Client Report : Air Overpressure from Le Maitre Flash Report Effects

Clients : Le Maitre
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1. Preamble.

This report summarises the results of trials undertaken in Earls Court involving the initiation of a variety of Flash Report Effects. The trials were undertaken during an event organised by World Wrestling Entertainment.

2. Sound Pressure Scales.

Sound pressure is the general term used for changes in air pressure caused by sound waves. Peak sound pressure levels can be given in either Pascals(Pa) or Decibels(dB).

When sound recordings are to be used to either assess human annoyance or hearing damage it is normal for the raw sound wave to be processed via an 'A' weighting filter thus giving peak levels with units of dB(A). The 'A' weighting process effectively filters out much of the low frequency, sub-audible, energy in the recording. However, when recording sound pressure levels from concussive or explosive events much of the energy is sub-audible and it is normal to use unweighted signals giving peak values in dB(Linear). Such low frequency recordings are often referred to as air overpressure recordings and are normally taken as applying to frequencies above 2.Hz.

Although there is no clear guidance on the levels of air overpressure likely to cause damage to the human ear, a level of 140.dB(Linear) is often taken as a sensible maximum value. This value is typically applied to work entailing the use of poorly confined explosives, for example, demolition. It is therefore proposed that this level should also be applied to concussive effects used in stage and concert shows. It therefore follows that if levels above 140.dB(linear) are expected ear protection should be worn.

It is widely recognised that the levels of air overpressure required to cause structural damage is higher than 170.dB(Linear) with even weak windows surviving levels of 150.dB(Linear).

2. Earls Court Trials.

Le Maitre arranged for a trial monitoring programme to be undertaken at Earls Court in London during an event organised by World Wrestling Entertainment. The show included the firing of series of closely spaced flash reports of various sizes. The reports were fired in concussion mortars in a rack suspended 12m above the arena floor in the back stage area. The opportunity was also taken to record single events fired in the same rack before the show to determine if the presence of an audience was significant or not.

Trial 1 Details
The first trial was undertaken in the afternoon before the show with no audience. Three single flash reports were fired, one each of, numbers 1 to 3.

Trial 2 Details
The second trial was undertaken during the show and consisted of a salvo of 8 flash reports fired over a 1.6 second period in the following order : 2,2,2,3,3,4,4 and 5.

The nominal powder weights for the devices are as follows :

No 1 = 2 grammes No 2 = 5 grammes No 3 = 10 grammes

No 4 = 14 grammes No 5 = 19 grammes

3. Monitoring Details.

Monitoring of air overpressure was undertaken with instruments complying with the specification recommended by the International Society of Explosives Engineers. These instruments record unweighted sound pressure levels down to 2.Hz and therefore report peak values in dB(Linear).

Monitoring locations were established as listed below.

Monitoring Point 1 : Directly under the concussion mortar rack with a vertical separation distance of 12m.

Monitoring Point 2: Located at the back of the main stage with a separation distance to the mortar rack of 13m. This point was located 1.5m above floor level to simulate a standing person.

Monitoring Point 3: Located at the nearest point members of the public could be with a separation distance to the mortar rack of 26m.

Monitoring Point 4: Located in the main seating area at a distance of 69m from the mortar rack. This monitoring point was only employed in the trial carried out with no audience.

Monitoring Point 5: Located in the main seating area at a distance of 74m from the mortar rack. This monitoring point was only employed during the actual WWE show.

4. Monitoring Results.

4.1 Peak Values.

The recorded peak values in dB(Linear) are listed in the tables below.

Trial 1 : With No Audience

Flash Report Number	Powder Weight (g)	Monitoring Point Number and Unit Serial Number				
		1 *1402*	2 *1410*	3 *2836*	4 *1549*	5 *1549*
1	2	126	126	122	114	
2	5	137	135	130	122	
3	10	142	138	133	125	

Trial 2 : During Show with Audience

Flash Report Number	Powder Weight (g)	Monitoring Point Number and Unit Serial Number				
		1 *1402*	2 *1410*	3 *2836*	4 *1549*	5 *1549*
2	5	135	134	132		119
2	5	140	135	132		See note
2	5	139	136	131		See note
3	10	145	139	137		123
3	10	143	139	131		See note
4	14	145	141	138		126
4	14	145	142	138		See note
5	19	147	143	139		128

Note : It was not possible to determine the peak values associated with each flash report at monitoring point 5 due to reverberation and noise from the music system.

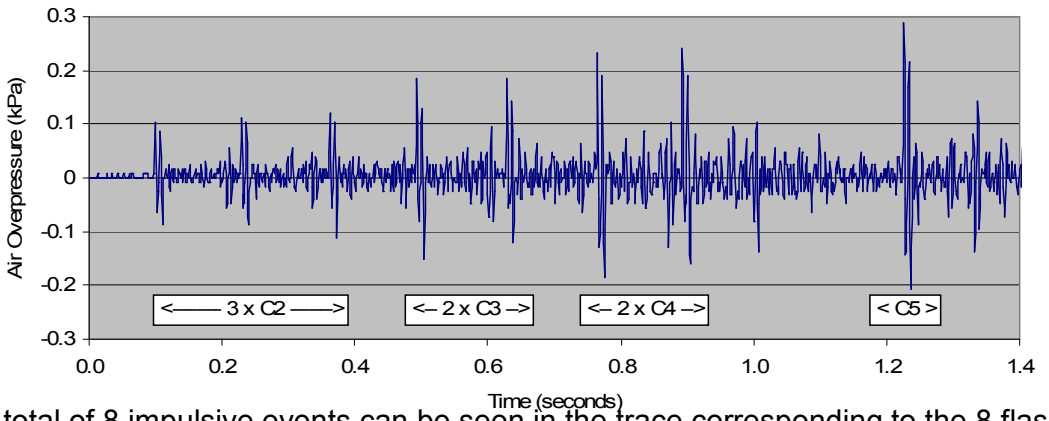
In addition to the standard monitoring instrument at point 3 a ‘Type 2’ Sound Level Meter was also employed. During the Trial 2 salvo, this equipment recorded a peak sound level of 123.3 dB(A) with an unweighted peak of 135.2 dB. During much of the show the sound level at this location was between 90 and 110 dB(A).

4.2 Pulse Width.

Examination of the air overpressure traces shows that the duration of the positive portion of the pressure pulses for all types of flash report were in the region of 4 to 6 milliseconds. There is no noticeable broadening of the pulse over the distances monitored.

4.3 Example Recording.

Shown below is the recording made during the Trial 2 Salvo at monitoring point 2 which was located at the back of the main stage 1.5m above floor level.



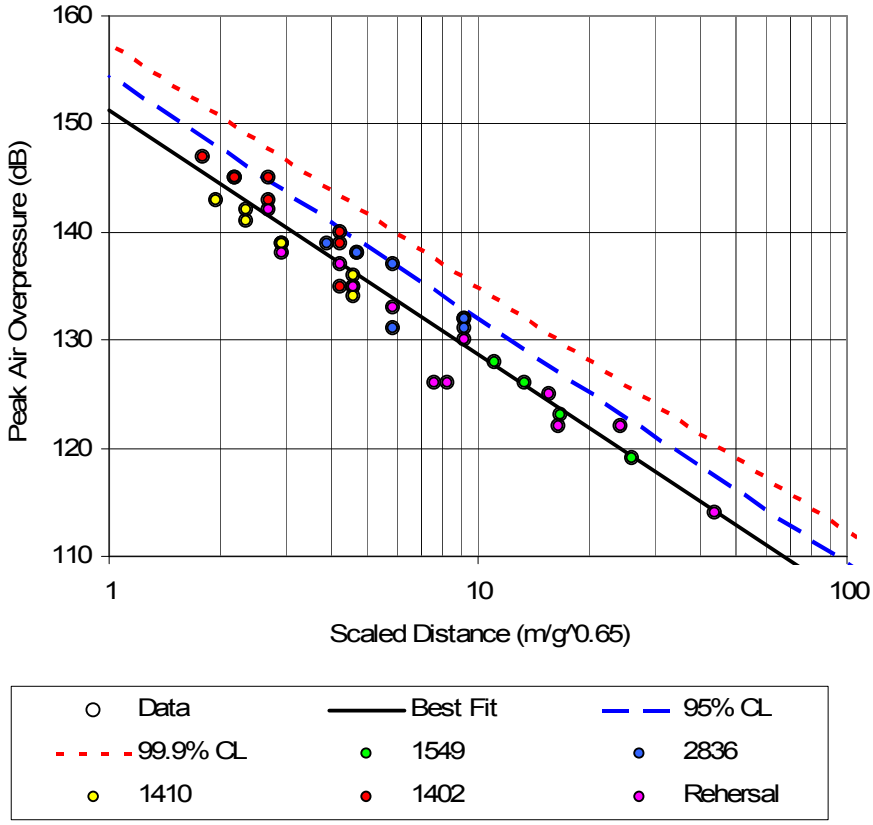
A total of 8 impulsive events can be seen in the trace corresponding to the 8 flash reports. The type of flash report is indicated on the trace and it can clearly be seen that the size of the impulse relates to the charge weight in the device.

Careful examination of each impulse shows a strong reflection from the floor of the auditorium occurring with a time lag in the region of 8 milliseconds. The strength of the pulse is the result of the floor being a ‘hard’ surface at this location. The presence of seats other floor coverings and/or people would have considerably reduced the strength of the reflected pulse. It can be seen that the reflected pulse has a lower peak value in all cases. If the pulse width had been longer than 8 milliseconds then we could have expected an increase in the peak level.

5. Regression Analysis.

5.1 Data from Trial on 23/4/2007.

The data recorded from both trials undertaken on 23/4/2007 has been input into a standard regression analysis. The regression line is show below.



The data on the graph has been colour coded to indicate the individual monitoring locations and to highlight the data recorded during the rehearsal. Examination of the graph shows no significant difference between any of the monitoring points or between the data recorded in the show and the rehearsal.

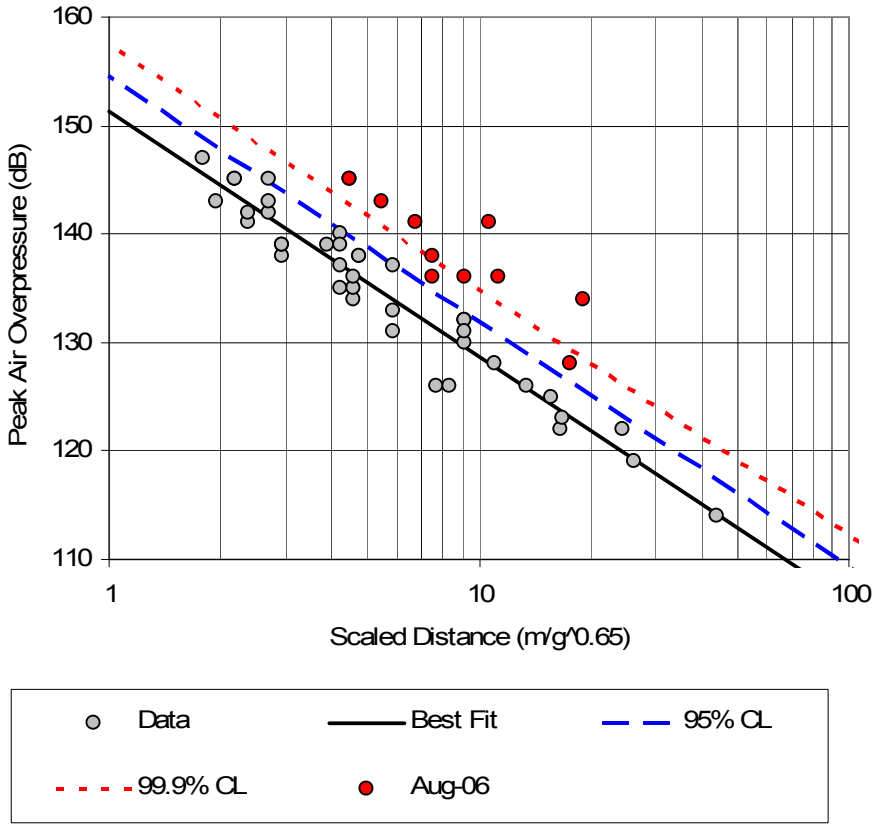
Normally, in work involving explosives, the scaled distance factor is worked out using a power factor of 1/3, however, in this case a factor of 1/1.55 has been found more appropriate. It is not clear why this factor is more relevant although it could be due to the pyrotechnic nature of the devices.

The above regression line can be used to generate predictions of air overpressure levels against distance and charge weight and such an approach is used in section 6 of this report.

5.2 Comparison of Data with Previous Earls Court Trial.

Trials were undertaken in August 2006 in Earls Court with many of the same flash reports but with the auditorium empty and with the concussion mortars placed on the floor.

The graph below shows the data from this trial plotted on the regression graph shown previously.

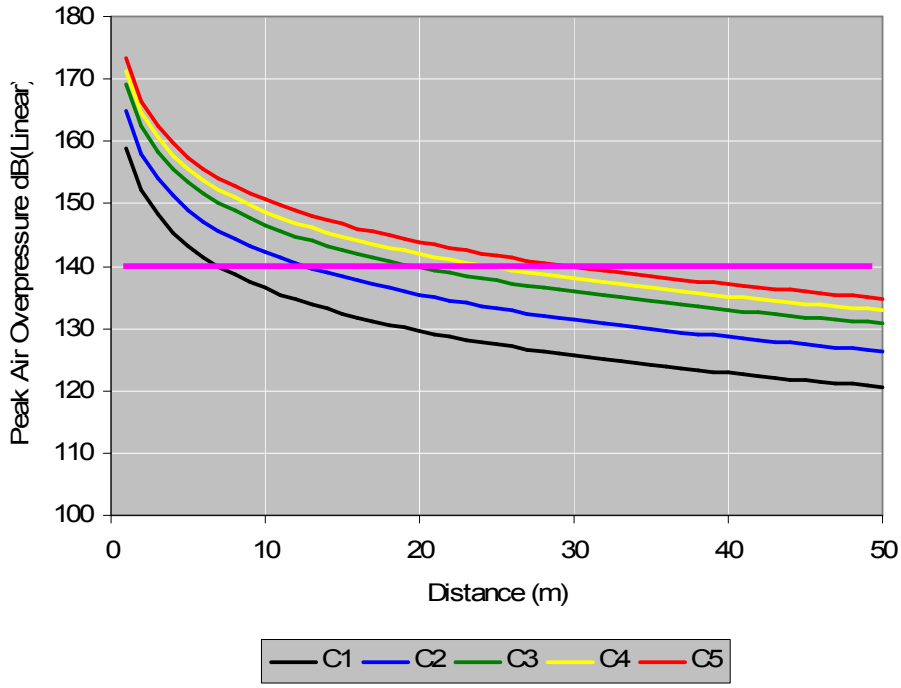


It can clearly be seen that the data from the previous trials lies well above the new data set. However, it can also been seen that the data trend for the August 2006 data is approximately parallel to the latest regression line suggesting the attenuation of the air overpressure pulses is the same. The most likely explanation of the difference is therefore the fact that the August 2006 data was fired with the mortar pot on the floor and the latest data was fired with the mortar pots on a rack suspended 12m above floor level. It would appear that the rack has acted as a shield reducing the air overpressure level at source.

It should therefore be noted that the regression line generated from the WWE data can only be used to generate prediction (and therefore limiting distances) for devices fired on a mortar rack suspended above the auditorium floor.

6. Air Overpressure Predictions and Limiting Distances.

Using the regression line given in section 5.1 along with the charge weight in each type of flash report it is possible to generate a prediction of peak air overpressure for each device over a range of distances as shown in the graph below.



The graph shown is based upon a prediction with a 95% confidence level. In other words there is a 1 in 20 chance that the level will be higher than predicted. However, even if a level is higher than predicted it is highly unlikely to be substantially higher.

Also indicated on the graph is a level of 140 dB and the intercept of this line with the lines relating to each device gives a limiting distance below which 140dB is likely to be exceeded.

For the trial these values are given in the following table.

Flash Report Number	1	2	3	4	5
Charge Weight (g)	2	5	10	14	19
Limiting Distance (m)	7	13	20	25	30

7. Conclusions.

A series of trials have been undertaken relating air overpressure levels to various sizes of flash reports.

A table of limiting distances has been generated indicating distances below which a peak air overpressure level of 140 dB(Linear) can be expected to be exceeded. If 140.dB(Linear) is considered to be a reasonable limiting value for people then either people should be kept at least the limiting distance away from the flash reports or they should be provided with ear protection.

It is important to note that the prediction upon which the limiting distances are based has been carried out at a 95% confidence level.

A comparison has been made between peak levels monitoring from devices fired on a mortar rack suspended 12m above floor level and historical data where the devices were fired in mortars at floor level. There are strong indications that floor based mortars will generate substantially higher levels than indicated in the table of limiting distances. This table should therefore only be used for devices fired in a suspended mortar rack. Additional work is required to generate a comparable table for floor based devices.

As with all such work there is a degree of variability that can be expected in levels generated by flash reports due to variability in charge weights, confinement and auditorium environment. It is therefore recommended that levels continue to be monitored to increase the size of the current data set.

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