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October 2015

Dear Natasha,

PRELIMINARY BLAST EVALUATION OF THE DRILL AND BLAST OPERATION FOR THE PROPOSED MOKALA MANGANESE PROJECT.

1. Background

When the mining operation commences, there will be numerous mining related disturbances that impact on people and structures located in the vicinity of the operation. When blasts are set off ground vibration and air blast disturbances occur, which diminish in intensity with increase in distance. On occasion, fly rock, after blast fumes and dust may occur. These disturbances occur unexpectedly and for this reason often attract unwelcome attention.

To help manage this situation a systematic approach to the drill and blast operation needs to be adopted. This approach should initially assess the potential environmental impact of the drill and blast operation and then control and manage the day-to-day operations to ensure that the impacts are managed such that the disturbance levels fall within accepted industry norms. The aim of this report is to assess the possible impact of the drill and blast operation and to provide guidelines to help ensure that the blasting process is correctly implemented.

2. Proposed Site

The proposed mine site is located approximately three kilometers west of the town of Hotazel in the Northern Cape. The mine location and the general area around the mine are shown in the attached Google image (Appendix 1).

The mine site is remote and no third party residential structures are located in close proximity to the mine. The closest buildings are 680m to the north of the proposed mine. The closest infrastructure that may be affected by blasting at the mine includes the main tar road, various gravel roads, a mine shaft with the related surface infrastructure, the associated underground workings and numerous buildings to the north and east of the mine.

3. Objective

This report considers the possible impact of the blasting operations on the surrounding areas. It provides an assessment of the possible disturbance levels that may be experienced at various distances from the mine. It considers the preliminary work that should be carried out prior to the start of blasting and then the ongoing monitoring work that is required when blasting is underway.

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The following aspects of the blasting operation were assessed:

3.1 Blast design and general safe blasting practice.
3.2 Ground vibration is one of the major concerns.
3.3 Airblast is a major concern and usually attracts the most attention.
3.4 Unwanted side effects such as fly rock, after blast fumes and dust.
3.5 Pre blast surveys – why these are necessary and how they should be carried out.
3.6 Disturbance monitoring – equipment required, placing of equipment and the standards against which disturbance levels are measured and assessed for compliance.
3.7 Legal requirements as required by the authorities.
3.8 Mitigation measures. A number of suggestions are made. These generally affect all aspects of the operation so the points have been grouped together.

3.1 Blast Design

Prior to the start of blasting a proposed blast design should be modelled to determine the firing sequence, number of holes firing together and the combined charge mass per delay. Based on these figures the peak particle velocities should be calculated at the points of concern. These predictions should be compared to recognised standards - such as the United States Bureau of Mines Standard (USBM RI 8507) and DIN standards - to ensure compliance. When acceptable results are obtained, the design should be fixed for use in the field.

The final blast design should be marked and drilled off in the field. After the blast is drilled off and charging commences then the process should be audited to ensure that all stages of the operation are proceeding as per the design. The blast pattern, hole depths, charge mass per hole and final stemming lengths should all be checked. Any unusual occurrences should be noted.

If sensitive structures are present in an area then specific design work will need to be carried out to ensure that blasting does not cause damage to these. Initiation using electronic detonators may be required.

3.2 Ground Vibration

Ground vibration and air blast generally excite the greatest comment from people living in the neighbourhood. Ground vibration disturbances will need to be quantified to ensure compliance with recognised and accepted industry standards such as USBM RI 8507 or the DIN standard (see Appendix 2 for a summary of these standards).

Factors Affecting Ground Vibration and Prediction of Ground Vibration Levels

Ground vibrations are an undesirable consequence of blasting activity. The intensity of the vibrations depends on a number of factors some of which can be managed and controlled to help reduce the impact.

The two principal factors that control vibration levels are distance and charge weight. Vibration energy is attenuated by the rock mass so normally lower amplitudes are experienced further from a blast. Vibration levels will increase as the charge weight increases. The larger the charge mass the higher the amplitude of the vibration. The charge weight can be controlled by reducing the blasthole diameter or limiting the number of holes that fire at an instant in time.

Vibration Control

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Effective vibration control can be exercised by making use of a propagation law developed by the US Bureau of Mines, which relates peak particle velocity (vibration), charge weight and distance. This is referred to as the "Scaled Distance Relationship" which takes the following form:

$$Sd = D/\sqrt{E}$$

and

$$PPV = a(Sd)^{-n}$$

Where

Sd = Scaled distance. Sd should be greater than or equal to 31 where no monitoring is carried out.

PPV = Peak Particle Velocity (mm/sec).

D = Distance to property of concern (m).

E = Mass of explosive per delay (kg).

a = Site specific constant, which is a function of the rock mass.

n = Site specific constant, which is a function of the rock mass.

This method should initially be used as an estimate only, since it assumes site-specific constants, which differ from site to site depending on the rock types. In the absence of site-specific information, a value of 1143 for "a" and a value of –1.6 for "n" can be used. Calculated values using these constants are usually conservative but provide a useful starting point.

The maximum allowable ground vibration amplitudes are frequency dependant with higher frequencies allowing higher peak amplitudes (Graph 1, Appendix 2). In general, at lower frequencies, the ground vibration should not exceed 12.7 mm/sec at houses, but at higher frequencies, the limit can increase to 50 mm/sec. Suggested maximum levels for peak particle velocity are summarized in the table below.

Nature of structure	**PPV in mm/sec**
Heavily reinforced concrete structures.	120
Property owned by concern performing blasting (minor plaster cracks acceptable)	84
Private property in reasonable repair, where public opinion is not an important consideration.	50
Private property where maximum level of public concern is taken into account.	12
National roads / Tar roads	150
Steel pipelines	50
Green Concrete i.e. aged for less than 3 days	5
Concrete > 10 days	20

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Human Response

Human beings are easily disturbed at low levels of vibration. Levels of 0.76 to 2.54 mm/sec are quite perceptible, but the probability of damage is almost nonexistent. Levels between 2.54 and 7.62 are disturbing and levels above 7.62 can be very unpleasant.

Human perception is also affected by frequency. The approximate human response curves are combined with the USBM limiting curve for damage (Graph 2, Appendix 2). These curves slope in opposite directions. In other words, humans are more tolerant to low frequency vibrations.

To avoid damage to buildings the USBM limiting curve should be applied. To avoid constant complaints from residents, the vibration should be kept below the unpleasant curve and definitely below the intolerable curve.

Vibration Levels – Predictions

The drill and blast parameters for the mine have not been finalised as yet. However, based on the discussions held at the offices of SLR I modelled a blast layout using168mm diameter holes and 15m bench levels to predict the ground vibration levels that could be encountered at various distances from the blasts. The burden and spacing dimensions used were 4.5m by 5.1m. This resulted in a powder factor of 0.88 kgs/cubic meter. This may be too low. I anticipate that a powder factor of around 1.1 kgs/cubic meter may be required.

The shortest distances are to the underground workings. These range from 60m to 240m. The distances to the buildings adjoining the mine range from 680m north of the mine to 735m south of the mine and 2,870m east of the mine (Hotazel). The distances to the surface infrastructure were determined using Google earth imagery. The modelling is based on the distances given above. Please bear in mind that the Google image used to position the mine and the various buildings is dated and it is possible that additional structures may have been erected in the area. This must be verified by means of an on-site field check or current imagery.

The number of holes firing together (and hence the charge mass) was progressively increased from 1 to 6 holes to determine the effect on the PPV levels at various distances. A bulk explosive with an average in hole density of 1.15 was used in the calculation. In the first data table the potential impact to the underground operations is covered. The following ground vibration levels were predicted:

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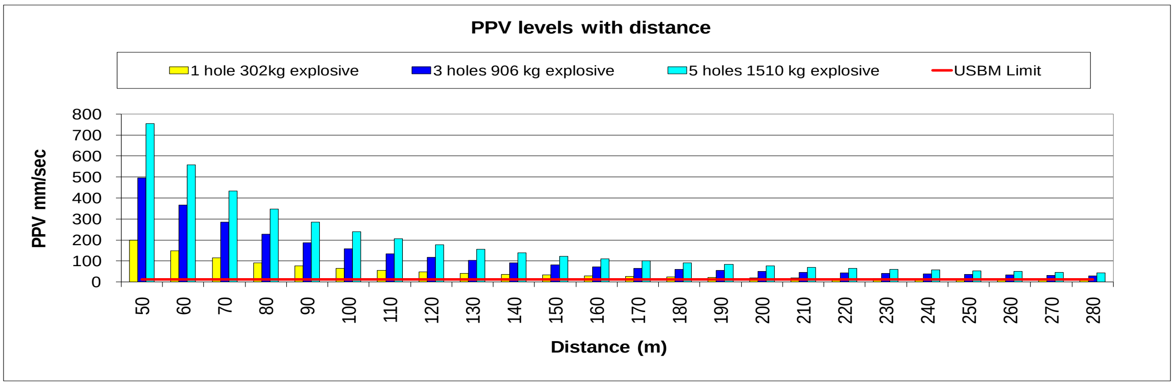
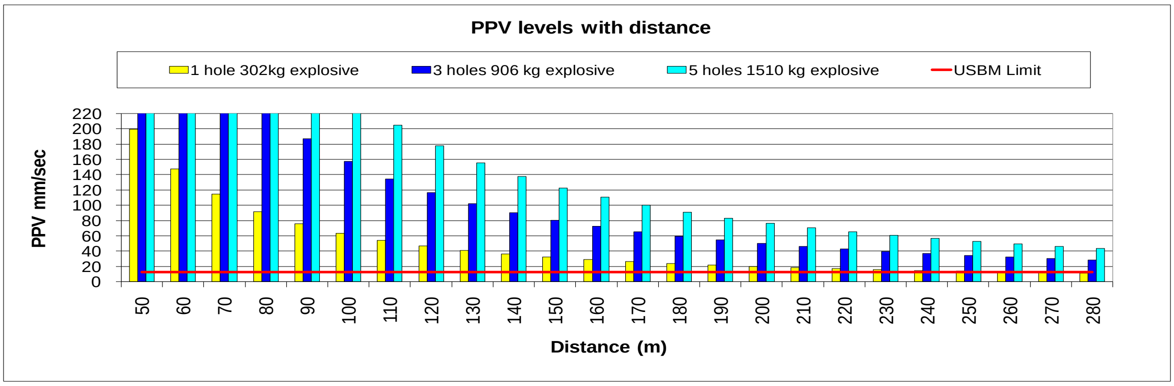
VIBRATION	Mokala	Mokala	Mokala	Mokala	Mokala	Mokala
Holes Detonated Per Delay	1	2	3	4	5	6
Combined charge mass firing	302	604	906	1208	1510	1812
Distance increment in metres						
10	Production	Production	Production	Production	Production	Production
Distance (m)	PPV	PPV	PPV	PPV	PPV	PPV
50	199.88	354.09	494.75	627.28	754.07	876.47
60	147.95	262.10	366.21	464.31	558.16	648.76
70	114.72	203.24	283.97	360.04	432.81	503.06
80	92.04	163.05	227.82	288.84	347.23	403.59
90	75.78	134.25	187.58	237.83	285.90	332.30
100	63.69	112.83	157.65	199.88	240.28	279.28
110	54.42	96.41	134.71	170.79	205.31	238.64
120	47.14	83.51	116.69	147.95	177.85	206.72
130	41.31	73.18	102.25	129.64	155.85	181.15
140	36.56	64.76	90.48	114.72	137.91	160.30
150	32.62	57.79	80.75	102.38	123.07	143.05
160	29.33	51.95	72.59	92.04	110.64	128.60
170	26.54	47.01	65.68	83.28	100.11	116.36
180	24.15	42.78	59.77	75.78	91.10	105.89
190	22.09	39.13	54.67	69.31	83.32	96.85
200	20.29	35.95	50.23	63.69	76.56	88.99
210	18.72	33.17	46.35	58.76	70.64	82.11
220	17.34	30.72	42.92	54.42	65.42	76.04
230	16.11	28.55	39.89	50.57	60.79	70.66
240	15.02	26.61	37.18	47.14	56.67	65.87
250	14.04	24.88	34.76	44.07	52.98	61.58
260	13.16	23.32	32.58	41.31	49.66	57.72
270	12.37	21.91	30.62	38.82	46.66	54.24
280	11.65	20.63	28.83	36.56	43.94	51.08

The data tabulated above also shows how the PPV levels for a given charge mass attenuate rapidly with distance. This can be seen more clearly when the data is graphed - below.



The next graph is an expanded view of the graph above. This emphasises the PPV levels associated with single hole firing.



In the next data table the potential impact to buildings located north and south of the mine as well as the houses located at Hotazel is covered.

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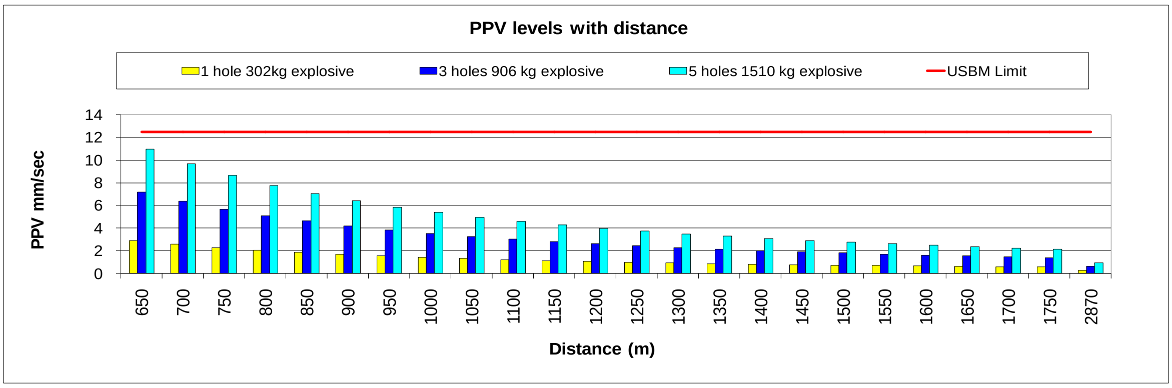
VIBRATION	Mokala	Mokala	Mokala	Mokala	Mokala	Mokala
Holes Detonated Per Delay	1	2	3	4	5	6
Combined charge mass firing	302	604	906	1208	1510	1812
Distance increment in metres						
50	Production	Production	Production	Production	Production	Production
Distance (m)	PPV (mm/s)	PPV (mm/s)	PPV (mm/s)	PPV (mm/s)	PPV (mm/s)	PPV (mm/s)
650	2.90	5.14	7.18	9.11	10.95	12.73
700	2.57	4.55	6.36	8.06	9.69	11.26
750	2.29	4.06	5.67	7.19	8.65	10.05
800	2.06	3.65	5.10	6.47	7.77	9.04
850	1.86	3.30	4.61	5.85	7.03	8.18
900	1.70	3.01	4.20	5.32	6.40	7.44
950	1.55	2.75	3.84	4.87	5.85	6.80
1000	1.43	2.53	3.53	4.47	5.38	6.25
1050	1.32	2.33	3.26	4.13	4.96	5.77
1100	1.22	2.16	3.02	3.82	4.60	5.34
1150	1.13	2.01	2.80	3.55	4.27	4.96
1200	1.06	1.87	2.61	3.31	3.98	4.63
1250	0.99	1.75	2.44	3.10	3.72	4.33
1300	0.92	1.64	2.29	2.90	3.49	4.06
1350	0.87	1.54	2.15	2.73	3.28	3.81
1400	0.82	1.45	2.03	2.57	3.09	3.59
1450	0.77	1.37	1.91	2.42	2.91	3.39
1500	0.73	1.29	1.81	2.29	2.76	3.20
1550	0.69	1.23	1.71	2.17	2.61	3.03
1600	0.66	1.16	1.63	2.06	2.48	2.88
1650	0.62	1.11	1.54	1.96	2.35	2.74
1700	0.59	1.05	1.47	1.86	2.24	2.60
1750	0.57	1.00	1.40	1.78	2.14	2.48
2870	0.25	0.44	0.62	0.79	0.94	1.10

In the above table the vibration levels that correspond closely to the USBM threshold limit for private property (12.75mm/s at low frequency) have been highlighted. The results show that up to six holes can be fired together before the USBM recommended limit is reached at the closest buildings.



However, the limiting criteria are the impact to the underground workings. Individual hole firing using electronic detonators will be required. In addition holes may have to be deck charged to reduce the charge mass per delay even further.

In my experience the results obtained using the USBM formula with the given constants are conservative and the actual vibration levels are usually lower than those predicted. The geology in the area surrounding the mine will control the attenuation of the shock waves. The geological controls are not easily observed but can be determined using the IsoSeismic analysis technique, which allows an IsoSeismic contour map to be constructed around the mine. The data obtained can be used to determine site specific constants for use in the prediction of ground vibration in the area.

3.3 Airblast

Airblast is usually the main cause of blasting related complaints. Airblast is an atmospheric pressure wave consisting of high frequency sound that is audible and low frequency sound or concussion that is sub-audible and cannot be heard. Either or both of the sound waves can cause damage if the sound pressure is high enough (Konya).

Airblast results from explosive gasses being vented to the atmosphere that results in an air pressure pulse. This occurs as a consequence of stemming ejections or hole blowouts, direct rock displacement through face ruptures or surface cratering, the use of high Velocity of Detonation (VOD) accessories that are left unconfined and / or uncovered (e.g. detonating cord on surface), by ground vibration or by various combinations of the above.

It is difficult to predict air blast levels with certainty due to unknown blast conditions as well as varying atmospheric conditions. However, airblast can be successfully contained below 130dB by precise control of the charging operation. Airblast amplitudes up to 135dB should not cause damage but it is recommended that the airblast be kept below the 130dB level. (Overcharged holes can generate amplitudes that exceed 142dB). Suggested threshold limits for air blast (below) have been proposed by Personn et.al. 1994. Chiappetta (personal communication) recommends that a threshold level of 125dB should be used to avoid all complaints.

120 dB	Threshold of pain for continuous sound
>130 dB	Resonant response of large surfaces (roofs, ceilings). Complaints start.
150 dB	Some windows break
170 dB	Most windows break
180 dB	Structural Damage

Airblast Prediction
Given the variables associated with airblast any attempt to predict air blast levels <u>can only be regarded as subjective</u>. In my opinion good blast management coupled with the correct blast procedures will keep the airblast levels to acceptable limits. Blasts that have been correctly designed, laid out and executed should not result in excessive airblast and this should be the focus.

There are a number of equations that can be used to try and predict airblast. Airblast is scaled according to the cube root of the charge weight:

$$K = D/W^{0.33}$$

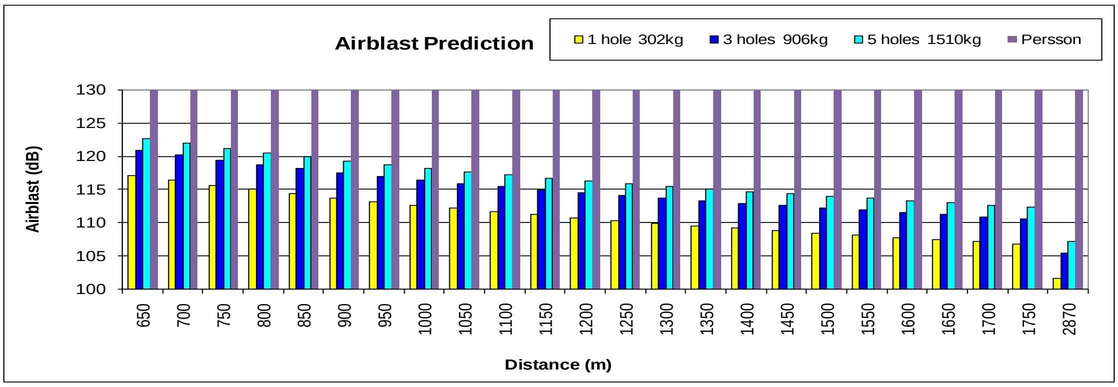
The following equation can be used for the calculation of air blast:

$$L = 165 - 24 \operatorname{Log}_{10} (D/W^{0.33})$$

Where
- K = Scaled distance value.
- L = Airblast level (dB)
- D = Distance from source (m)
- W = Charge mass per delay (kg)

I have calculated the air blast levels using the same charge masses used for the prediction of ground vibrations. No data relating to the underground workings is presented as airblast will have no impact on this environment. The airblast levels relating to the surface infrastructure are given in the table below. The data is graphed against the Persson recommended limit.

AIRBLAST						
Holes Detonated Per Delay	1	2	3	4	5	6
Combined charge mass firing	302	604	906	1208	1510	1812
Distance increment in metres						
50	Production	Production	Production	Production	Production	Production
Distance (m)	dB	dB	dB	dB	dB	dB
650	117	120	121	122	123	123
700	116	119	120	121	122	123
750	116	118	119	120	121	122
800	115	117	119	120	121	121
850	114	117	118	119	120	120
900	114	116	118	119	119	120
950	113	116	117	118	119	119
1000	113	115	116	117	118	119
1050	112	115	116	117	118	118
1100	112	114	115	116	117	118
1150	111	114	115	116	117	117
1200	111	113	115	116	116	117
1250	110	113	114	115	116	116
1300	110	112	114	115	115	116
1350	110	112	113	114	115	116
1400	109	112	113	114	115	115
1450	109	111	113	114	114	115
1500	108	111	112	113	114	115
1550	108	110	112	113	114	114
1600	108	110	112	113	113	114
1650	107	110	111	112	113	114
1700	107	109	111	112	113	113
1750	107	109	111	112	112	113
2870	102	104	105	106	107	108



The airblast levels are all below the recommended Persson threshold limit. Damage to structures will not occur at these levels.

3.4 Unwanted Side Effects - Fly Rock

Side effects such as fly rock or excessive post blast fumes are undesirable and usually occur unexpectedly, sometimes for unknown reasons. This makes pro-active preventative management difficult. If any incidents occur they should immediately be investigated to determine the likely cause to allow corrective action to be taken.

Fly rock typically originates either from the free face or the surface of the blast or possibly from secondary blasting. The main causes are under burdened holes on the free face, geological discontinuities, poor blast timing leading to over confinement of holes and overcharged blastholes that result in cratering of the hole.

The only solution to the above is to plan and design the blast correctly. This must be followed by care and good control during the charging up of the blast. Holes must receive the correct quantity of explosive. Correct stemming lengths must be used. As a safety measure a minimum safe distance (normally 500m) from the blast area must be cleared of people and animals. The drill and blast company must define the procedures and method.

Unwanted Side Effects - Post Blast Fumes and Dust
Explosives are formulated to be oxygen balanced to minimize fumes and optimize the energy output. Fumes such as carbon monoxide and oxides of nitrogen can be produced in the detonation process. Dust on the other hand is an inevitable consequence of blasting.

A number of factors can contribute to the creation of fumes. A number of these are mentioned below:

- Poor quality control and incorrect formulation;
- Excessively long sleep times;
- Damage to the explosive;
- Inadequate water resistance;
- Poor ground conditions;
- Premature loss of confinement;
- Inadequate priming; and
- Insufficient charge diameter.

If fumes occur after a blast then the immediate vicinity of the blast area must be kept clear until these have dissipated. The wind direction and conditions must also be kept in mind to ensure that the fumes do not impact further afield.

It is difficult to ensure that post blast fumes never occur because some of the factors above are outside the blasters control. The best tools here are to ensure that strict quality control standards are in place and to exercise ongoing care and control during all stages of the charging up side of the operation. This is easily controlled if packaged explosive is used, as this is factory manufactured. If Anfo or bulk explosive is used, then the on-site QC controls are critical as the products are blended and placed directly into the blasthole. Problems such as running out of diesel (Anfo) or gassing solution (bulk) are not uncommon.

3.5 Pre Blast Surveys
Cracks occur in most structures but the owners are usually unaware of them. The purpose of the pre-blast survey is to document the crack damage in the various structures located around the mine that fall within a specified distance of the pit. The mine should generate a survey plan, which should be reviewed with the explosive supply company and the person carrying out the house inspections. A decision relating to the required inspection distance must be agreed on. All structures within this area should be examined internally and externally. In addition sensitive structures that are located outside of this distance should be included. This could for example, include schools, hospitals and churches.

Any damage identified should be quantified using an engineering reference framework and digitally photographed. A report describing the damage and linking it to a photo database should be produced. Despite this information it is likely that future claims could still arise. Bear in mind that cracks in structures are dynamic in nature. They change with time in response to variations in temperature, humidity, rainfall, wind, soil conditions and structural integrity. Despite these ongoing environmental stresses when blasting starts it may well be blamed as the cause of all of the damage.

The pre-blast crack information is useful but it should only be regarded as a means to an end. It is important to have this baseline data available but more importantly blast disturbances must be monitored on an ongoing basis.

3.6 Disturbance Monitoring – Ground Vibration and Airblast

Disturbance monitoring is essential and should be carried out from the first blast. The information obtained can be used first and foremost to ensure that the predicted and recommended vibration amplitudes and air blast levels are not being exceeded. The disturbance levels recorded should be compared to the predictions as well as accepted industry norms to ensure compliance with design and standard. The records give a clear indication of whether or not changes to the blast design need to be considered. The records can also be used to demonstrate compliance.

Disturbance monitoring should be carried out using industry standard seismographs such as White Industrial Seismology equipment. Each seismograph is equipped with a triaxial geophone and a separate microphone. This allows ground vibrations and air blast to be measured simultaneously. The ground vibrations are measured in three directions. The three primary measurements can be plotted directly against an accepted standard, the two most common being the USBM and DIN standards. The USBM is most commonly used in South Africa. The DIN standard is more stringent as it restricts vibration levels to lower limits than the USBM standard. I have attached two printouts of measurements taken of a blast event (Appendix 3). The first shows the data measured at a specific monitoring station plotted against the USBM standard and the second shows the same data plotted against the frequency spectrum.

Air blast can be measured at levels in excess of 100dB with the White seismographs. The peak air blast level as well as the associated frequency spectrum is measured.

Seismographs should be positioned at sensitive or potentially sensitive locations. They can initially be positioned on a blast-by-blast basis but once ongoing production blasting is underway it much simpler and easier to establish a number of permanent monitoring stations. These stations remain in place for as long as is required and can be moved to different locations as areas of the mine are mined out. This is useful as it shows the level of local disturbance (caused for example by storms) that goes unnoticed. A reference database should be established and all data saved here. I recommend that an independent third party carry out the ground vibration and air blast monitoring.

Crack Monitoring

A recent innovation is a novel technique for continually monitoring movement across a crack with an accuracy of down to one micron. A gauge is placed across a crack in a structure. It is set to sample at a pre-set rate or to trigger off movement at a predefined level. The crack is monitored continually. Temperature and humidity information is collected at each crack gauge.

Any movement of the crack can be correlated to the blast schedule, seismograph records, temperature / humidity conditions and rainfall figures if monitored. This combined information shows very effectively which elements contribute to movement of the crack.

3.7 Requirements – Legal and Other

In addition to the legal requirements that must be adhered to, there are standard safety procedures associated with blasting operations that should be applied. These include but are not limited to:

- Clear notification of blast times and location to be given. This information should be posted at the entrance to the mine for information of mine personnel. It should also be made available to members of the community. A method for distributing this information will need to be put into place.
- Defining a suitable safety radius around the area of the blasts. This may vary depending on circumstances.
- Clearing the area prior to blasting.
- Special operating procedures must be drawn up to address blasting in close proximity to the existing underground workings. It is imperative that the adjoining underground mine is notified in good time of planned blasts. This is to ensure that all personnel are removed from the underground workings prior to the surface blasts being set off. There is little risk to underground infrastructure but there is a real risk that the blast induced vibrations could result in a fall of ground. For this reason the underground workings must be free of all personnel.
- Placing guards to ensure that no people or animals re-enter the cleared blast area.
- Closing of roads within a defined safety radius may need to be considered.
- Traffic moving in all directions should be stopped at least 500 m away from the blast area.
- Blasting should be carried out to cause the least disturbance to the members of the community. For example, blasts could be planned to coincide with times when most people are not at home. Avoid blasting early in the morning or late in the afternoon.
- Local conditions such as wind strength and direction, presence of low clouds or temperature inversion conditions need to be considered when making a decision as to whether a blast should be set off or not.
- The MR380 the tar road runs through the mine property. The road itself can withstand ground vibration at levels up to 150mm/sec. The concern was expressed that the road could be displaced by blasting. To help prevent this when blasting within 200m of the road individual hole firing must be used and the blast must be designed to run away from the road.

3.8 Mitigation Measures

A number of measures are suggested that may be useful in helping to ensure that the drill and blast operation proceeds smoothly. Some of the measures (e.g. quality acceptance) apply to specific areas of the operation. Others apply to a number of aspects of the operation to varying degrees.

- Exercise ongoing care and control during all stages of the drilling and blasting operation. Check, check and check again.
- Prior to charging up the blast, the holes drilled should be inspected and all ‘problem’ holes identified for corrective action. Examples of ‘problem’ holes could include holes that are under burdened, holes that are short drilled, holes surrounded by badly cracked ground and off pattern holes that could potentially lead to problems.
- Production QC checks must be implemented as part of the Standard Operating Procedures. This is particularly important if Anfo or bulk explosives are being used.

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During charging up of the holes the bulk explosive product should be sampled on an ongoing basis to ensure acceptable quality.

- After charging up is complete and prior to stemming the holes closed, they should be taped to determine the explosive column rise to ensure that the required stemming length is obtained. Any errors must be corrected before the hole is stemmed closed.
- The tie up should be carried out according to the blast plan to ensure that the timing and sequencing of the blast proceeds as planned.
- Avoid prolonged sleeping of blasts particularly in wet ground conditions. It is preferable to charge and blast in the shortest possible time frame.
- If fumes occur after a blast then the immediate vicinity of the blast area must be kept clear until these have dissipated. The wind direction and conditions must also be kept in mind to ensure that the fumes do not impact further afield.
- Good neighbourliness is important. Circulating a blast schedule on a weekly / monthly basis is a big help as this conditions people into expecting a blast and when the blast takes place it is not totally unexpected. There will still be complaints but this approach may help reduce the number of queries and / or complaints.
- It is advisable to schedule the blast for a time when the least number of people are likely to be at home.

4. Knowledge Gaps

The prediction of the possible disturbance levels at various distances is based on reasonable assumptions regarding the blast patterns to be drilled and blasted. Generally accepted equations and modeling methods were used to perform the calculations on which the predictions are based. However, prior to the start of the drill and blast operation these figures must be reviewed to correct for any variances between ‘actual’ versus ‘modeled’.

It is likely that some time will elapse between publication of this report and the development of the mine. The surface surroundings may change in this time and this aspect must be kept in mind prior to final design review and decision making.

5. General Information and NEMA Regs (2014)

The scope of this report was to assess the potential impact of blasting activity on areas surrounding the proposed mine development. No site investigation was carried out as this is an initial appraisal. The report focuses on:

- Prediction of ground vibration for increasing charge mass at various distances;
- Prediction of air blast as above; and
- Assessment of unwanted side effects such as fly rock, post blast fumes and dust.

The report was compiled to provide input to assist with information required to assess proposed management measures as well as possible alternatives.

The above report addresses routine ongoing drill and blast applications. Any sensitive structures (if any) will need to be addressed individually. Blasts will need to be specifically designed to accommodate such structures.

My (alphabetical) customer base includes the following companies: Afridex (DRC), Anglo Platinum at various operations, Aquarius Platinum Marikana Mine, Bombela Consortium, Bulk Mining Explosives, Council for Geoscience, Enviro Blast, Gecamines (DRC), imPafa Technologies, Impala Platinum, Lonmin, Lyttelton Dolomite, Mashala Resources, Master Blaster, MCC Contracts Drilling and Blasting, Moolman Mining, Mubiji Mayi (DRC), Murray and Roberts, NuCoal, Pilanesberg Platinum Mine, Pretoria University, SLR

Consulting (Africa), Shanduka Colliery, Tharisa Minerals, Total Coal, Tselentis Mining and Xstrata Coal and alloys.

This report was prepared by Erik Kohler, B.Sc. Geology (UCT). I operate independently or with associates on an as and when required basis. This allows the services and expertise of other professionals who offer specialised services and/or equipment for a specific need to be accessed. I have no vested interest in the projects that I am involved in other than to be compensated for the services that I render, which is a normal requirement.

NEMA Regs (2014) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Section 5.
The expertise of that person to compile a specialist report including a curriculum vitae	Section 5.
A declaration that the person is independent in a form as may be specified by the competent authority	Section 5.
An indication of the scope of, and the purpose for which, the report was prepared	Section 5.
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	N / A
A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 4.
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 2.
An identification of any areas to be avoided, including buffers	Sections 3.2 and 3.3
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Appendix 1.
A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 4.
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Sections 3.2 and 3.3
Any mitigation measures for inclusion in the EMPr	Section 3.8
Any conditions for inclusion in the environmental authorisation	Section 8
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 3.6
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Section 8
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 8
A description of any consultation process that was undertaken during the course of carrying out the study	Section 7
A summary and copies if any comments that were received during any consultation process	Section 7
Any other information requested by the competent authority.	Section 5.

6. Suggestions

I would like to suggest that the initial blasts be audited and monitored. The purpose of the exercise is to spot potential problems to allow these to be corrected before a blast is set off. The audit helps ensure compliance with design and addresses “finger problems” such as overcharged holes, underburdened holes etc. These oversights need to be managed accordingly as any errors at this stage can have knock on effects that can increase disturbance levels significantly.

Keep accurate and comprehensive blast records. All of the blast parameters as well as the timing and sequencing used to delay the blast should be recorded, as the individual seismograph measurements made need to be linked to the blasts. The blast information can be referenced and used to assist with future blast designs. To facilitate this, the drill and blast contractor should keep accurate records of the following, which are essential inputs to the blast vibration report:

- Blast type (e.g. Overburden, waste, reef, pre-split etc.);
- Hole diameter drilled;
- Blast pattern – dimensions, number of rows and holes per row, burden and spacing, position of cut and cut design;
- Final drill depths;
- Total number of holes per blast – design and actual;
- Position of any additional or relieving holes;
- Any irregularities in the blast such as underburdened or overburdened holes;
- Explosive type used to charge the blast;
- Explosive charge mass per individual hole and the total amount of explosive used per blast;
- The explosive column rise and the final stemming length achieved;
- Details of the final blast tie up with a schematic showing the position and value of the time delays used as well as the number of holes per delay;
- The date and time of firing the blast;
- The prevailing weather conditions at the time of the blast; and
- Longitude and latitude of the blast and the monitoring stations to allow the distance to the blast to be determined.

7. Consultation with interested and affected parties (IAPs)

Consultation with interested and affected parties was undertaken as part of the environmental impact assessment and environmental management programme process. In this regard, comments that were raised by interested and affected parties are included in the table below.

Interested and affected party	Date comment was received	Issue raised	Response to issue
Comment raised by Jan Theart	15 April 2015 at the public scoping meeting	When will blasting take place? The law states that blasting should only take place during the day. Mokala should also be aware that there is an existing forum which assists in notifying people of planned blasts.	Blasting activities will be limited to the day time hours and scheduled blasts need to be communicated with IAPs.

8. Recommendations

- The modelling results indicate that the disturbance levels that could be experienced at the various locations around the planned mine should not cause damage to surface infrastructure. The potential ground vibration levels experienced underground, especially in areas close to the open pit, are very high.

With the above in mind clear and precise blast notifications must be given to all mine divisions (offices, workshops, plant etc) at least a day prior to the blast. Notifications should also be sent to Kalagadi shaft and Assmang informing them of the date and time of the blast. These could be sent via email, sms, fax or other means.

- The internal notification should be include a plan showing the block to be blasted and the surrounding area. The 500m safety circle must be superimposed. This will show what mine infrastructure if any falls within the safety radius. All personnel in these areas must be evacuated prior to the blast being set off. The same applies to clearing the open pit of personnel prior to the blast being set off.
- Similarly a fool proof method must be put into place to ensure that all underground personnel have returned to surface before the blast is set off. If they cannot all be accounted for, the blast must be postponed.
- Notification boards could be placed at the entrance to the mine as well as alongside main roads. The date and time of the next blast should be shown.
- Blasting operations must be conducted between the hours of sunrise and sunset. It may be prudent to apply for blasting permission on all weekdays as well as on Saturdays. No blasting should take place on Sundays.
- The first blast should be audited. Aspects such as pattern layout, hole depths, method of charging holes, explosive column rise, stemming length and finally the timing and sequencing of the blast must be checked.
- The charging operation must be accurately controlled. Overcharged holes can result in excessive airblast and flyrock and are therefore unacceptable. It is therefore essential that the correct control measures are put into place from day one to help control and minimise the disturbance levels. The bulk explosive supply company must be informed of this.
- The blast should monitored at a number of locations to allow the disturbance levels to be measured. Industry approved seismographs capable of recording ground vibration and airblast simultaneously should be used for this. The monitoring locations will need to be decided on.
- After the first blast the actual measurements made must be compared to the predictions. The design can then be remodelled if required.

The proposed Mokala Manganese mine is located in a remote area. If the drill and blast procedures are well controlled and executed then there is no reason why this activity should not be authorised and carried out. It follows that the mitigation measures/recommendations and monitoring requirements as outlined in this report should form part of the conditions of the environmental authorisation.

If you have any queries regarding the above, please contact me at 083 488 1392.

Yours sincerely

E. Köhler

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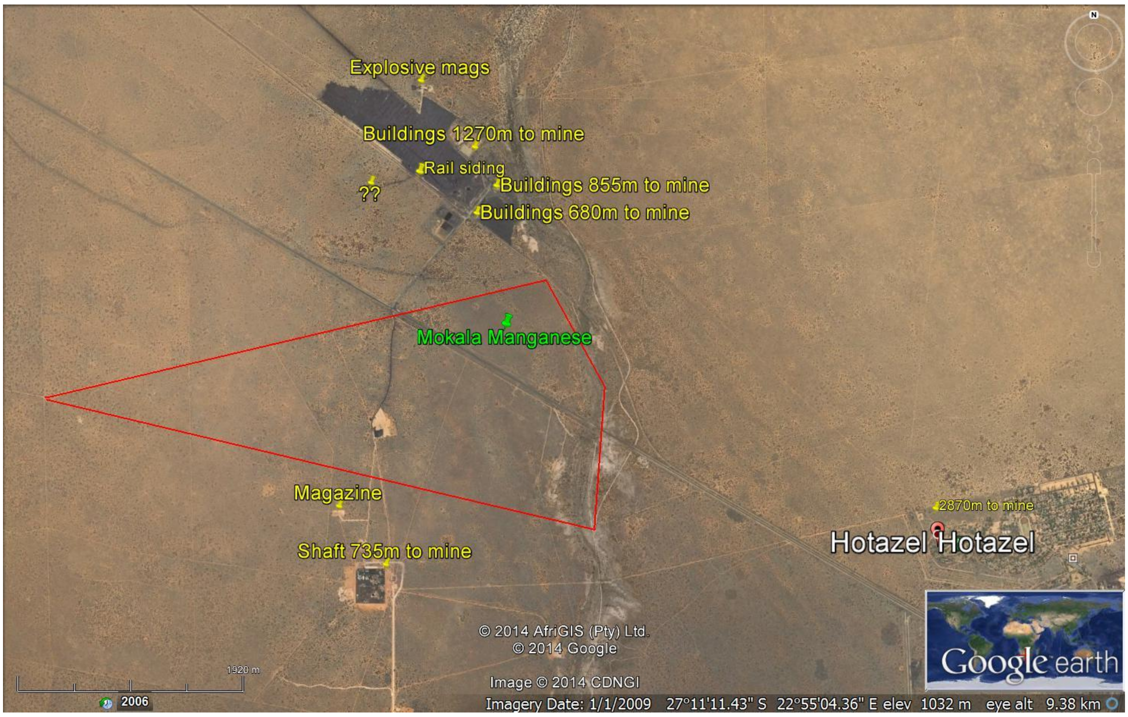
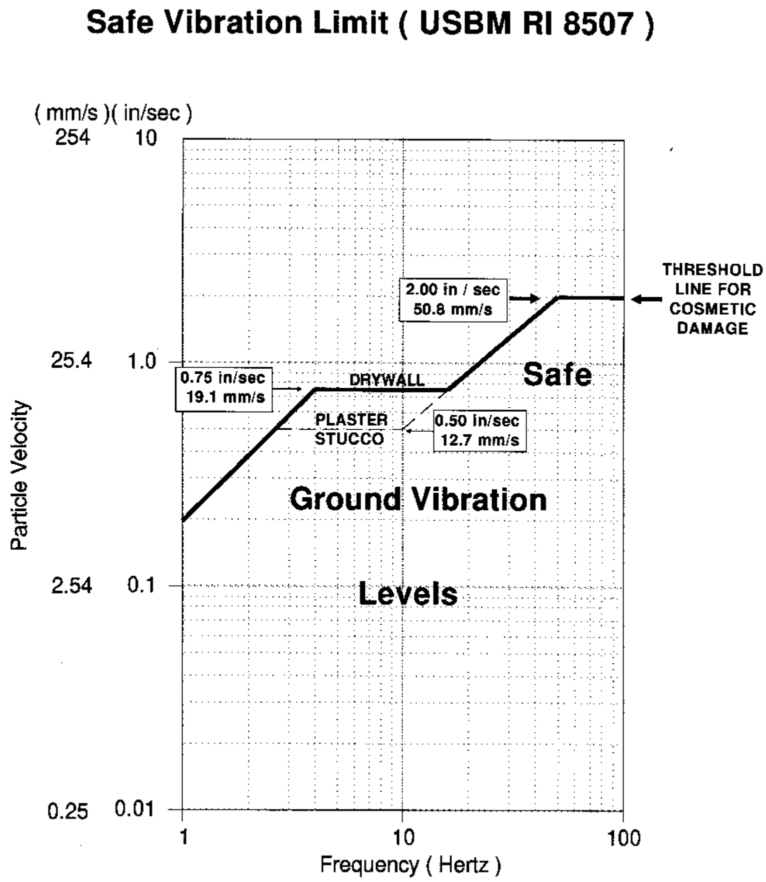


<u>Appendix 1</u>. Google Earth view of proposed Mokala Manganese Mine development.

Vibration and Air Blast Limits

Ground Vibration - Building response to ground vibration

Although there are no legislated limits to vibration, the US Bureau of Mines limits are commonly applied in South Africa. The limiting curve is shown in Graph 1 and has been developed from empirical studies (Siskind *et.al.* 1980).



Graph 1. USBM curve that is generally used in South Africa. (After Chiappetta, March 2000)

The limiting curve in Graph 1 represents the limit for cosmetic damage to a house. The maximum ground vibration amplitudes are frequency dependent with higher frequencies allowing higher peak amplitudes. Most modern blasting seismographs will display the vibration data in terms of the USBM limiting criterion. In general, at lower frequencies, the ground vibration should not exceed 12.7 mm/s, but at higher frequencies, the limit can increase to 50 mm/s.

Appendix 2: Vibration and Airblast Limits.

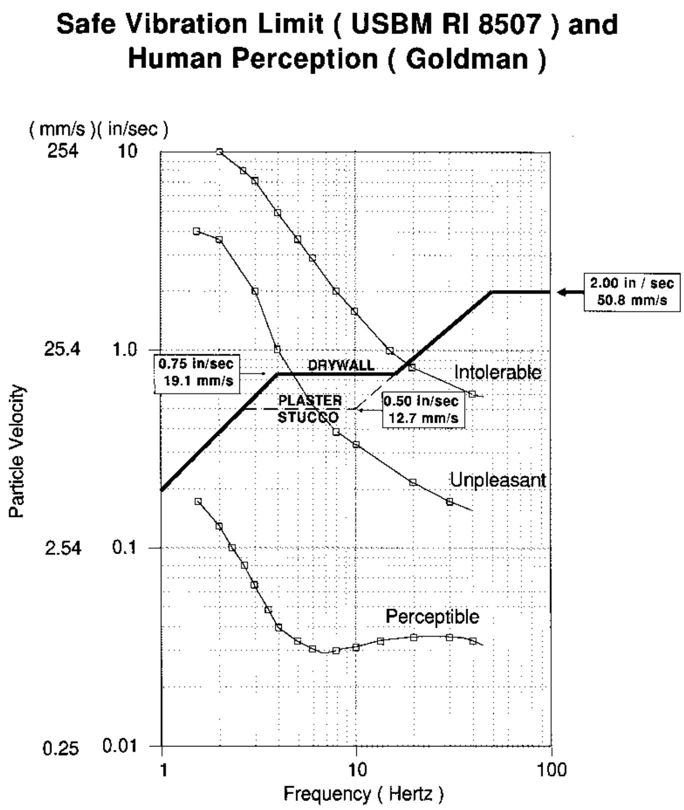
<u>Human response to ground vibration</u>

Although buildings can withstand ground vibration amplitudes of 12.7 mm/s or more, depending on the frequency, human beings are easily disturbed at lower levels. The typical human response to ground vibration is illustrated in the table below.

Effects on Humans	Ground Vibration Level mm/s
Imperceptible	0.025 – 0.076
Barely perceptible	0.076 – 0.254
Distinctly perceptible	0.254 – 0.762
Strongly perceptible	0.762 – 2.540
Disturbing	2.540 – 7.620
Very disturbing	7.620 – 25.400

Human response to vibration (Chiappetta, 2000)

Ground vibration levels of 0.76 to 2.54 mm/s received at a structure are quite perceptible, but the probability of damage is almost nonexistent. Levels in the 2.54 to 7.6 mm/s can be disturbing and levels above 7.6 mm/s can be very unpleasant, although permanent damage is unlikely.



Graph 2. Human response curves compared with potential damaging limits. (After Chiappetta, 2000).

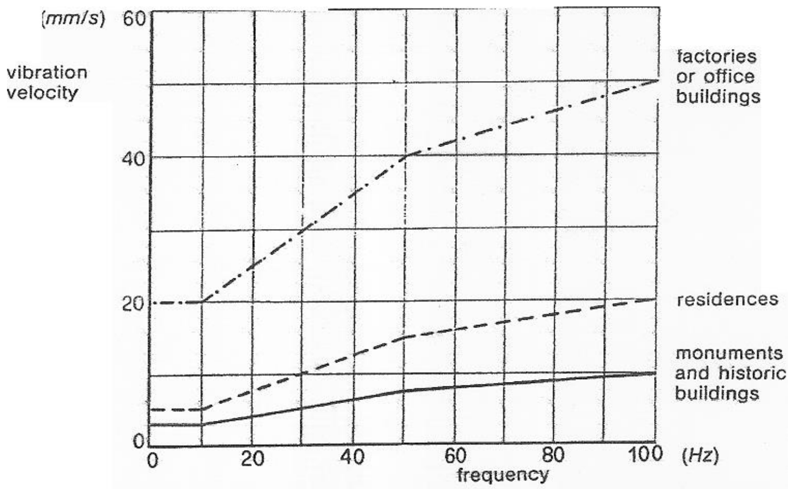
<u>Appendix 2 (cont)</u>: Vibration and Airblast Limits.

Human perception is also affected by frequency. The approximate human response curves are combined with the USBM limiting curve for damage in Graph 2. These curves slope in the opposite direction. In other words, humans are more tolerant to low frequency vibrations.

To avoid damaging buildings, the USBM limiting curve should be applied. However, to avoid constant complaints from neighbours, the vibration should preferably be kept beneath the *unpleasant* curve and definitely be kept beneath the *intolerable* curve.

DIN STANDARD 4150 (Western Germany, 1983). Limit values of vibration expressed in mm/sec.

Recording spots / Type of structure	Foundations			Floor of the highest storey of the building
	< 10 *Hz*	10 – 50 *Hz*	50 – 100 *Hz*	Any frequency
1. Office or factory building	20	20 – 40	40 – 50	40
2. Residential building with plastered walls	5	5 – 15	15 – 20	15
3. Historic and other buildings to be treated with care	3	3 – 8	8 – 10	8
With frequencies > 100 Hz higher levels may be accepted				



Vibration velocity threshold for different types of constructions as a function of frequency, as defined by DIN STANDARD 4150 (West Germany)

It may be prudent to apply the DIN standard where 3rd world housing is encountered, as these buildings are often poorly constructed.

Appendix 2 (cont): Vibration and Airblast Limits.

Air Blast Limits

As with ground vibration, there are no legislated limits to air blast amplitudes from blasting activity.

Siskind *et.al.* (1980), indicate that monitored air blast amplitudes up to 135 dB are safe for structures, provided the monitoring instrument is sensitive to low frequencies (down to 1 Hz). Persson *et.al.* (1994) have published the following estimates of damage thresholds based on empirical data.

120 dB	Threshold of pain for continuous sound
>130 dB	Resonant response of large surfaces (roofs, ceilings). Complaints start.
150 dB	Some windows break
170 dB	Most windows break
180 dB	Structural Damage

Damage thresholds for air blast.

References

Siskind, D.E., Stagg, M.S., Kopp, J.W. & Dowding, C.H., 1980. *Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting*, U.S. Bureau of Mines RI 8507.

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Siskind, D.E., Stachura, V.J., Stagg, M.S. & Kopp, J.W., 1980. *Structure Response and Damage Produced by Airblast from Surface Mining*, U.S. Bureau of Mines RI 8485

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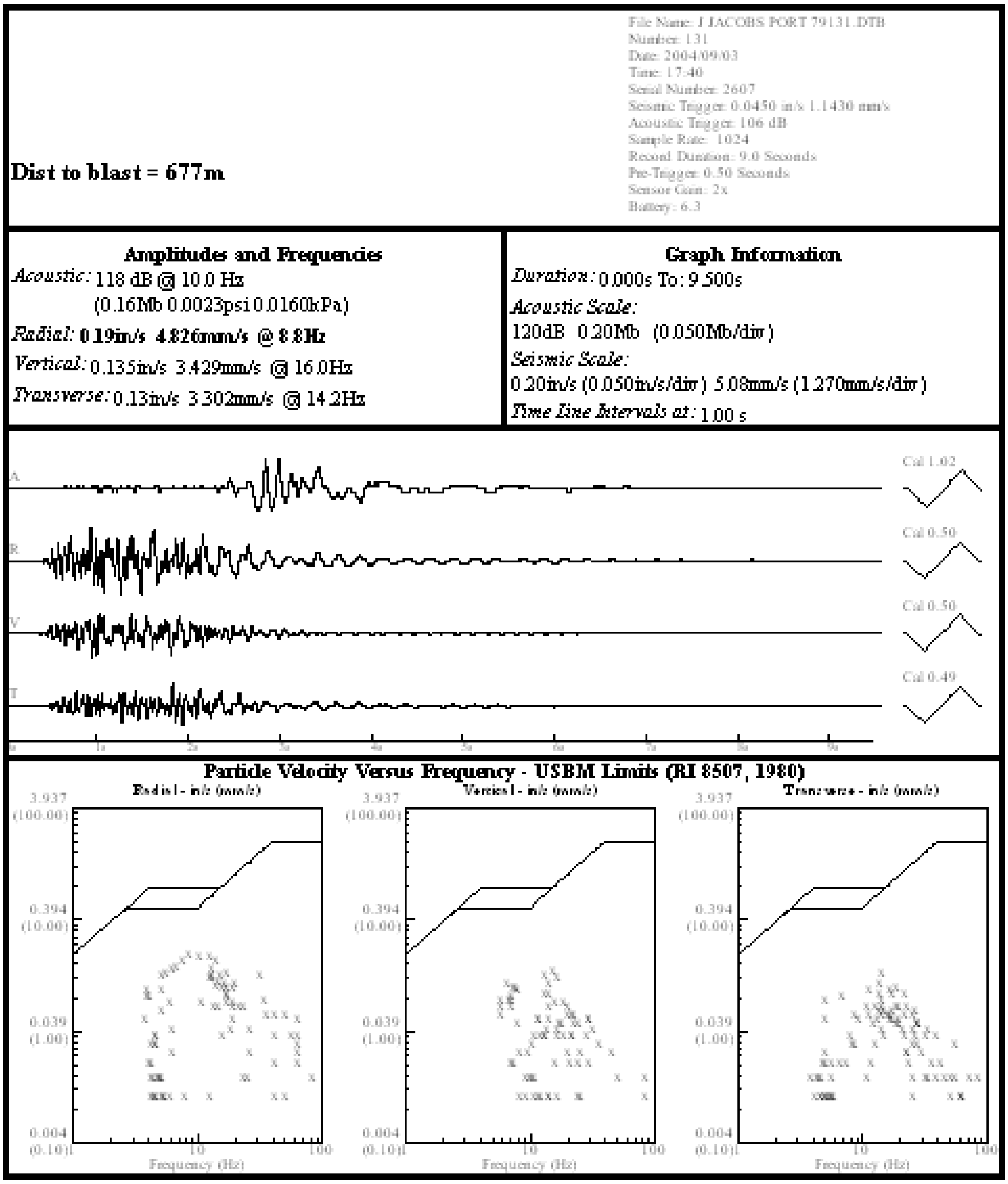
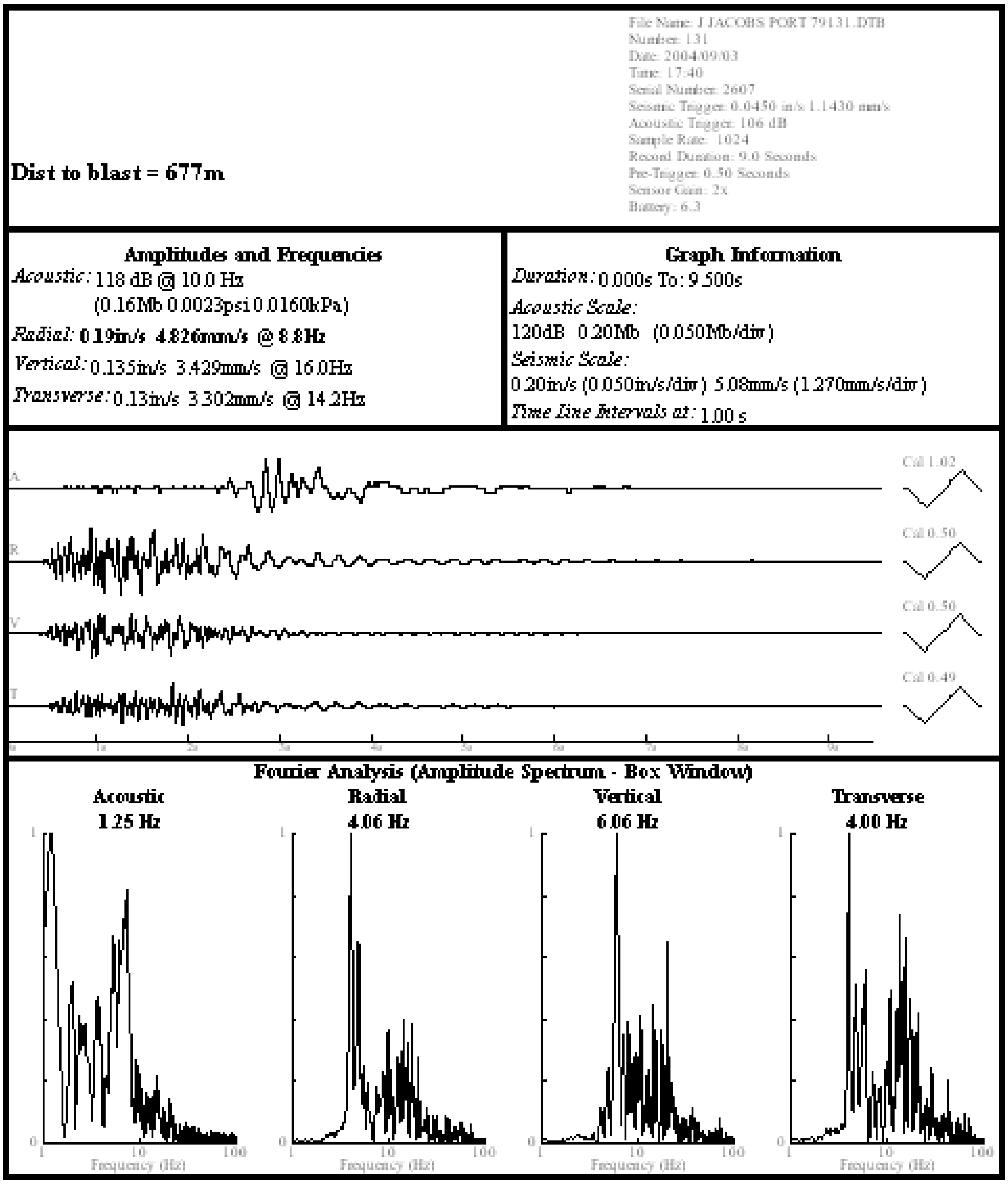


<u>Appendix 3</u>: Vibration and Airblast Data plotted against the USBM Standard.



<u>Appendix 3 (cont)</u>: Vibration and Airblast Data plotted against frequency.