APPENDIX J: BLASTING REPORT

Cambrian CC

Reg. No. 2001/031939/23

50 Krige Avenue
P O Box 977
Irene
0062
South Africa

Mrs. Linda Munro
Metago Environmental Engineers (Pty) Ltd
P O Box 1596
Cramerview
2060

20th August 2014.

Dear Linda,

IMPACT ASSESSMENT OF THE DRILL AND BLAST OPERATION FOR THE PLANNED PIT EXTENSIONS AT THARISA MINERALS.

1. Background.

The ongoing and future drill and blast operations at Tharisa will cause various 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 attention.

To 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 controlled to acceptable levels. 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. Tharisa Mine.

The Tharisa mine is located approximately 1.5 kilometers to the north of the N4 freeway on both sides of the tar road that runs to Marikana. Mining is carried out in three areas namely the West Mine, the Centre pit and the East pit. These are shown in the attached Google Earth image (Appendix 1). The green lines define the southern pit limits and the blue lines trace the N4 east / west and the main tar road to Marikana. The proximity of the villages to the mining operations can clearly be seen.

3. Objective.

This report considers the possible impact of the blasting operations on the surrounding neighbourhood. It provides and 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.

The following aspects of the blasting operation are assessed:

3.1 Blast design and general safe blasting practice.
3.2 Ground vibration, one of the major concern issues.
3.3 Airblast, also a major cause of concern.
3.4 Unwanted side effects such as fly rock, after blast fumes and dust.

Members: Erik Kohler (managing)
Tel: +27 12 6673808 Fax: +27 12 6673808 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

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 Explosives Act, Mine Health and Safety Act or the Department of Mineral and Energy Affairs (DME).
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) or DIN standard - to ensure compliance. When acceptable results are obtained, the design should be fixed for use in the field.

Information from the mine's geological department relating to the geology surrounding the mine should be obtained. The presence of dykes and / or faults as well as information on their orientation is helpful. Any geological features should be shown on the mine plan and close attention paid to drilling and blasting in these areas to ensure that these features do not have an influence the disturbance levels caused by blasting.

The final 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 will probably 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, which is generally accepted in South Africa (see Appendix 2 for a summary of this standard).

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.

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

Vibration Control

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

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 can be 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

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

curves slope in the opposite direction. 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 – General.

The villages of Lapologang, Maditlokwa / Silver City and Tsilong are closest to the Tharisa open pits (see Appendix 1) and will be affected by blasting. The distance from Lapologang to the southern limit of the West Mine is around 570m. This distance will increase as mining continues and the pit is developed to the north. The distance from the closest houses in the village of Maditlokwa / Silver City to the northern side of the West Mine mining area is around 400m but this will reduce to around 220m as the pit is developed to the north. The distance from the village of Tsilong to the northern side of the West Mine mining area is around 680m but this will reduce to around 450m as the pit is developed to the north.

The distance from the eastern portion of Maditlokwa / Silver City to the western half of the East Mine is around 960m but this distance will reduce to around 300m as this pit is developed to the north. The distance from the eastern portion of Maditlokwa / Silver City to the eastern half of the East Mine will range between 1,700m to around 1,600m. Blasting in this section of the mine will have a minimal impact on the village and will not be considered further.

The disturbance levels experienced at Lapologang will decrease as the West Mine is developed. The disturbance levels experienced at Maditlokwa / Silver City and Tsilong will increase as the West Mine and the western half of the East Mine are developed to the north.

Vibration Levels – Predictions.

Modelling of a typical blast layout (i.e. 165mm diameter holes & 15m bench levels) was carried out to predict the ground vibration levels that could be encountered at various distances from the blast. The number of holes firing together (and hence the charge mass) was progressively increased from 0.5 to 5 holes to determine the effect on the PPV levels at given distances. The 0.5 was used to simulate a reduced charge mass which can be achieved by using deck charging techniques. The results obtained are given in table below.

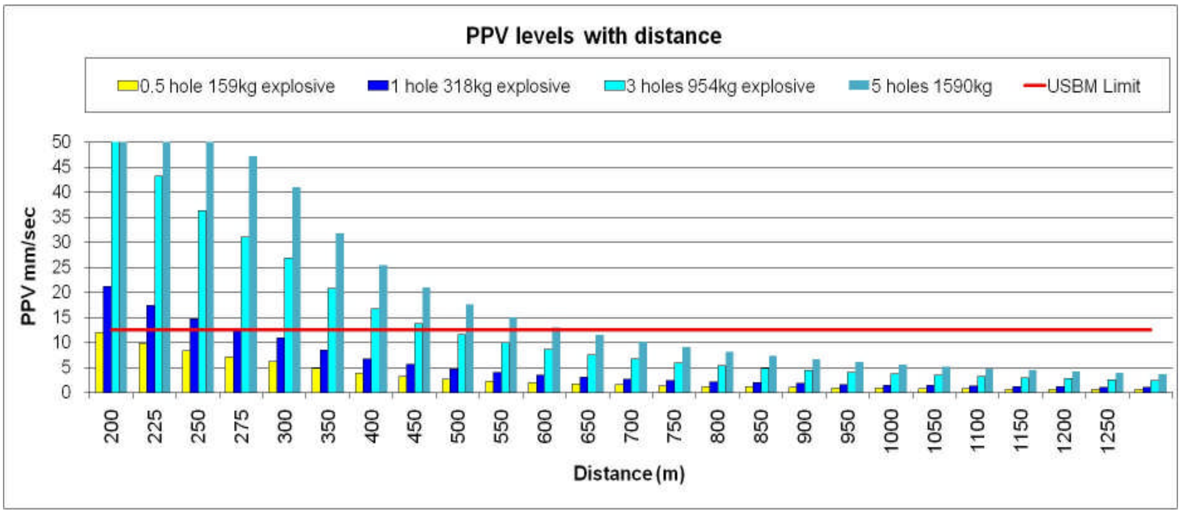
In the data table the vibration level that corresponds closely to the USBM threshold limit for private property has been highlighted. The results clearly show that the 12mm/sec threshold vibration limit is reached at a distance of 200 metres when 159kgs of explosive (0.5 hole) is detonated. When a single hole fires (318kgs of explosive), this level is reached at a distance of 275m. 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.

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

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

mine. The data obtained can be used to determine site specific constants for use in the prediction of ground vibration in the area.

VIBRATION						
Holes Detonated Per Delay >>>	**0.5**	**1**	**2**	**3**	**4**	**5**
Combined charge mass firing >>>	**159**	**318**	**636**	**954**	**1272**	**1590**
Distance increment in metres						
50	Tharisa	Tharisa	Tharisa	Tharisa	Tharisa	Tharisa
Distance (m)	**PPV**	**PPV**	**PPV**	**PPV**	**PPV**	**PPV**
200	11.95	21.17	37.51	52.41	66.45	79.88
225	9.84	17.43	30.88	43.15	54.71	65.77
250	8.27	14.65	25.96	36.27	45.98	55.27
275	7.07	12.52	22.18	30.99	39.29	47.23
300	6.12	10.84	19.21	26.84	34.04	40.91
350	4.75	8.41	14.90	20.82	26.39	31.73
400	3.81	6.75	11.95	16.70	21.17	25.45
450	3.14	5.55	9.84	13.75	17.43	20.96
500	2.64	4.67	8.27	11.56	14.65	17.61
550	2.25	3.99	7.07	9.87	12.52	15.05
600	1.95	3.46	6.12	8.55	10.84	13.04
650	1.71	3.03	5.36	7.50	9.50	11.42
700	1.51	2.68	4.75	6.63	8.41	10.11
750	1.35	2.39	4.24	5.92	7.50	9.02
800	1.21	2.15	3.81	5.32	6.75	8.11
850	1.10	1.95	3.45	4.81	6.10	7.34
900	1.00	1.77	3.14	4.38	5.55	6.68
950	0.91	1.62	2.87	4.01	5.08	6.11
1000	0.84	1.49	2.64	3.68	4.67	5.61
1050	0.77	1.37	2.43	3.40	4.31	5.18
1100	0.72	1.27	2.25	3.15	3.99	4.80
1150	0.67	1.18	2.09	2.92	3.71	4.46
1200	0.62	1.10	1.95	2.73	3.46	4.15
1250	0.58	1.03	1.82	2.55	3.23	3.88
1300	0.54	0.96	1.71	2.39	3.03	3.64



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.

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

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. Overcharged holes can generate amplitudes that exceed 142dB. Airblast amplitudes up to 135dB should not cause damage but it is recommended that the airblast be kept below the 130dB level. Suggested threshold limits for air blast have been proposed by Personn et.al. 1994.

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 can only be regarded as subjective. 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:

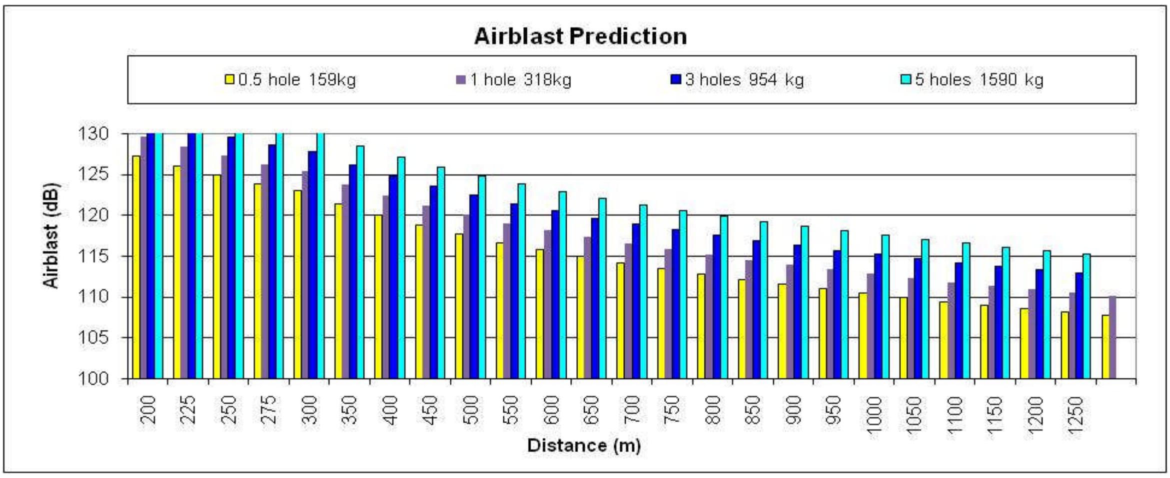
$$K = D/W^{0.33}$$

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

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

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. The data is graphed (below) and presented in table form. I have highlighted the 130dB level to allow a quick comparison to be made.



AIRBLAST						
Holes Detonated Per Delay >>>	0.5	1	2	3	4	5
Combined charge mass firing >>>	159	318	636	954	1272	1590
Distance increment in metres						
50	Tharisa	Tharisa	Tharisa	Tharisa	Tharisa	Tharisa
Distance (m)	**dB**	**dB**	**dB**	**dB**	**dB**	**dB**
200	127	130	132	133	134	135
225	126	128	131	132	133	134
250	125	127	130	131	132	133
275	124	126	129	130	131	132
300	123	125	128	129	130	131
350	121	124	126	128	129	129
400	120	122	125	126	127	128
450	119	121	124	125	126	127
500	118	120	122	124	125	126
550	117	119	121	123	124	125
600	116	118	121	122	123	124
650	115	117	120	121	122	123
700	114	117	119	120	121	122
750	113	116	118	120	121	121
800	113	115	118	119	120	121
850	112	115	117	118	119	120
900	112	114	116	118	119	119
950	111	113	116	117	118	119
1000	110	113	115	117	118	118
1050	110	112	115	116	117	118
1100	109	112	114	116	117	117
1150	109	111	114	115	116	117
1200	109	111	113	115	116	116
1250	108	110	113	114	115	116
1300	108	110	112	114	115	116

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 vertical cratering of the hole.

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012   Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

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 and aggregate sized at 10% of the hole diameter should be used as stemming material. Drill chippings and / or soil are inadequate. 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 - Past 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.

3.5 Pre Blast Surveys

Cracks occur in most structures but the owners are usually unaware of them. Virtually all of the houses in this neighbourhood suffer from crack damage, which ranges from minor to severe. 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 perimeter of the open 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. I recommend that a distance of one thousand five hundred metres (1,500 m) be considered. 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 as a number of houses in the area are poorly constructed and show signs of ongoing deterioration. Bear in mind that cracks in structures are dynamic in nature. They change

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

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 very important and should be carried out from the first blast. The information obtained can be used first and foremost to ensure that the predicted vibration amplitudes and the 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 with the blast design.

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 and the vector sum calculated from these values. 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 commonly used in South Africa and has by default become the accepted industry norm. The DIN standard is more stringent as it restricts vibration levels to lower limits than the USBM standard. I have attached information on the USBM standard for reference. I have also 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.

Specific locations for the positioning of the seismographs can be identified during the pre-blast survey. 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 may 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 a 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 as well as rainfall figures. This combined information shows very effectively which elements contribute to movement of the crack.

3.7 Legal requirements.

The legal requirements are covered by various acts such as the Explosives Act and the Mine Health and Safety Act. In addition the Department of Mineral and Energy Affairs (DME) may also have specific requirements.

Standard safety procedures associated with blasting operations should be applied. These include but are not limited to:

- Clear notification of blast times and location to be given. This information must be posted at the entrance to the mine for information of mine personnel. It must also be made available to members of the community. A method for distributing this information must 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.
- Placing guards to ensure that no people or animals re-enter the cleared blast area.
- Closing of roads within a 500m radius or other safe distance as determined by the blaster in charge must be considered.
- Traffic moving in all directions should be stopped at least 500m 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.

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.

- The use of detonating cord is prohibited.
- Electronic initiation will be required to ensure that individual hole firing is guaranteed so that the charge mass per delay is limited to one hole. This is essential given the proximity of the villages to the mine operations.
- As the blasting activity moves closer to the villages of Maditlokwa / Silver City and Tsilong the use of deck charges may be necessary to further limit the charge mass per delay. Electronic detonators must be used to ensure precise sequencing of the deck charges and of the blast.
- Clearing a safety area, normally a minimum of 500m radius, around the blast is essential. As the blasts move closer to Maditlokwa / Silver City and Tsilong more and more houses will fall inside this radius and the people living here will need to be evacuated. It may be necessary to organise bus transport, shelter, toilet facilities and refreshments. Special transport may be necessary for elderly and / or handicapped people.

- 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 lead to overburdening. Corrective action such as re-drilling the hole, not charging the hole or short charging the hole should be taken. This is necessary to help control fly rock, which cannot be tolerated.
- Production QC checks must be implemented as part of the Standard Operating Procedures. 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. This is necessary as fly rock cannot be tolerated.
- All holes must be stemmed closed with the correct stemming material. Drill cuttings and loose surface material are inadequate. Aggregate sized to approximately 10% of the hole diameter should be used. Any re-drilled or abandoned holes should also be stemmed closed.
- The surface tie up should be carried out according to the blast plan to ensure that the timing and sequencing of the blast proceeds as planned.
- Walk the blast after it has been tied up as a double check to make sure that all of the shock tube connectors or electronic detonators are firmly attached and properly connected.
- Strict raw material quality acceptance standards and procedures must be in place. No raw materials used in the production of the explosive should be accepted unless the delivery is accompanied by the manufacturer's certificate of compliance.
- This also applies to factory manufactured explosives such as boosters, packaged products and shock tube assemblies.
- 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.

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.

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

5. General.

The above report addresses routine ongoing drill and blast applications. Any sensitive structures will need to be addressed individually. Blasts will need to be specifically designed to accommodate these structures when mining moves into these areas.

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. Shaft, development, stope, reef, waste, presplit, secondary etc.);
- Hole diameter drilled;
- Blast pattern (staggered or square) as well as burden and spacing dimensions;
- 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 charge mass per hole and total amount of explosive per blast;
- Final explosive column rise and 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, and
- The prevailing weather conditions at the time of the blast.
- Longitude and latitude of the blast and the monitoring stations to allow the distance to the blast to be determined.

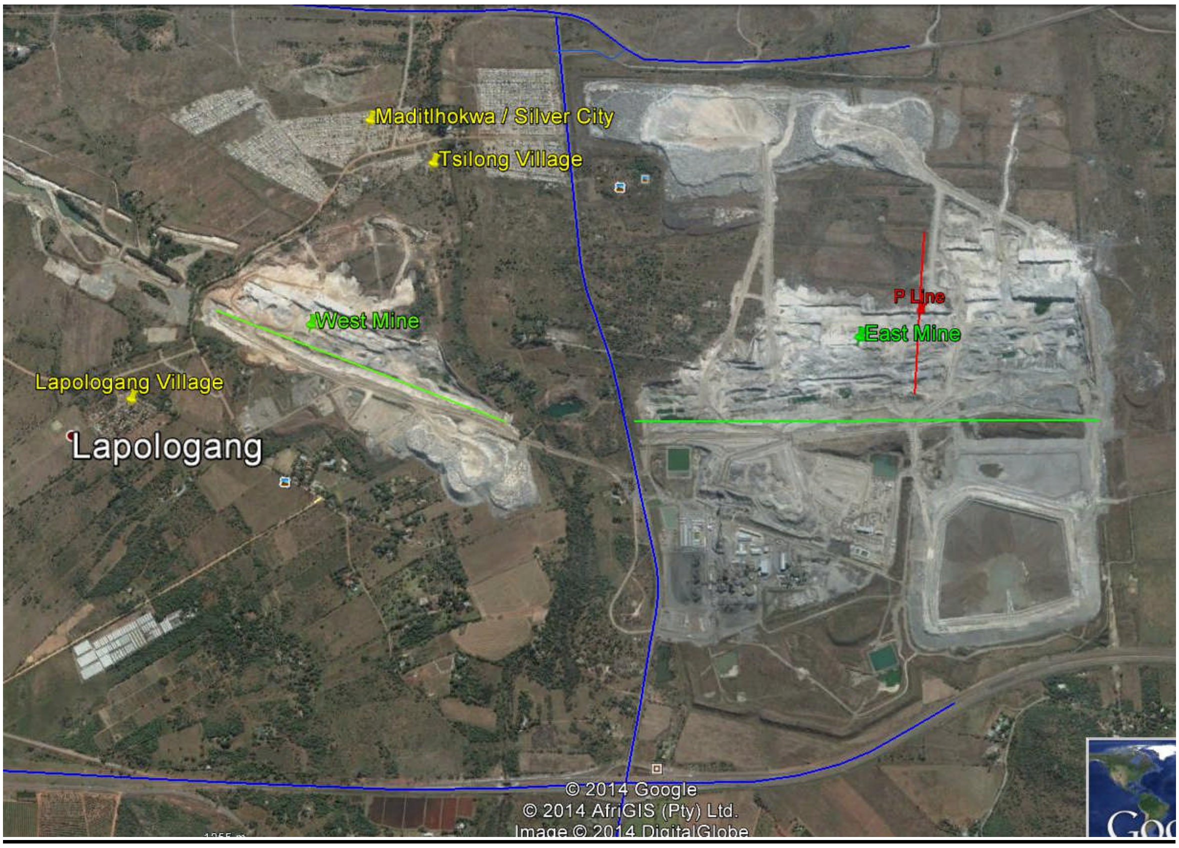
If you have any queries regarding the above, please contact me at 083 488 1392.

Yours sincerely

E. Köhler

Erik Kohler.

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

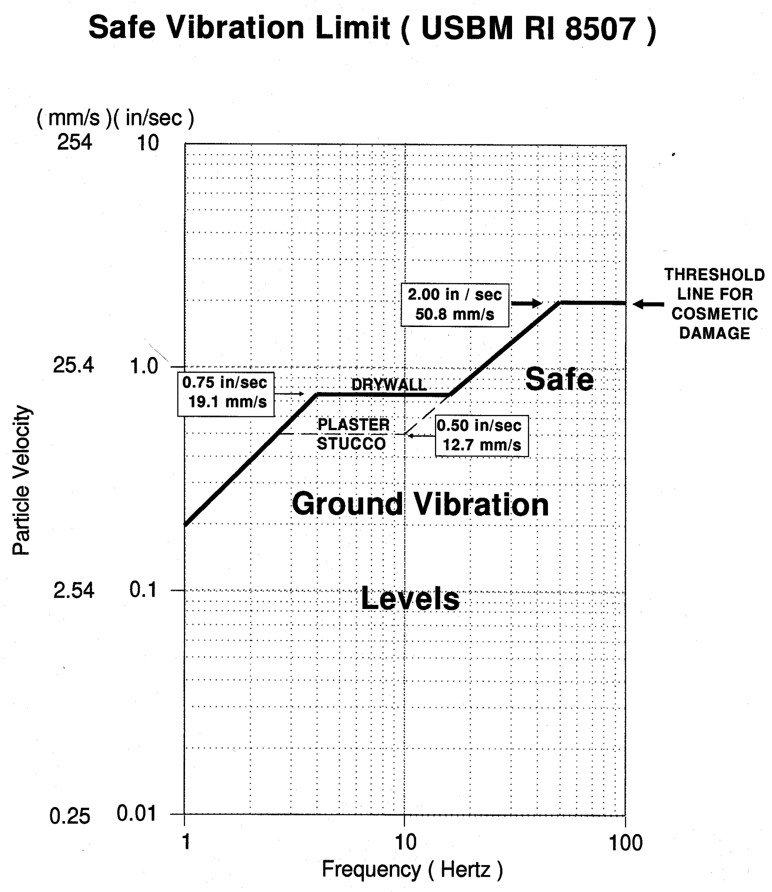


<u>Appendix 1</u>. Google Earth image of the Tharisa Minerals Mine.

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.

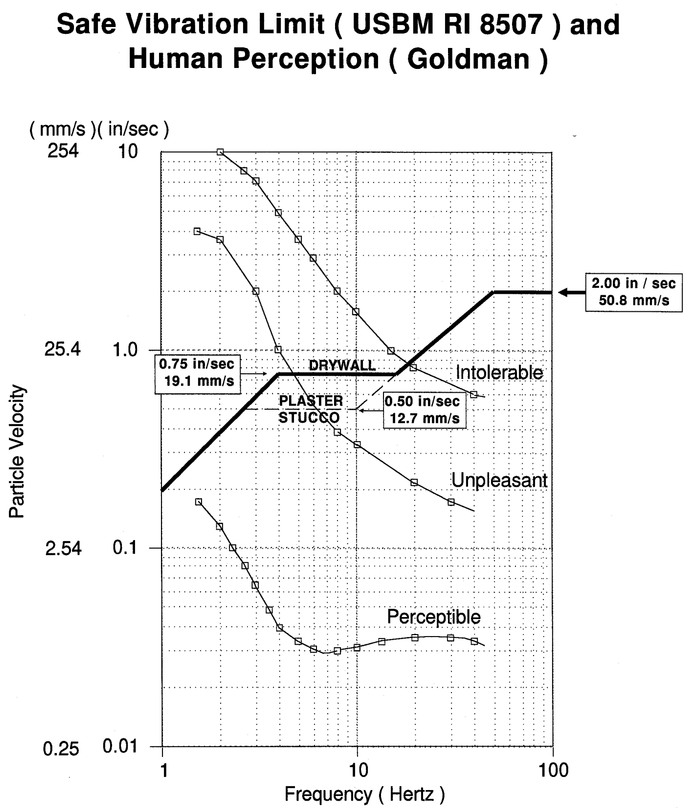
Human response to ground vibration

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.

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za

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.

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

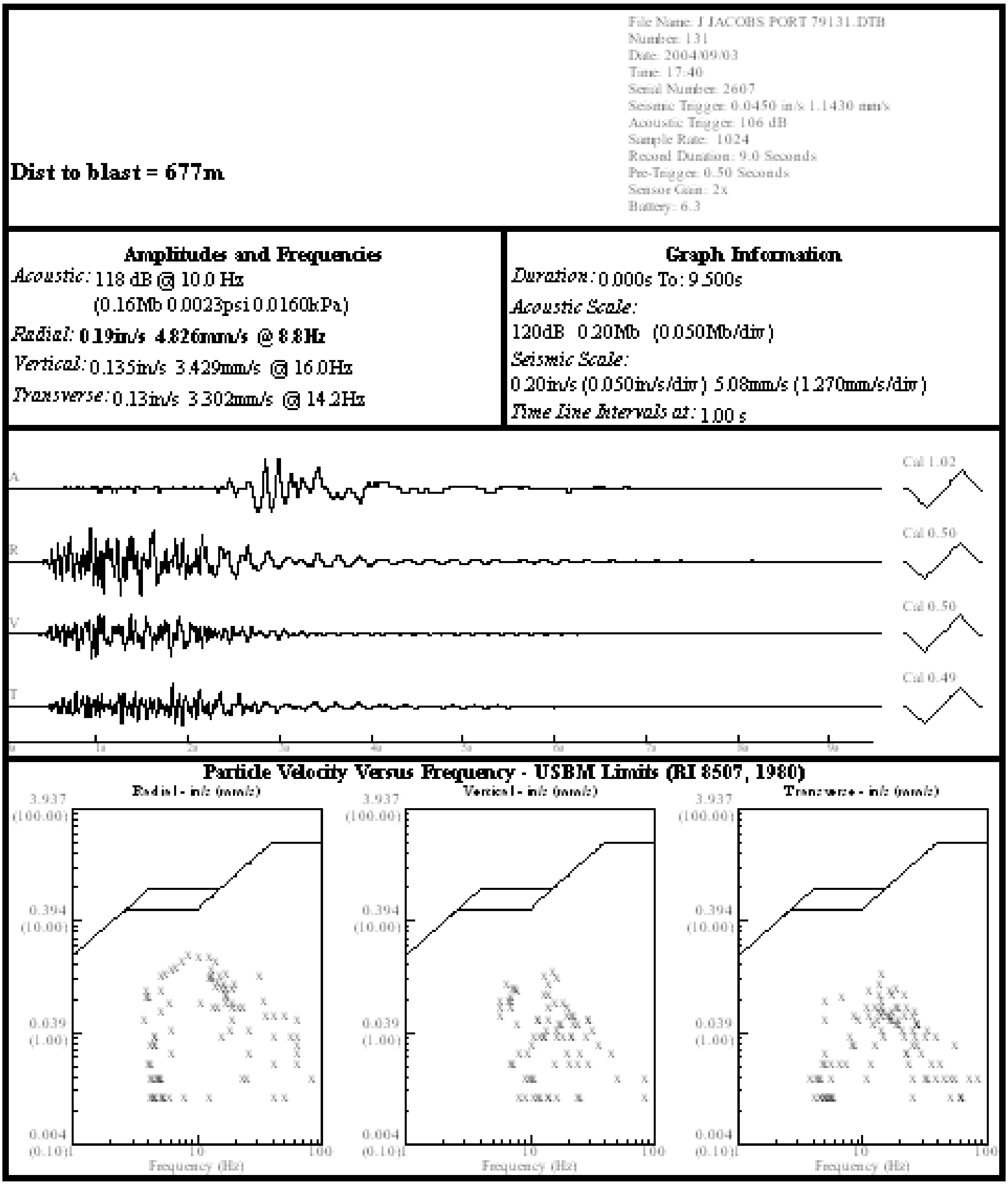
Siskind, D.E., Stagg, M.S., Kopp, J.W. & Dowding, C.H., 1980. *Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting,* U.S. Bureau of Mines RI 8507.

Chiappetta, R.F., 2000, *Vibration/airblast controls, Damage criteria, record keeping and dealing with complaints*. The Institute of Quarrying, Southern Africa, Symposium, Durban

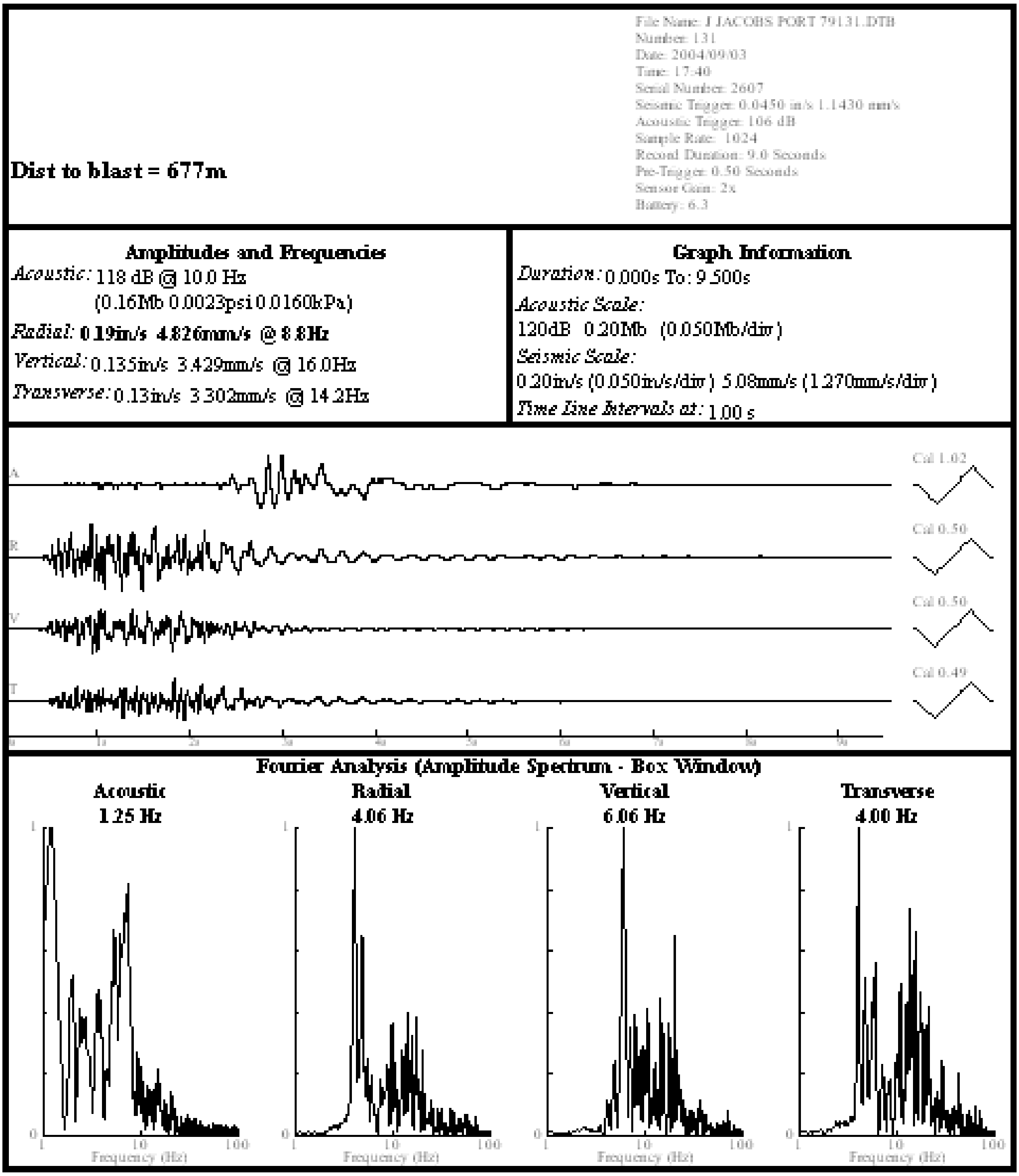
Persson, P-A, Holmberg, R and Lee, J, 1994, *Rock Blasting and Explosives Engineering*. CRC Press, USA.

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

Members: Erik Kohler (managing)
Tel: Fax to mail: +27 865501012 Cell: 083 488 1392
e-mail: ekohler@absamail.co.za



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



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