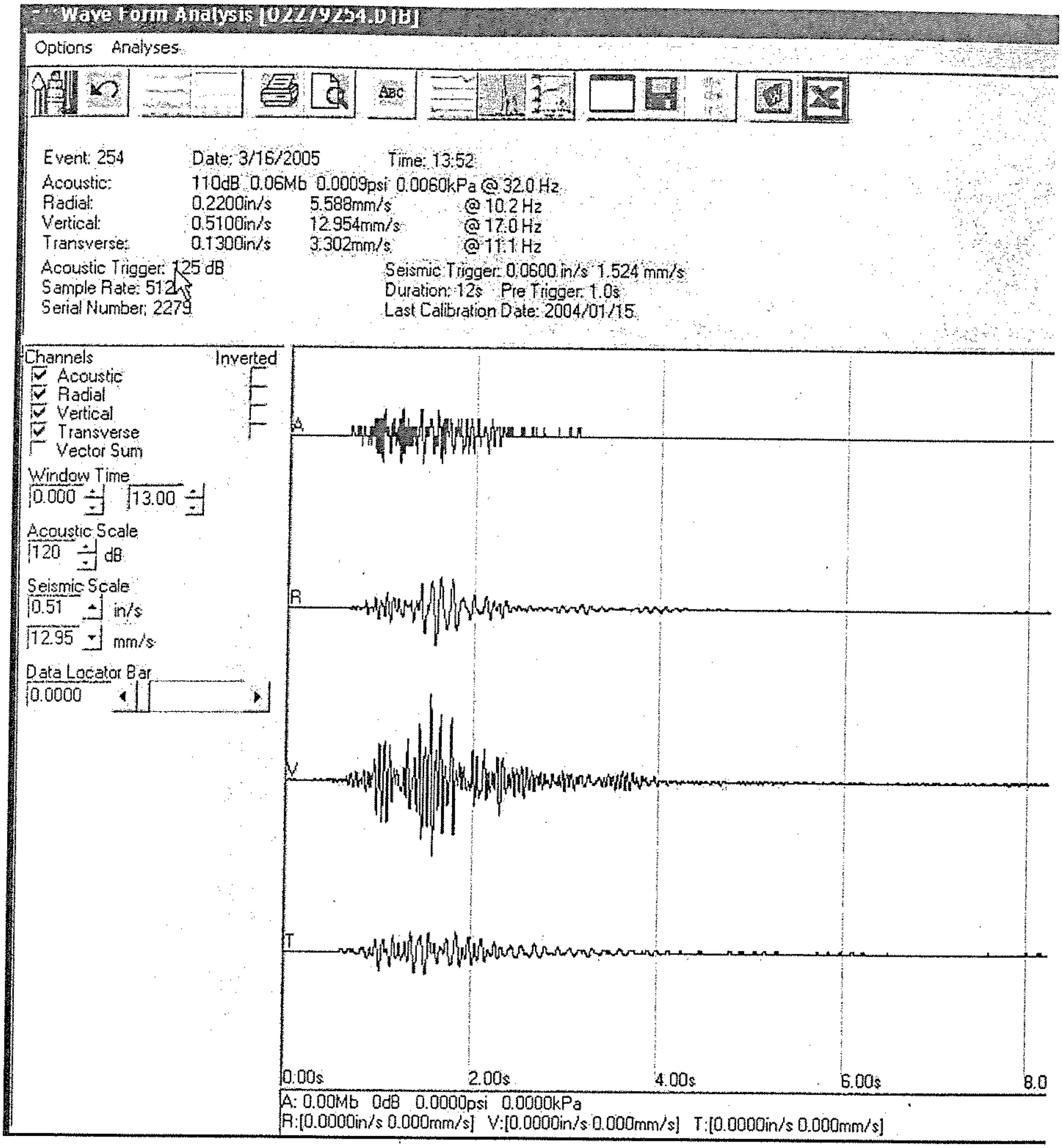
505-838-2229
505-980-9949 cell
505-835-3863 FAX

e-mail: cathy@aimonemartin.com
website: www.aimonemartin.com

Calibration date.doc



Event: 254 Date: 3/16/2005 Time: 13:52

Acoustic: 110dB 0.06Mb 0.0009psi 0.0060kPa @ 32.0 Hz

Radial: 0.2200in/s 5.588mm/s @ 10.2 Hz

Vertical: 0.5100in/s 12.954mm/s @ 17.0 Hz

Transverse: 0.1300in/s 3.302mm/s @ 11.1 Hz

Acoustic Trigger: 125 dB

Sample Rate: 512

Serial Number: 2279

Seismic Trigger: 0.0600 in/s 1.524 mm/s

Duration: 12s Pre Trigger: 1.0s

Last Calibration Date: 2004/01/15

Channels Inverted

☑ Acoustic ☐

☑ Radial ☐

☑ Vertical ☐

☑ Transverse ☐

☐ Vector Sum

Window Time 0.000 13.00

Acoustic Scale 120 dB

Seismic Scale 0.51 in/s 12.95 mm/s

Data Locator Bar 0.0000

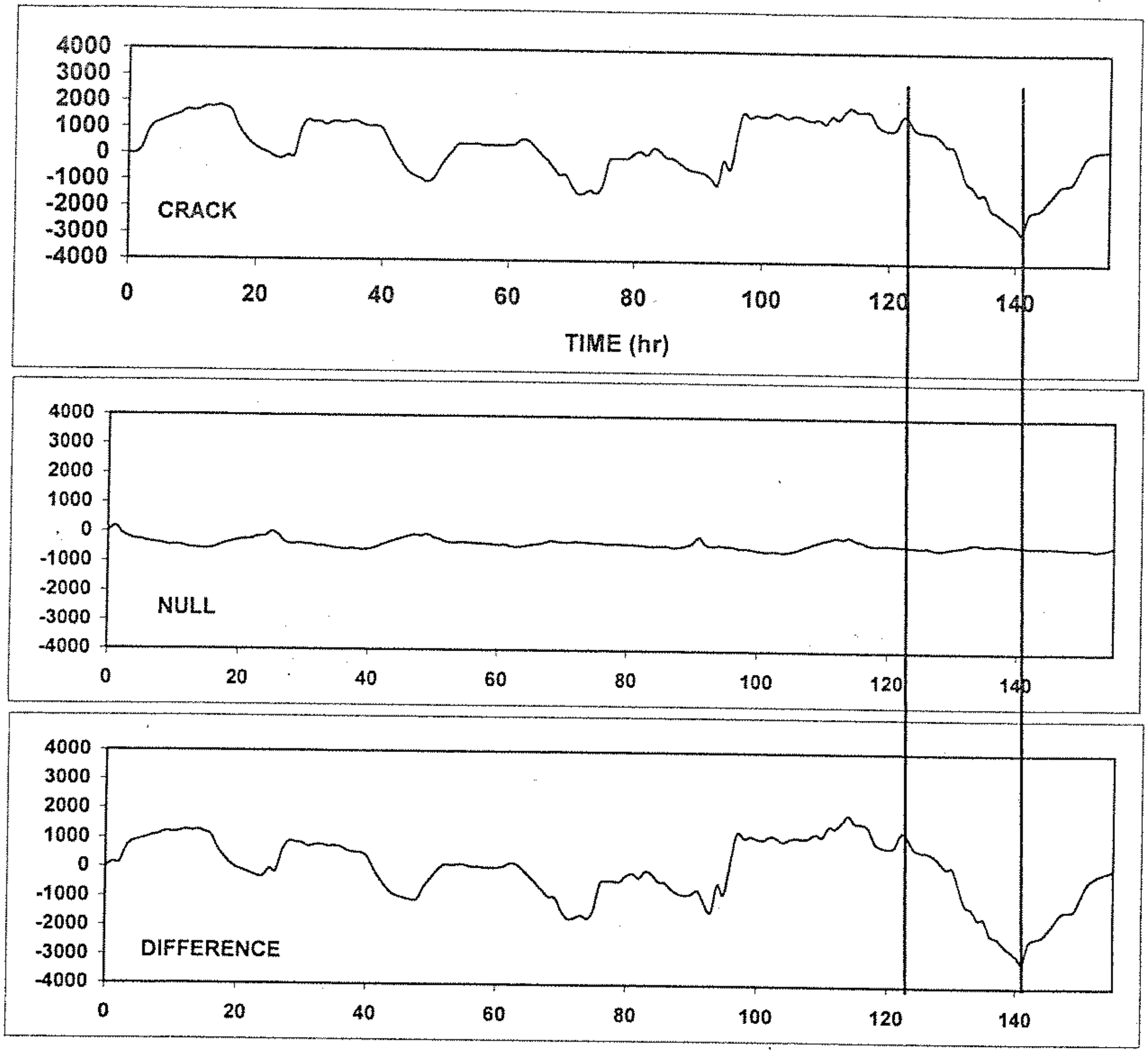
A: 0.00Mb 0dB 0.0000psi 0.0000kPa

R:[0.0000in/s 0.000mm/s] V:[0.0000in/s 0.000mm/s] T:[0.0000in/s 0.000mm/s]

one.jpg

Big Horn data.xls

NULL COMPARISON.xls

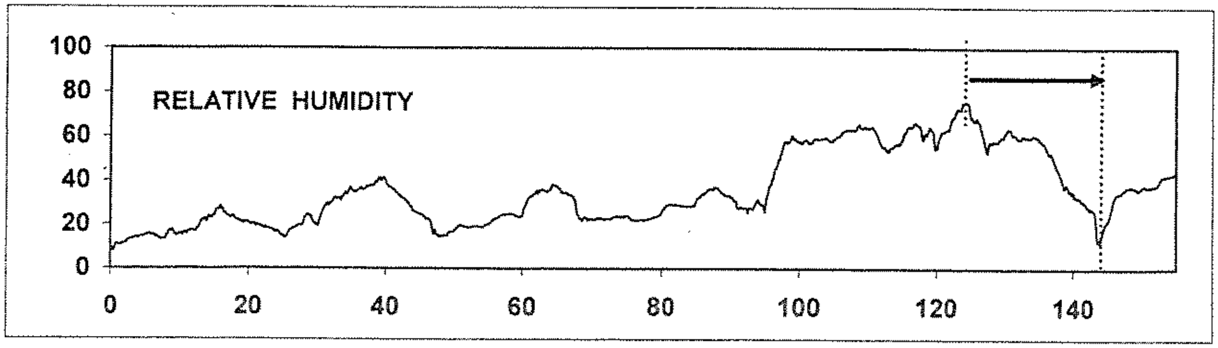


why using the null is insignficiant when crack response alone is very large:
Take the two times at 122 hr (blue line) and 141 hr (red line) where the crack is wide and the lowest.
Computing the overall difference that influences crack potential:
micro-inch absolute values are

	at 122 hr	at 141 hr	overall change due to humidity (see plot right)
crack	+1615.7	-2799.4	4415 micro-in
null	- 347	- 323	24
difference	+ 1268.4	-3122	4390.4

the error in estimating the largest variation in crack movement by considering only the crack alone and ignoring the null gage data over this time period is

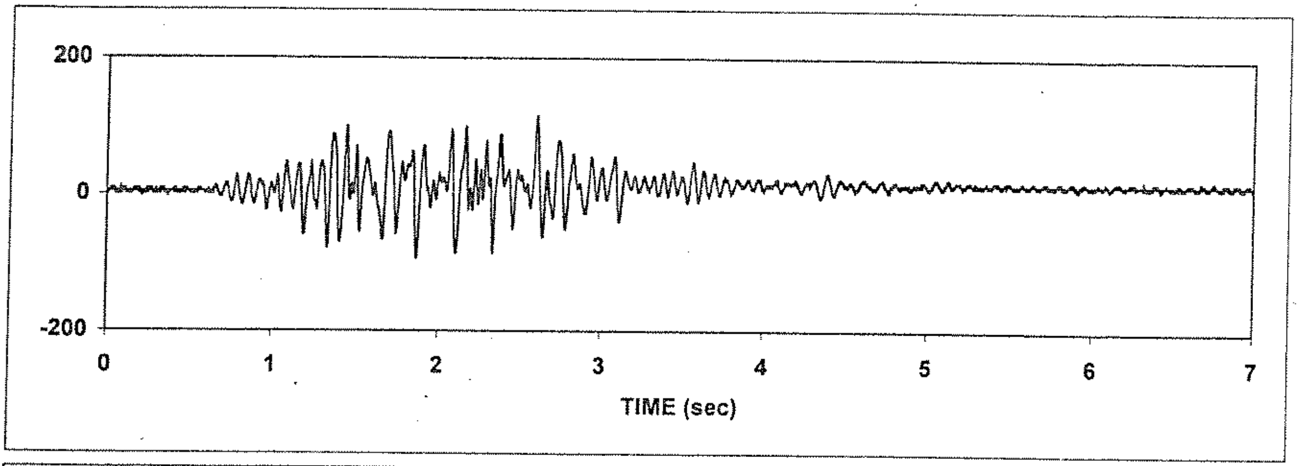
4415-4390.4 = +35 mico-inch error (overestimating +opening) or +35/4380 = +0.8% error
or -35/4415 = -0.8% error (which ever way you want to look at the error)

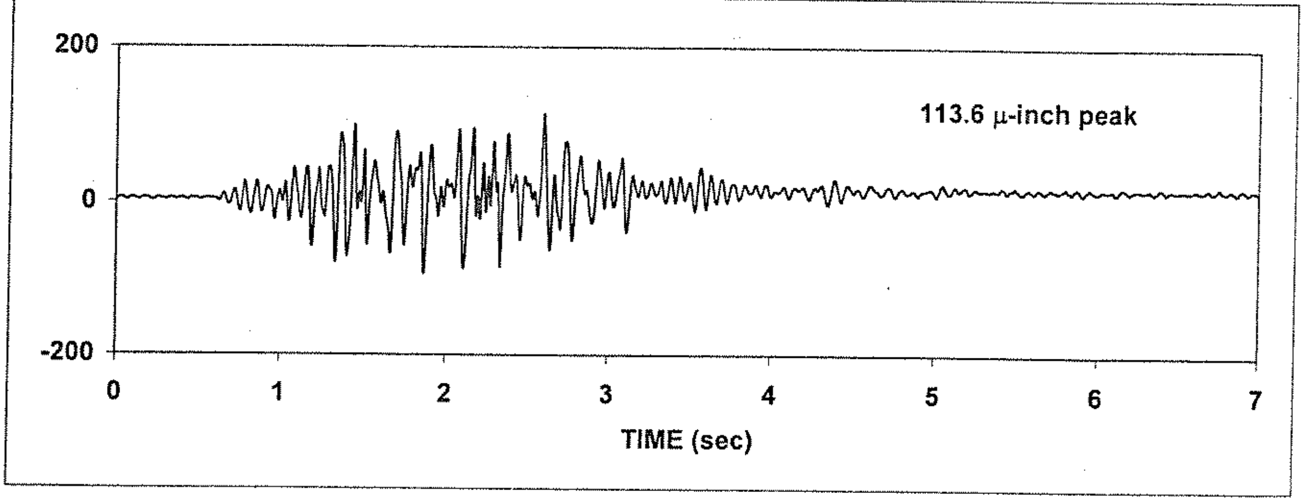


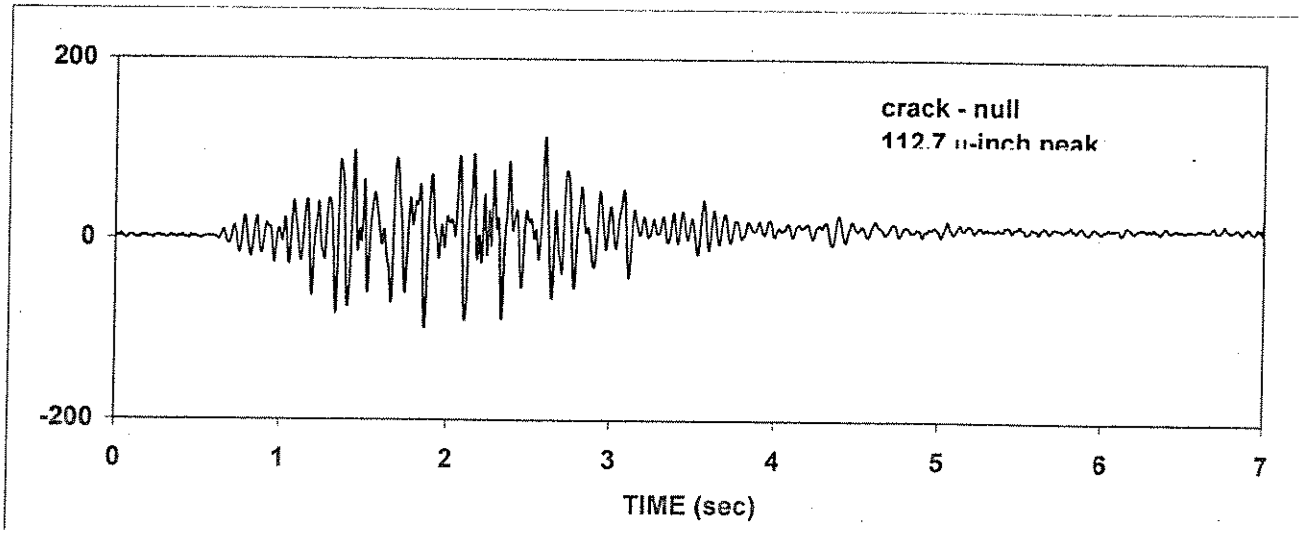
At 124 hours, highest humity and at 144 hours, lowest humidity over which time the crack, being wide open, then proceeded to close

SN:S0020701-01-01
System Model:SMU9000-2U

crack gage 3	crack-null
MAX	
113.63975	112.73595
-94.40686	-98.75998

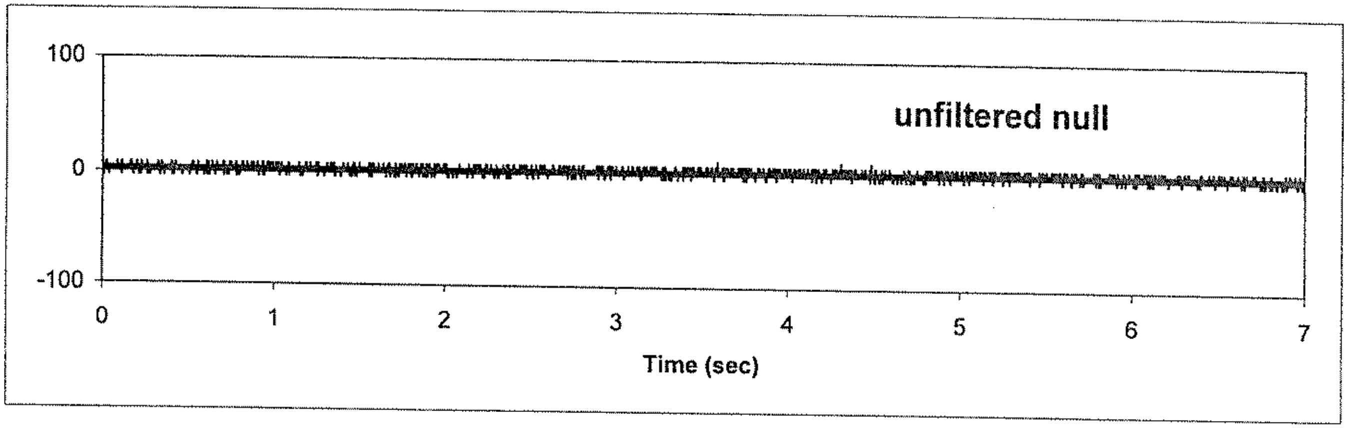


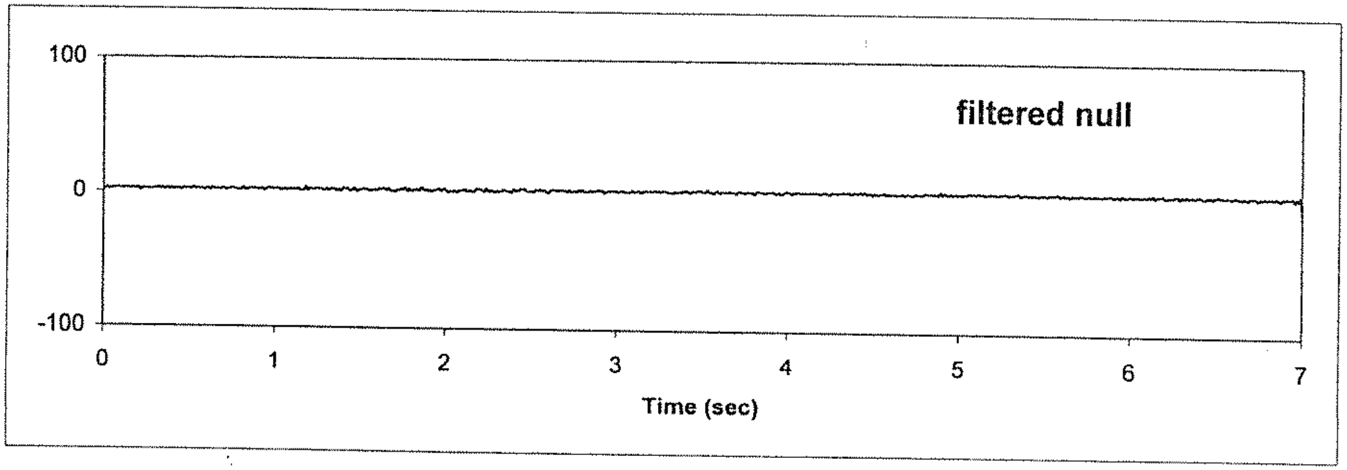


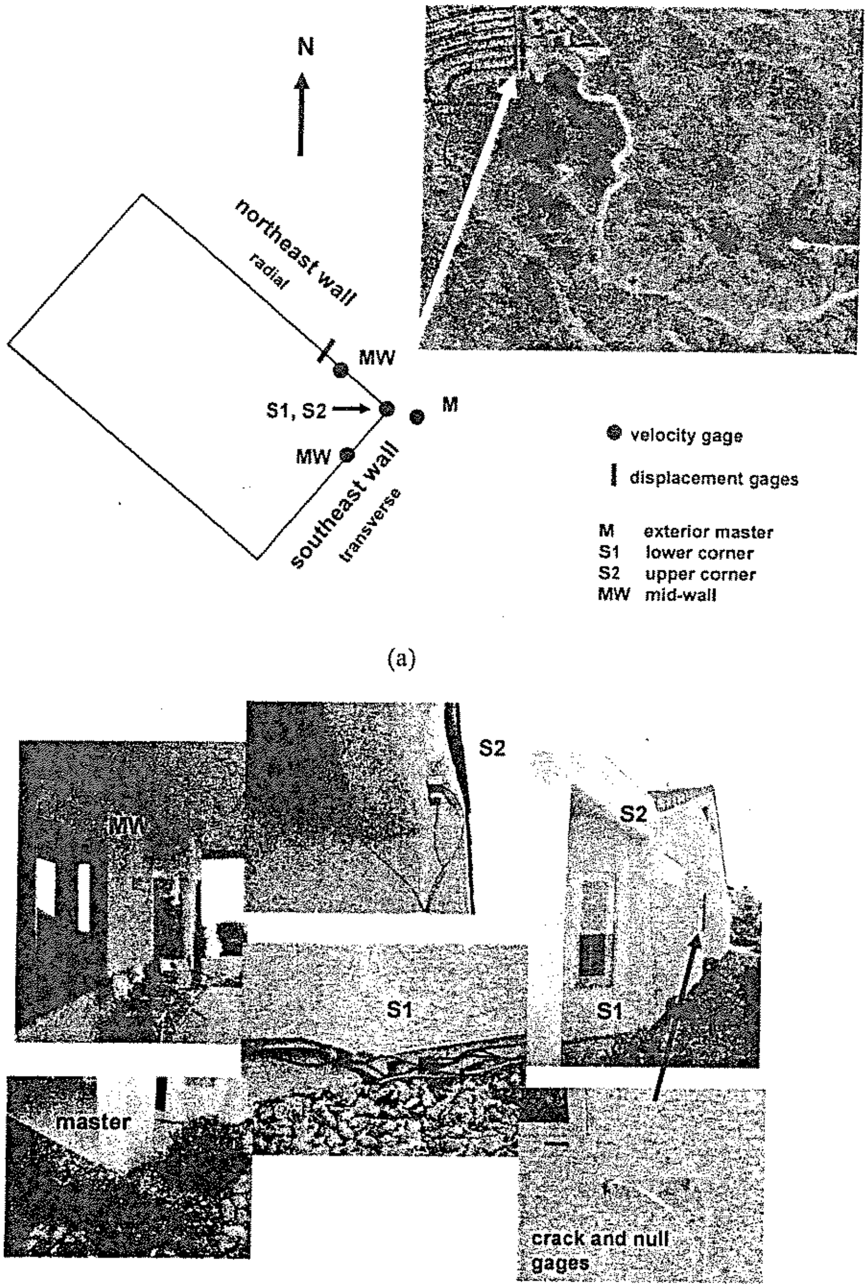


SN:S0020701-01-02
System Model:SMU9000-2U

Null gage 4
MAX
4.53611



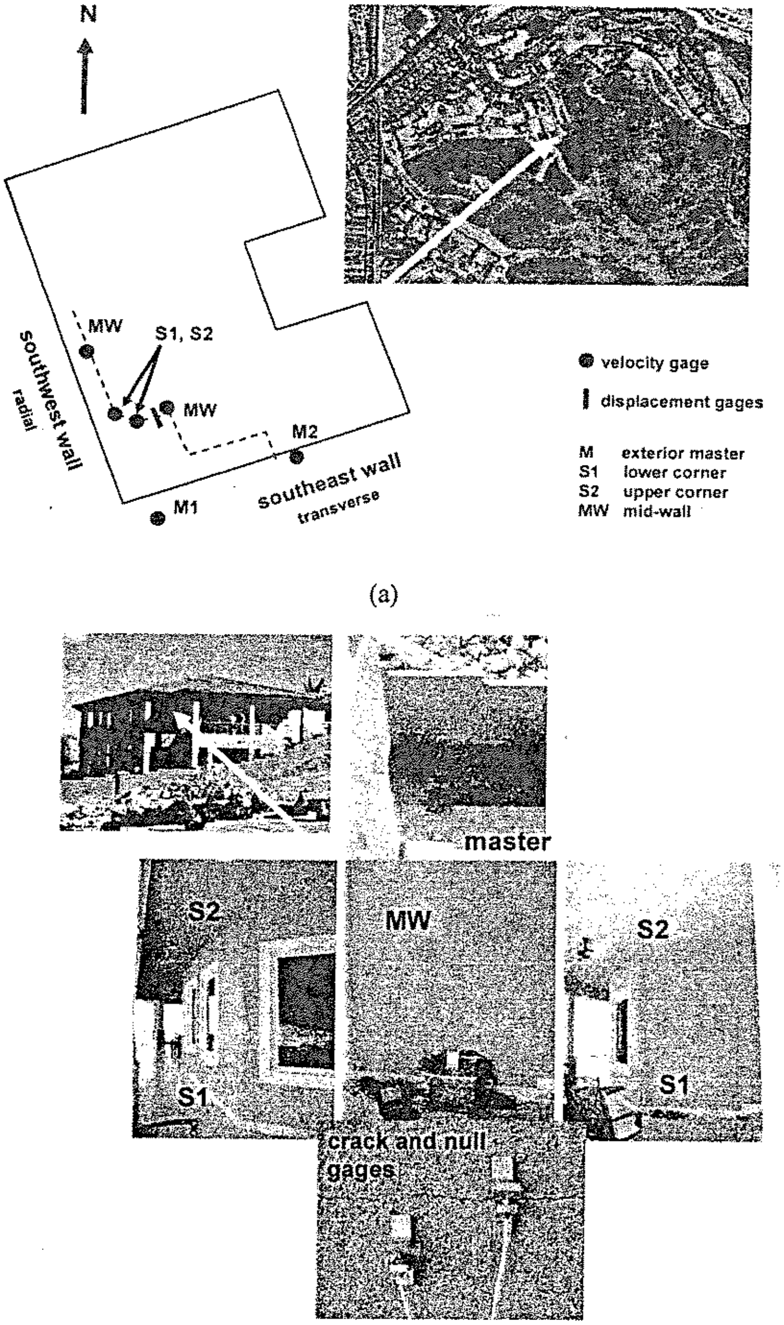




(a)

(b)

Figure 2 Structure outline showing locations of instrumentation (a) and photographs detailing Instrumentation (b)



(a)

(b)

Figure 3 Structure outline showing locations of instrumentation (a) and photographs detailing Instrumentation (b)

To: Charles Dowding <c-dowding@northwestern.edu>
From: Cathy Aimone-Martin <cathy@aimonemartin.com>
Subject: more info

Here is more information

1. P as a function of wind speed
There is no direct relations between Pressure and wind speed and building codes use all type of approaches.
I calculated P directly from wind speed as is done for most codes: the relationship between the velocity or "stagnation" pressure, P (kN/m^2) and the basic wind speed, V (km/h), measured 10 meters above grade in open terrain, can be derived from Bernoulli's equation for streamline flow:

$P = 0.5\ p\ V^2$

where p is the mass density of air. Making some assumptions about air temperature to calculate p, and converting the units to kN/m^2 for P and km/h for V, we get:

$P = 0.0000474\ K(V)^2$

where K accounts for heights above ground different from 10 meters as well as different "boundary layer" conditions, or exposures, at the site of the structure.

At a height 10 meter above grade in open terrain, $K = 1.0$

I used a web-based calcualtor to do this and I found the following to be useful: http://www.cactus2000.de/uk/unit/masswsp.shtml

I know that this is only an approximation but I felt it was acceptable for this application.

2. The use of 512 samples per second to record far-field ground and structure motions

THERE IS NOTHING IN THE 1999 SEISMOGRAPH GUIDELINE THAT SPECIFIES ONE MUST USE 1024 SAMPLE PER SECOND FOR ANY APPLICATION. So I am not sure why you say that I must use 1024. My study does not contradict any guidelines that I am aware of. Please review these guideline and let me know where you read this.

reasoning:
I used 512 sample per second as the seismographs that I own do not have sufficient memory to allow 1024 sample with over 9 seconds of recording time (actually 8.5 sec. at 1024 as 0.5 sec is reserved for the pre-trigger buffer). I wanted to ensure that I recorded the full time histories of both the ground and air pressure traces, particular for blasts at long distances to the structures. I did not want to miss any data and therefore used the 512 setting as I normally do for structure response studies such at this.