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Report

To: Mr. Tom Maul

EOG Resources, Inc.

S & S Mine

Chippewa County, WI

Date: December 18, 2014

Subject: Blast Damage Complaint Investigation

Ed Dachel Residence

5585 County Highway B

Chippewa Falls, WI 54729

PURPOSE

The purpose of this report is to determine whether the blasting activity at the EOG Resources S & S Mine in Chippewa County, Wisconsin may have caused or contributed to the alleged blast damage claimed by the property owner. Mr. Ed Dachel, who resides at 5585 County Highway B, Chippewa Falls, Wisconsin 54729, has claimed repeatedly since the mine opened in 2011 that the blasting activity at the mine has caused damages to his home.

PROCEDURE

All available seismic recordings and blasting logs for the blasting activity at the S & S Mine were obtained from EOG Resources or Olson Explosives, which is the blasting company for the mine. The first blast at the S & S Mine occurred on October 7, 2011. Since the beginning of blasting operations at the mine there have been a total of 86 blasts through April 21, 2014. During every blast a portable seismograph was set up at the Dachel residence by Olson Explosives personnel. The GPS location of each blast was noted on the blasting logs and the distances to the Dachel residence have been verified by the author through Google Earth software. Additional information that was documented on the blasting logs, such as the maximum amount of explosive per 8-ms delay interval has been utilized for the purposes of this report.

Three reports that were prepared by Ayres Associates have been made available to the author and have been reviewed. The first report was completed in June 2011. The purpose of this report was to document the existing conditions of the Dachel residence prior to the beginning of blasting activity at the S & S Mine. The second report was completed in November 2011 following the beginning of blasting activities. This report discusses the blasting activities through November 17, 2011 and examines alleged blasting damages claimed by Mr. Dachel. The third report was completed in August 2013 and again examines alleged blasting damages claimed by Mr. Dachel. There were no damages that were attributed to blasting in any of the reports that were prepared by Ayers Associates.

NATURE of the CLAIM

It must be noted that Mr. Dachel did not allow access to his property in order for the author to inspect the alleged damages for the purposes of this report.

Based upon the Ayers Associates reports from November 2011 and August 2013 it appears that the alleged damages are of the following nature:

- Cracks and settlement in the poured concrete floor slabs in the basement of the home, garage and all outbuildings on the Dachel property.

- Cracks in the joints of the concrete block masonry foundation of the home that are visible in the basement and on the exterior foundation of the home.
- Cracks in the joints of the concrete block masonry walls of both garages.
- Drywall crack in the ceiling of the home where the dining room meets the hallway.
- Drywall damage above the bedroom door near the NE corner of the home.

FACTS of the CASE

The Dachel residence is located at 5585 County Highway B in Chippewa Falls, Wisconsin. It is a one-story ranch home with a basement and an attached two-car garage. On the property there is also a storage shed and a second two-car garage that are both detached from the home. The interior construction of the home appears to be drywall with a concrete block foundation. The shed and garages appear to sit on poured concrete slab floors. The walls of the garages are partially constructed of concrete block masonry. Figure 1 below shows a Google Street View photo of the Dachel property.

Figure 1: Google Earth™ Street View Photo of 5585 County Highway B

During the time period of October 7, 2011 through April 21, 2014 a total of 86 blasts were detonated at the S & S Mine. A portable seismograph was set up in the vicinity of the claimant's property for all 86 of the blasts. The monitoring was conducted by Olson Explosives personnel with a portable seismograph that was placed near the northeast corner of the main house at the Dachel residence.

According to the blast logs that were provided by Olson Explosives the maximum pounds of explosives per 8-ms delay at the S & S Mine ranged between 35 and 942 pounds during all 86 blasts that have occurred over this time period.

The aerial image shown in Figure 2 shows the Dachel property as well as the seismograph monitoring location and the location of the closest blast that has occurred at the S & S Mine. The distance from the Dachel property to the closest blasting location was at least 1,500 feet to the northwest.

Figure 2: Dachel Residence in Relation to Closest Blasting Activity

GROUND VIBRATION and AIR OVERPRESSURE DAMAGE CRITERIA

Seismological research by the U.S. Bureau of Mines, foreign investigative groups and individual seismologists has established criteria relating the occurrence of structural damage to certain frequencies and levels of ground motion.

USBM Report of Investigations 8507[1] states that residential structures are most prone to damage as a result of vibration energy within the frequency range of 4-12 hertz. Within this range a 0.50 inch-per-second maximum particle velocity is recommended for the protection of plaster on lath interior construction. A maximum particle velocity of 0.75 inch-per-second is recommended for the protection of modern drywall interior construction. Above 12 hertz the maximum particle velocity limit increases as the frequency increases up to 40 hertz. Above 40 hertz, a constant 2.0 inches-per-second level is recommended to protect interior walls and ceilings of structures. Figure 3 is a graphical representation of the USBM recommended criteria as shown in the velocity versus frequency curve.

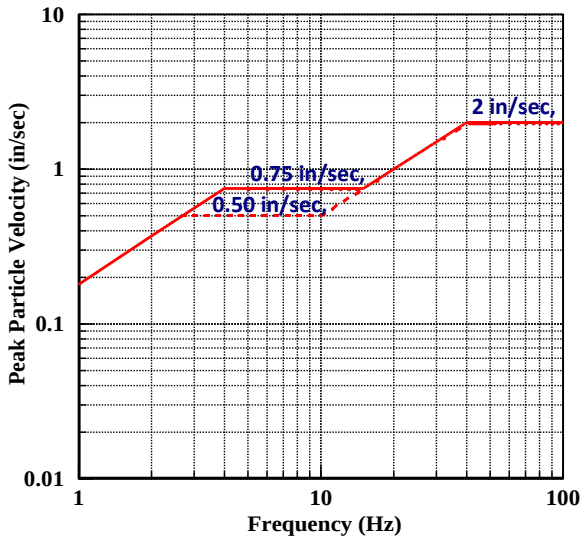

Figure 3: U.S. Bureau of Mines Recommended Vibration Criteria (From RI-8507)

The limits cited above are designed to prevent the occurrence of even threshold damage to the most brittle portions of a structure. More massive materials such as brick and mortar can withstand vibrations greater than 2.0 inches-per-second. A study by Crawford and Ward[2] established the threshold level of damage to be 3.0 inches-per-second for masonry walls regardless of type. Far greater velocities would be required to damage poured concrete. Motion on the order of 10 inches-per-second would be required before blasting vibrations could be considered responsible. Therefore, a conservative vibration limit for building elements such as poured concrete foundations and slab floors is generally accepted as being 10.0 in/sec.

In conjunction with the ground vibration recording, peak air overpressure was also monitored. Structural damage as a result of air overpressure is generally considered not to be possible without extensive window breakage, as the glass is the weakest portion of a structure's exterior where this

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1 Siskind, David et al, Structure Response and Damage Produced by the Ground Vibration from Blasting, U.S. Bureau of Mines RI 8507, 1980.

2 Crawford, R., and H.S. Ward, Dynamic Strains in Concrete and Masonry Walls, National Research Council of Canada, Note 54, December 1965.

pressure acts. Windowpanes are designed to safely withstand changes of 1.0 psi (170 dB) when properly installed, and even in the worst situation a pane should be able to withstand 0.1 lbs/in (150 dB). Air overpressures from blasting rarely exceed 0.01 psi. (130 dB), about one one-hundredth of the overpressure that a window can safely withstand.

The U.S. Bureau of Mines has concluded in its Report of Investigations RI 8485[3] based on a minimal probability of the most superficial type of damage in a residential-type structure that 133 dB(L) represents a safe maximum air overpressure level for a 2 Hz High-Pass system.

RESEARCH on REPEATED VIBRATIONS from RI-8896

In 1984, the USBM published RI-8896 entitled, "Effects of Repeated Blasting on a Wood Frame House". This study was the first to document long term strain response on a house. Strain is an engineering measure of deformation used to predict failure. A strain of 1 mil/in indicates that on average, every inch of a material was stretched or compressed one thousandth of an inch. For example, the length of an eight foot long section of wallboard would change by approximately $\pm$ 0.1 in. Long-term strain measurements allowed blast-induced strains to be compared with those produced by changes in environmental factors such as temperature, humidity, and human activity.

During this study the Bureau arranged to have a wood-frame test house built in the path of an advancing surface coal mine so that the effects of repeated blasting on a residential house could be studied. In a two-year test period 587 production blasts were fired with peak particle velocities ranging from 0.10 in/sec to 6.94 in/sec. Later the entire house was shaken mechanically to produce fatigue cracking in walls. The first crack appeared in a drywall tape joint after the equivalent of 56,000 cycles. This is the equivalent of 28 years of shaking by blast-induced ground motions of 0.50 in/sec twice a day.

HUMAN PERCEPTIBILITY to VIBRATIONS

The objective of this section of the report is to show that human perception to low levels of vibration is extremely sensitive. As evidence in the graph below, thresholds of human perception to vibrations can be as low as 0.01 in/sec, well below any criteria for structural damage. Because of this great human subjectivity, complaints cannot be totally eliminated. Discernible vibrations however, are by no means criteria for possibility of structural damage.

The startling effect of blast vibrations must not be underestimated when considering human tolerance to vibration in their homes. Often seismographs are used to perform field demonstrations for concerned residents in their homes. The vibrations produced by normal household activity are measured within a residence and compared to the levels resulting from blasting/construction activities. Normal household

[3] Siskind, David et al, Structure Response and Damage Produced by Airblast from Surface Mining, U.S. Bureau of Mines, RI 8485, 1980.

vibration levels frequently exceed those produced by blasting/construction activities by several times. But when the vibration source is familiar, and the vibrations are expected, as with most common household vibrations, people are much less alarmed than when ground vibrations from blasting/construction activities arrive unexpectedly. Human tolerance to vibration decreased not only when it occurs within their homes, but also when the cause of the vibration is not readily apparent or anticipated. Human reaction is dependent on the vibration and amplitude of the vibration event, as well as innumerable other factors beyond the operator's control.

The majority of the studies done on human tolerance to vibrations have been of steady-state sources, meaning that the amplitude and frequency content of the energy source remain constant over the test period. This type of testing usually results in an event of relatively longer duration than a typical mine or quarry blast event. Since the vibration limits in the following studies require a reasonable level of comfort from long-term vibration sources; they are certainly more restrictive than for sources of short duration and infrequent occurrence such as blasting.

Figure 4 is the compilation of two different studies on human response to steady-state and transient vibrations. The first study denoted on the graph by response levels, represented by the solid line, was completed by Reiher and Meister in 1931. In this study 15 people were subjected to 5-minute duration vertical and horizontal vibrations in a variety of body positions. The study established the threshold levels of subjective human response as defined by three categories. The threshold levels were described as "Barely Noticeable, Objectionable, and Uncomfortable".

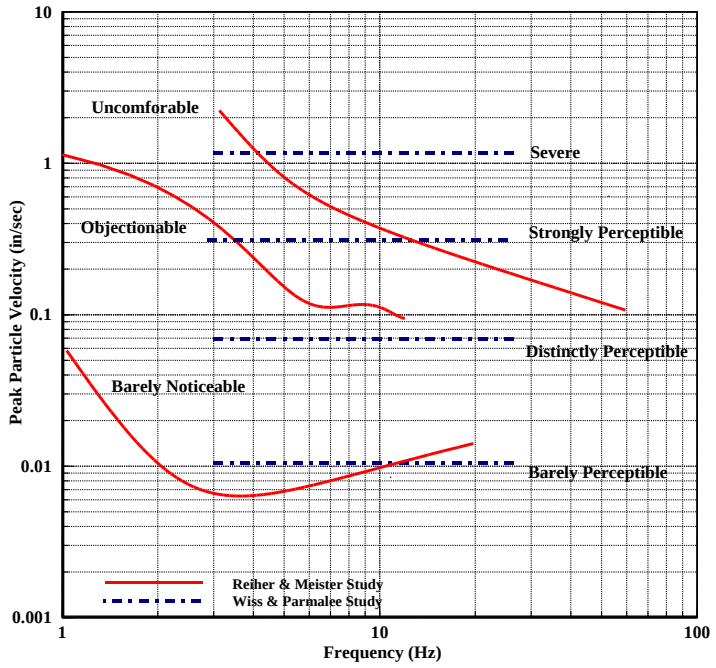


Figure 4: Human Response to Steady-State and Transient Vibrations

These levels were comparable to subjective responses in a second study completed by Wiss and Parmelee in 1974. The Wiss and Parmelee threshold levels of subjective human response are denoted by response levels represented by the dashed line in Figure 4. Four thresholds of subjective human response to vibration were categorized and are described as "Barely Perceptible, Distinctly Perceptible, Strongly Perceptible, and Severe". In this study, the responses of 40 people to transient vibrations consisting of damped 5-second sinusoidal pulses between the frequencies of 2.5 to 25 Hertz (Hz) were observed. All subjects were standing on an open platform and subjected to vertical vibrations. The study found that responses depended on vibration levels and damping, but were independent of frequency.

DISCUSSION of the CLAIM

The peak particle velocity recording at the Dachel residence was 0.515 in/sec at 37.0 hertz, which occurred on April 21, 2014 at 10:18am. This peak value was only 27.8% of the USBM RI-8507 recommended limit for the protection of drywall. This blasting event was located in the area of the mine that is closest to the Dachel residence and was the fourth overall closest blast. All other ground vibration recordings at the Dachel residence were significantly less than this peak event. In fact, the next highest ground vibration recording was 0.250 in/sec at 23.0 hertz, which occurred on April 9, 2014 at 10:36am during the closest blast to the Dachel residence. Additionally, a total of 38 of the blasts did not trigger the seismograph. This indicates that for 44% of the blasts at the S & S Mine the ground vibration level at the Dachel residence was less than the trigger level of 0.04 in/sec that was programmed in the seismograph.

The highest air overpressure recording at the Dachel residence was 127 dB(L), which occurred on February 18, 2013 at 12:45pm. All other air overpressure recordings were below these levels. Therefore, none of the air blasts that were recorded during the blasting on this project exceeded the USBM RI-8485 safe maximum air overpressure level of 133 dB(L).

A table containing all of the data obtained from the blasting and seismic recordings for the S & S Mine at the Dachel residence has been included at the end of this report. Also, a graph of all peak particle velocities with relation to frequency and compared to the recommended USBM damage threshold limit for drywall is shown below in Figure 5.

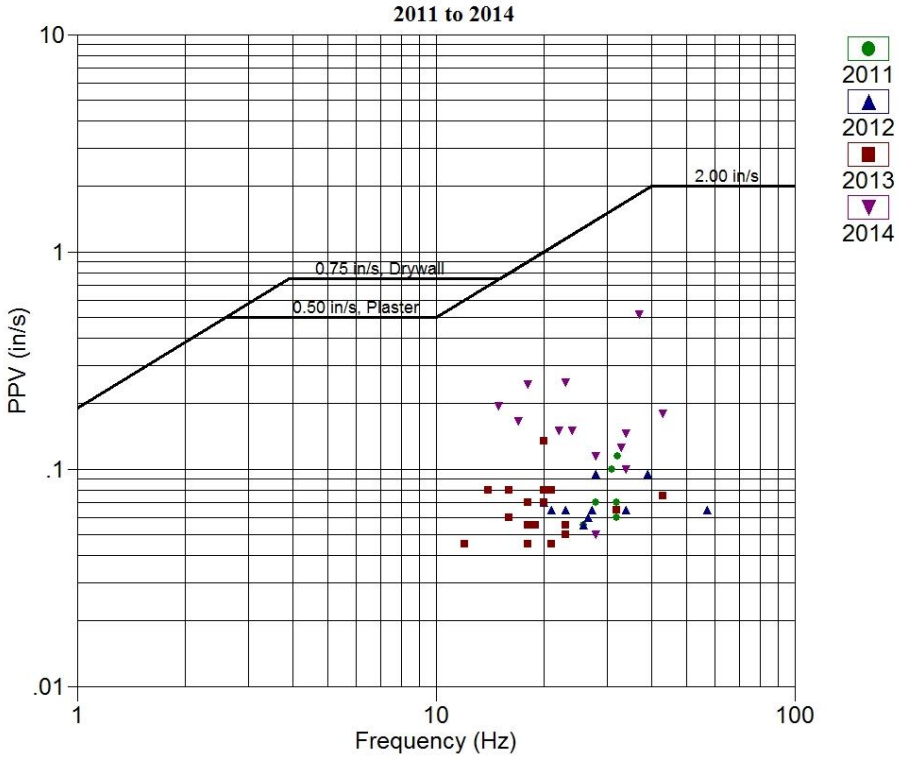


Figure 5: Seismic Data Plot Compared to USBM RI-8507

Additionally, the International Society of Explosive Engineers Blasters' Handbook[4] provides in chapter 38 a power law equation which may be used to estimate ground vibrations from blasting. The equation is very conservative, and most often overestimates the vibration level, meaning that actual vibrations are almost always less than those predicted by the formula. The equation is as follows:

$$V=K\left(D / W^{0.5} \right)^{-1.6}$$

Where

V = peak particle velocity in inches per second
K = numeric constant corresponding to blast confinement
D = distance between explosion and recording site in feet
W = maximum pounds-per-delay-period of 8ms or more

Using a K value of 242, which is the upper bound for typical downhole blasting, along with data obtained from the blasting logs and a worst-case scenario of maximum pounds of 942 at a distance of 1,500 feet we get the following:

$$V = 242\left(1500 / 942^{0.5} \right)^{-1.6} = 0.480 \text{ in/sec}$$

This means that if the maximum pounds per delay of 942, which is the most that was ever recorded at the S & S Mine, was utilized at the closest blasting location then there is a 90% probability that the ground vibration magnitude at the Dachel property would be no greater than 0.480 in/sec. Even if one assumes that the frequency content of this theoretical blasting event would be in the most restrictive range this vibration level is still only 64% of the USBM RI-8507 recommended limit for the protection of drywall.

As discussed earlier in this report the drywall in any home is the most susceptible material to damage from blasting vibration. Therefore, since the blasting records and the predicted vibration levels at the Dachel residence indicate compliance with the recommended limits for the protection of drywall then the blasting records would also be well below the recommended limits for the protection of other construction materials such as concrete block masonry and concrete floor slabs.

COMMENTS

It is not unusual to receive complaints as a result of blasting operations. Vibra-Tech's experience indicates that complaints can be attributed to one or a combination of the following:

1) Vibrations of the magnitude generated at the S & S Mine are perceptible. The human body can sense particle velocities as low as or lower than 0.02 in/sec. The degree of perceptibility, however, is not a reliable indication of whether or not vibration damage is possible or likely.

[4] ISEE, Blaster's Handbook, 18th Edition, 2011, pp.567.

2) Air-borne concussion and associated noise can be quite startling, especially when unexpected, and concussion as well as ground vibration can cause perceptible motion within buildings. Unless the concussion is sufficient to produce extensive window breakage other concussion damage to buildings is not possible.

3) The Department of the Interior, Bureau of Mines, has published a list of forty causes of cracks in masonry, plastered ceilings and walls that are related to construction and design practices found in many homes[5]. Twenty additional common reasons for cracks in residential properties were published by Oriard[6]. Very often the homeowner is unaware of these factors and the defects which they create until an unusual event (explosion, sonic boom, thunderstorm, etc.) draws attention to them, whereby the assumption is made that the defects which are discovered are caused by these events.

CONCLUSION

It is Vibra-Tech's professional opinion that vibrations from blasting at the S & S Mine could not have caused nor contributed to any of the alleged damages at the Dachel property. This conclusion is based upon the following:

1) The USBM RI-8507 recommended limits for the protection of drywall were never exceeded at the seismograph that was installed in the vicinity of the Dachel residence for every blast. Therefore, vibrations from blasting at the S & S Mine could not have caused any damages to the drywall construction of the Dachel residence.

2) The vibration prediction formula that is used to analyze a worst-case scenario for the blasting at the S & S Mine calculates a 90% probability value for the ground vibrations at the Dachel property that is well below the USBM RI-8507 recommended limits for the protection of drywall.

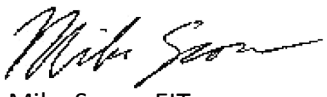
3) It has been well established by numerous studies that masonry and poured concrete construction are far less susceptible to blast vibration damage than interior drywall construction. Therefore, vibrations from blasting at the S & S Mine could not have caused any damages to the concrete block masonry or poured concrete floor slabs of the Dachel home or outbuildings.

4) Because the drywall is the weakest portion of any structure, if the blasting were responsible for any concrete block masonry or poured concrete damages then there

[5] The Small Home, Forty Reasons Why Walls and Ceilings Crack, Vol 4, No. 8, 1925.
[6] Oriard, L.L., The Effects of Vibrations and Environmental Forces, International Society of Explosives Engineers, 1999.

would have been significant drywall damages in the home, which apparently there are not. Vibrations of the magnitude that would have been necessary to cause the alleged damages to the concrete block masonry and poured concrete floor slabs would have resulted in the Dachel home and outbuildings being left in far worse condition than they appear to be now.

Sincerely,
Vibra-Tech, Inc.



Mike Spors, EIT
Area Manager

It must be noted that Mr. Dachel did not allow access to his property in order for the author to inspect the alleged damages for the purposes of this report. All opinions expressed in this report are based upon a reasonable degree of engineering certainty and only upon the information that was made available to the author.

Vibra-Tech Engineers, Inc. shall not be liable for any claims of tangible property damage where such damage is not solely, directly, and physically caused by Vibra-Tech Engineers, Inc. Additionally, Vibra-Tech Engineers, Inc. shall not be liable, in whole or in part, for any claims of tangible property damage brought by or on behalf of third-party claims.

APPENDIX

Vibra-Tech Seismic Analysis

EOG Resources - S & S Mine - Dachel Residence

	Date	Time	Distance	Comment	PPV Max	FREQ Max	DB	Max Lbs
1	10/07/2011	13:08:00	2144.000		0.115	32.200	106	182
2	10/12/2011	12:17:00	2210.000		0.070	27.900	103	160
3	10/27/2011	12:36:00	2236.000		0.055	25.800	114	282
4	10/31/2011	11:30:00	2149.000	No Trigger				35
5	11/11/2011	12:18:00	2337.000		0.070	32.000	103	130
6	11/17/2011	12:54:00	2395.000		0.060	32.000	110	168
7	12/06/2011	11:22:00	2378.000		0.100	31.000	115	202
8	12/22/2011	10:30:00	2458.000		0.055	25.800	117	214
9	01/13/2012	12:38:00	2466.000		0.095	28.000	123	414
10	01/20/2012	11:26:00	2552.000		0.060	26.600	119	252
11	01/31/2012	11:15:00	2450.000		0.065	27.300	119	220
12	02/07/2012	11:03:00	2529.000		0.055	25.800	113	250
13	02/21/2012	12:14:00	2542.000		0.065	21.000	121	430
14	02/24/2012	10:35:00	2519.000		0.070	20.000	118	202
15	03/06/2012	11:31:00	2649.000		0.065	57.000	114	350
16	12/14/2012	11:27:00	2461.000		0.095	39.000	118	285
17	12/21/2012	11:29:00	2696.000		0.065	34.000	122	390
18	12/28/2012	10:45:00	2649.000		0.065	23.000	120	500
19	01/07/2013	10:07:00	2696.000		0.055	23.000	119	490
20	01/14/2013	10:56:00	2684.000		0.045	12.000	124	460
21	01/18/2013	11:48:00	2688.000		0.070	18.000	116	630
22	01/30/2013	11:51:00	2347.000		0.075	43.000	116	260
23	02/06/2013	11:12:00	2301.000		0.065	32.000	114	390
24	02/11/2013	10:02:00	2787.000		0.060	16.000	119	670
25	02/18/2013	12:50:00	2812.000		0.055	18.000	121	660
26	02/18/2013	12:45:00	2232.000		0.080	21.000	127	470
27	02/25/2013	13:30:00	2830.000	No Trigger				295
28	03/01/2013	10:04:00	2858.000		0.070	20.000	123	942
29	03/04/2013	10:30:00	2910.000		0.045	21.000	120	720
30	03/11/2013	15:25:00	2936.000		0.080	20.000	126	768
31	03/12/2013	11:06:00	2204.000		0.080	16.000	109	450
32	03/15/2013	10:57:00	2942.000		0.080	14.000	121	685
33	03/26/2013	10:37:00	3030.000		0.050	23.000	124	600
34	04/02/2013	10:04:00	3024.000		0.045	18.000	119	690
35	04/05/2013	11:13:00	3047.000		0.055	19.000	120	660
36	04/15/2013	11:04:00	2842.000		0.055	19.000	115	225
37	12/26/2013	10:45:00	2175.000		0.135	20.000	114	384
38	12/26/2013	10:36:00	3046.000	No Trigger				80
39	01/03/2014	11:24:00	3126.000	No Trigger				120
40	01/10/2014	11:35:00	2094.000		0.125	32.900	114	330
41	01/13/2014	11:48:00	3062.000	No Trigger				200
42	01/16/2014	10:41:00	2785.000	No Trigger				242
43	01/17/2014	10:45:00	2100.000		0.180	43.000	121	300
44	01/22/2014	10:57:00	2855.000	No Trigger				228
45	01/29/2014	14:53:00	2066.000		0.100	34.000	110	514
46	01/29/2014	14:45:00	3058.000	No Trigger				138
47	01/30/2014	10:00:00	3527.000	No Trigger				66
48	02/04/2014	10:28:00	2855.000	No Trigger				200
49	02/05/2014	10:39:00	3576.000	No Trigger				80
50	02/10/2014	11:16:00	3150.000	No Trigger				210
51	02/10/2014	11:10:00	2178.000		0.165	17.000	116	312
52	02/13/2014	10:51:00	3089.000	No Trigger				180
53	02/18/2014	13:24:00	3419.000	No Trigger				100
54	02/18/2014	12:48:00	3190.000	No Trigger				196

Vibra-Tech Seismic Analysis

EOG Resources - S & S Mine - Dachel Residence

	Date	Time	Distance	Comment	PPV Max	FREQ Max	DB	Max Lbs
55	02/19/2014	10:50:00	2066.000	No Trigger				400
56	02/25/2014	10:00:00	3566.000	No Trigger				210
57	03/05/2014	10:02:00	3563.000	No Trigger				380
58	03/06/2014	10:58:00	3250.000	No Trigger				330
59	03/07/2014	10:04:00	1978.000		0.195	15.000	113	320
60	03/08/2014	10:01:00	3207.000	No Trigger				200
61	03/11/2014	11:50:00	3249.000	No Trigger				130
62	03/11/2014	09:57:00	3350.000	No Trigger				160
63	03/13/2014	11:01:00	2825.000	No Trigger				200
64	03/13/2014	10:50:00	1800.000		0.115	28.000	109	165
65	03/17/2014	09:48:00	3320.000	No Trigger				160
66	03/19/2014	10:17:00	3177.000	No Trigger				160
67	03/19/2014	10:17:00	3177.000	No Trigger				240
68	03/20/2014	09:52:00	1742.000		0.145	34.000	108	200
69	03/21/2014	10:24:00	3093.000	No Trigger				212
70	03/27/2014	10:37:00	3148.000	No Trigger				166
71	03/28/2014	09:58:00	1884.000		0.150	24.000	112	209
72	03/31/2014	10:56:00	2990.000	No Trigger				90
73	03/31/2014	10:56:00	2990.000	No Trigger				130
74	04/02/2014	13:16:00	1715.000		0.150	22.000	116	170
75	04/02/2014	11:02:00	3258.000	No Trigger				138
76	04/02/2014	10:59:00	3011.000	No Trigger				69
77	04/03/2014	11:10:00	2965.000	No Trigger				180
78	04/05/2014	09:46:00	2796.000	No Trigger				328
79	04/08/2014	10:24:00	3168.000	No Trigger				164
80	04/09/2014	10:36:00	1584.000		0.250	23.000	116	189
81	04/11/2014	10:36:00	2940.000	No Trigger				190
82	04/16/2014	11:23:00	1801.000		0.245	18.000	121	366
83	04/16/2014	11:19:00	3075.000	No Trigger				192
84	04/18/2014	10:33:00	2959.000		0.050	28.000	114	182
85	04/21/2014	10:18:00	1788.000		0.515	37.000	113	187
86	04/21/2014	10:17:00	3484.000	No Trigger				160