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THE PROPAGATION OF BLAST NOISE ACROSS ACOUSTICALLY HARD SURFACES

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ABSTRACT
In a previous paper the results of a trial to study the propagation of high energy, low frequency impulse noise across the sea were discussed. Water surfaces are generally considered as acoustically "hard" and of significance, as far as environmental effects are concerned, is the distance over which audible, high frequency energy dissipates as the wave propagates downwind. The waveforms were compared with those obtained from trials held over grass, an acoustically "soft" surface, where the high frequency energy was found to have dissipated over much shorter distances. It was suggested that the loss of high frequency energy is a function of the surface roughness which, in the case of the sea, is classified by the so called "sea state" and that the high frequencies would have remained in the wave to an even greater distance if the sea had been calmer. In order to investigate the effect of surface roughness additional trials have been carried out over smooth, acoustically hard surfaces (airfield runways) and this paper presents the results of those trials.

1 - INTRODUCTION
A study into the propagation of high energy, low frequency impulse noise across the sea was discussed in a previous paper [1]. Water surfaces are usually considered as being acoustically hard and in the study comparisons were made with blast noise propagating across grass, an acoustically soft surface. There was some evidence that the high frequency energy in the blast was retained over greater distances than expected as the wave propagated across the "harder" water surface. Consequently the results from another trial where the propagation of blast noise across a concrete surface was compared with propagation across grass have now been studied. This paper describes the trial and compares the results with those reported previously.

2 - TRIAL PROCEDURES
The trial took place on an airfield which had a concrete runway 2500m long and 45m wide with grass on either side. It was orientated at 027degrees. During the trial the wind was predominantly from the NE and firing points were set up at either end of the runway so that measurements could be made of noise propagating both downwind and upwind. For the downwind conditions, measuring points were set up along the center line of the runway, in line with the NE firing point at distances of 200m, 500m, 1000m, 1500m and 2000m. A similar array was located 22.5m to the side and parallel to the runway with a second firing point located on the grass. The upwind conditions were covered by simply re-locating the 200m point towards the south westerly end of the runway and repositioning the runway firing point at a third location at the south westerly end.
Low frequency capacitor microphones were located on stands 2m above the concrete runway and grass measuring points and the signals recorded for subsequent laboratory analysis on wide band digital tape recorders. The microphone diaphragms were set horizontally with their diaphragms at grazing incidence and standard foam windshields were fitted. An acoustical calibration was made on each tape before and

after the series of shots. An additional measuring system using an AWE B12 blast gauge was located at 25m from the firing point in use in order to calibrate the charges.

3 - MEASUREMENT CONDITIONS

Meteorological measurements of wind velocity and temperature were made close to the north eastern firing points at the top of a 10m mast. Relevant data is reproduced in table 1. Two sets, each of three charges of PE4 of 125gm or 1kg weight were fired at one and two meters above the ground respectively at each of the three firing points viz. NE over concrete, NE over grass and SW over concrete. Each set of three charges was fired within a 20 minute period to avoid significant weather drift.

Shot No	Time BST	Firing Point	Charge Weight Kg	Wind Direction Deg	Wind Speed M/s	Air Temp deg C
1	14.38.20	NE hard	0.125	78	5.2	14.8
4	15.03.37	NE hard	1.0	50	5.7	14.7
7	15.55.38	NE soft	0.125	47	8.2	14.1
10	16.16.01	NE soft	1.0	68	7.1	13.7
13	17.57.00	SW hard	0.125	83	5.8	13.1
16	18.17.20	SW hard	1.0	54	6.3	13.0

Table 1: Summary of meteorological conditions on the airfield.

4 - RESULTS

Typical waveforms of propagation both downwind and upwind, across concrete, and across grass for both 125gm and 1kg charges are shown in figures 1 to 6. The measured parameters, unweighted positive peak level (P+), sound exposure level (SEL) and their C-weighted values CP+ and CSEL, are given in table 2.

The unweighted peak levels are also shown in figures 7 to 10. Results from each of the three individual shots have been plotted for each condition. The full line represents the calculated peak level based on the ANSI standard [3] using a TNT pressure equivalence factor for PE4 of 1.14 as determined during previous trials by Ford [2].

5 - DISCUSSION

The downwind waveforms are shown in figures 1, 2, 4 and 5. With the firing point and receiving points over hard concrete the high frequencies in the waveform are retained out to the 2km position. This was also observed with propagation downwind over water [1]. With source and receiver over soft grass the high frequencies are lost much quicker, indeed there is very little showing in the waveform at 500m and this confirms observations made in earlier trials over grass [2]. Over both hard and soft ground, the separation of the leading and trailing parts of the wave increases with distance in a manner similar to a supersonic N-wave. This was also observed in earlier over sea trials [1].

Upwind waveforms are shown in figures 3 and 6. With the source and receiver located over the hard concrete there is some retention of the high frequency energy but this is mainly dissipated by 500m. With downwind propagation the measured parameters shown in figures 7 to 10 show a small reduction in peak overpressure compared with the ANSI predictions. There is a significant scatter between individual sets of results particularly beyond 1km. A possible cause of this is small meteorological changes at the time of firing and it should be noted that the scatter is greater than differences caused by propagation across different surfaces.

Also shown in figures 7 and 8 are the peak overpressures measured under upwind propagation conditions. Here the results fall significantly below the ANSI prediction. However the predicted lines do not take meteorological effects into account and the effect is similar to that reported previously [1,2]. Figures 9 and 10 give the soft ground results and shows that there was a much larger divergence from the predicted line for the 0.125kg charge which can be attributed to the rapid loss of high frequencies in the wave with distance from the smaller charge.

In figure 11 peak overpressures recorded from 1kg charges during both upwind and downwind propagation over a hard surface are compared with results obtained previously over the sea. As already observed the hard concrete surface results from the present study follow quite closely the ANSI predictions but do not exceed them in contrast to those recorded over the sea and reported in [1]. A more detailed analysis of the waveforms over the different surfaces will be required in order to elucidate the reason for enhanced pressure over water. As suggested in [1] this may be produced by channelling or it may be the result of more complex physical/atmospheric effects.

distance, m	P+, dB	SEL, dB	CP+, dBC	CSEL, dBC
Shot 1, 0.125kg PE4 @ 2m above hard ground; waveforms recorded @ 2m above hard ground				
25	163.2	133.6	162.0	132.9
200	138.6	113.4	136.6	112.0
500	129.3	105.7	127.3	104.6
1000	122.7	96.9	120.7	96.0
1500	119.3	92.6	118.2	91.7
2000	111.5	86.9	108.1	85.4
Shot 4, 1kg PE4 @ 2m above hard ground; waveforms recorded @ 2m above hard ground				
25	171.5	143.8	170.4	142.2
200	146.7	123.7	145.6	121.3
500	139.0	115.4	137.8	113.1
1000	130.1	105.6	128.1	103.2
1500	124.3	100.6	122.8	97.7
2000	118.5	98.2	117.2	93.8
Shot 7, 0.125kg PE4 @ 1m above soft ground; waveforms recorded @ 2m above soft ground				
25	157.1	130.7	156.0	129.6
200	132.1	110.4	127.8	108.8
500	122.9	101.6	118.2	99.0
1000	115.8	95.4	111.5	92.5
1500	110.6	90.3	109.5	87.3
2000	105.5	89.9	103.9	85.6
Shot 10, 1kg PE4 @ 2m above soft ground; waveforms recorded @ 2m above soft ground				
25	167.0	142.4	166.1	140.5
200	143.8	122.9	138.9	119.9
500	133.2	113.8	127.3	109.9
1000	126.6	108.9	121.3	104.9
1500	123.6	105.5	118.3	101.6
2000	120.8	104.0	116.9	99.8
Shot 13, 0.125kg PE4 @ 1m above hard ground; waveforms recorded @ 2m above hard ground				
25	162.6	133.7	161.7	133.0
200	132.7	109.6	130.5	108.0
500	118.4	96.1	113.4	93.6
1000	103.9	86.7	99.0	81.7
1500	96.7	83.9	85.2	72.4
Shot 16, 1kg PE4 @ 2m above hard ground; waveforms recorded @ 2m above hard ground				
25	170.4	143.6	169.5	142.0
200	142.1	121.2	139.8	118.1
500	129.9	109.7	123.6	105.4
1000	122.8	102.0	114.2	97.5
1500	113.3	95.8	104.4	88.4
2000	108.9	91.8	97.7	84.4

Table 2: Measured parameters for figures 1 to 6.

Table 2 shows clearly the considerable difference between the unweighted and C-weighted pressures which increase with distance and range from 1-11dB. This result is similar to that reported in a previous paper [1]. The results of this and earlier studies shows that there is a very significant effect due to the nature of the surface as well as to the meteorological conditions in determining the distance at which a given pressure level is obtained for a particular charge weight. This has an important bearing in a number of fields not least that of health and safety. Taking the 140dB peak level as an example the ANSI line predicts it will occur at a distance of about 470m from a 1kg charge whereas the "oversea" results produced this level at a distance of nearly 700m; an increase of almost 50%.

In reporting the trials results no attempt has been made at this stage to determine whether the "cube root scaling laws" [4] hold at these longer distances from the charges. Sufficient data has now been obtained from a range of charge weights for such an assessment to be carried out.

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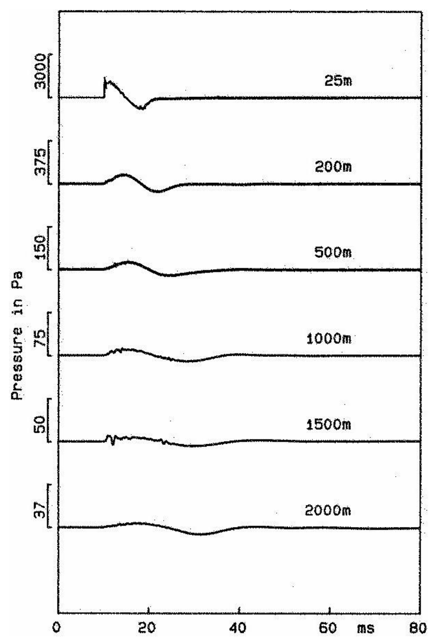

Figure 1: Shot 7, 125g PE4 @ 1m above soft ground; waveforms @ 1m above soft ground.

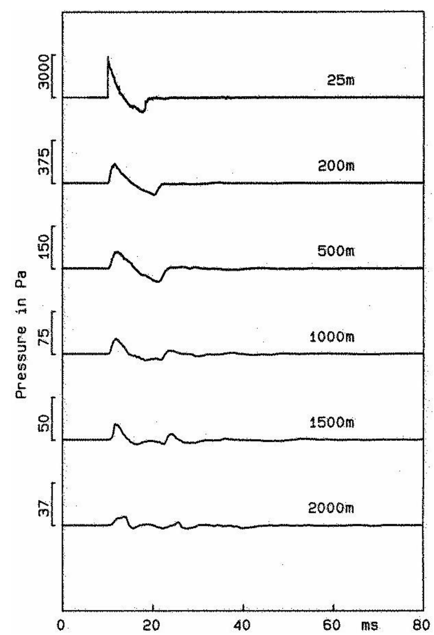

Figure 2: Shot 1, 125g PE4 @ 1m above hard ground; waveforms @ 1m above hard ground.

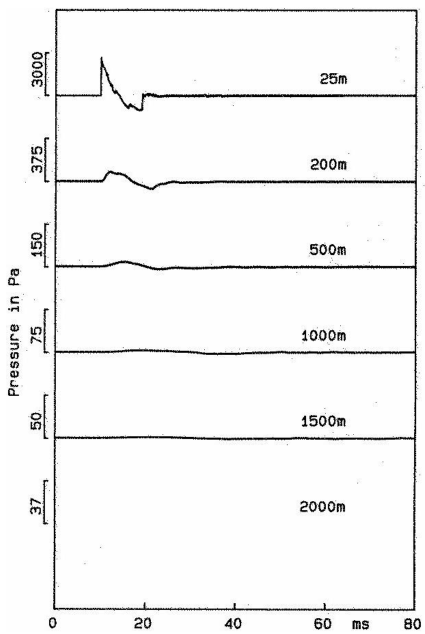

Figure 3: Shot 13, 125g PE4 @ 1m above hard ground; waveforms @ 1m above hard ground.

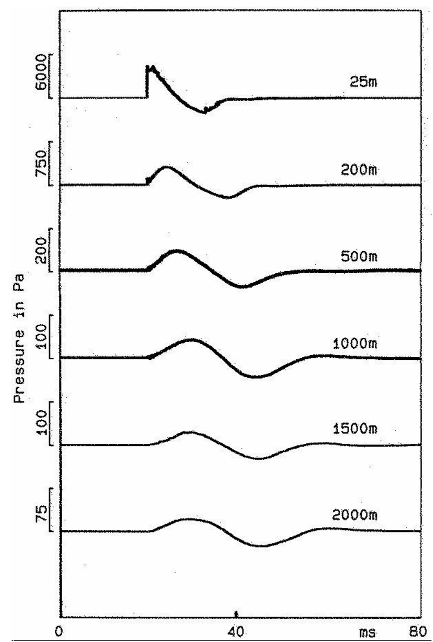

Figure 4: Shot 10, 1kg PE4 @ 2m above soft ground; waveforms @ 2m above soft ground.

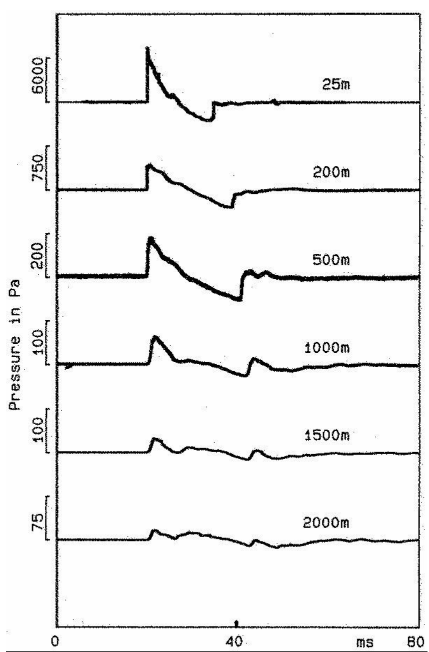

Figure 5: Shot 4, 1kg PE4 @ 2m above hard ground; waveforms @ 2m above hard ground.

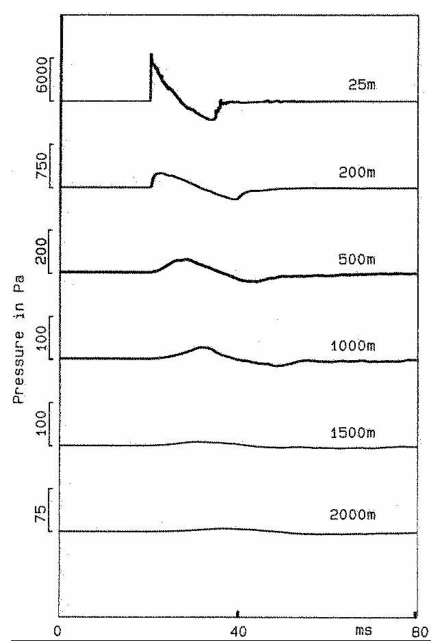

Figure 6: Shot 16, 1kg PE4 @ 2m above hard ground; waveforms @ 2m above hard ground.

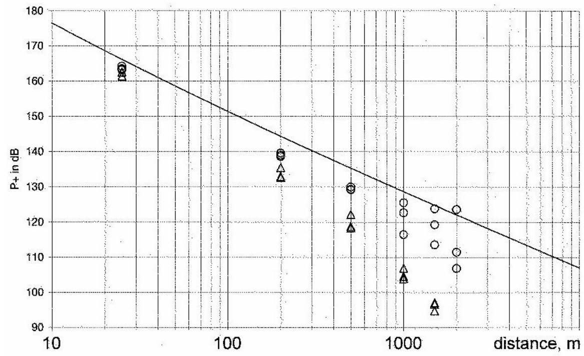

Figure 7: Propagation over a hard surface; 125g of PE4; ◯ - downwind; Δ - upwind; – - ANSI Prediction.

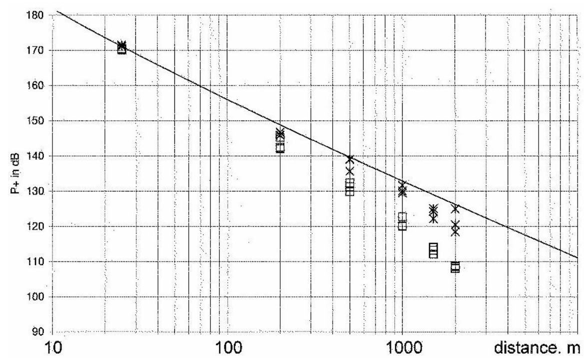

Figure 8: Propagation over a hard surface; 1kg of PE4; × - downwind; □ – upwind; – - ANSI Prediction.

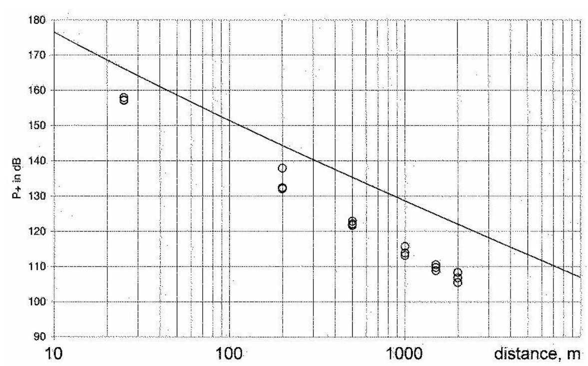

Figure 9: Propagation over a soft surface, downwind; 125g of PE4; – - ANSI Prediction.

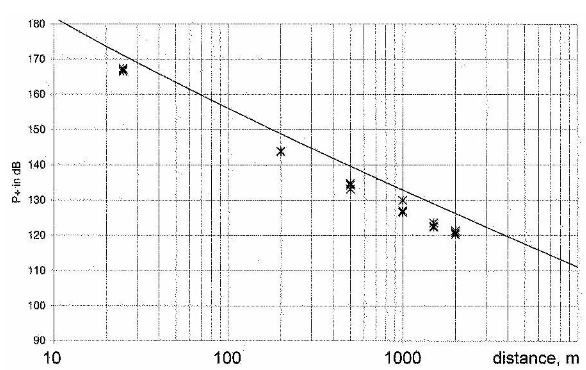

Figure 10: Propagation over a soft surface, downwind; 1kg of PE4; – - ANSI Prediction.

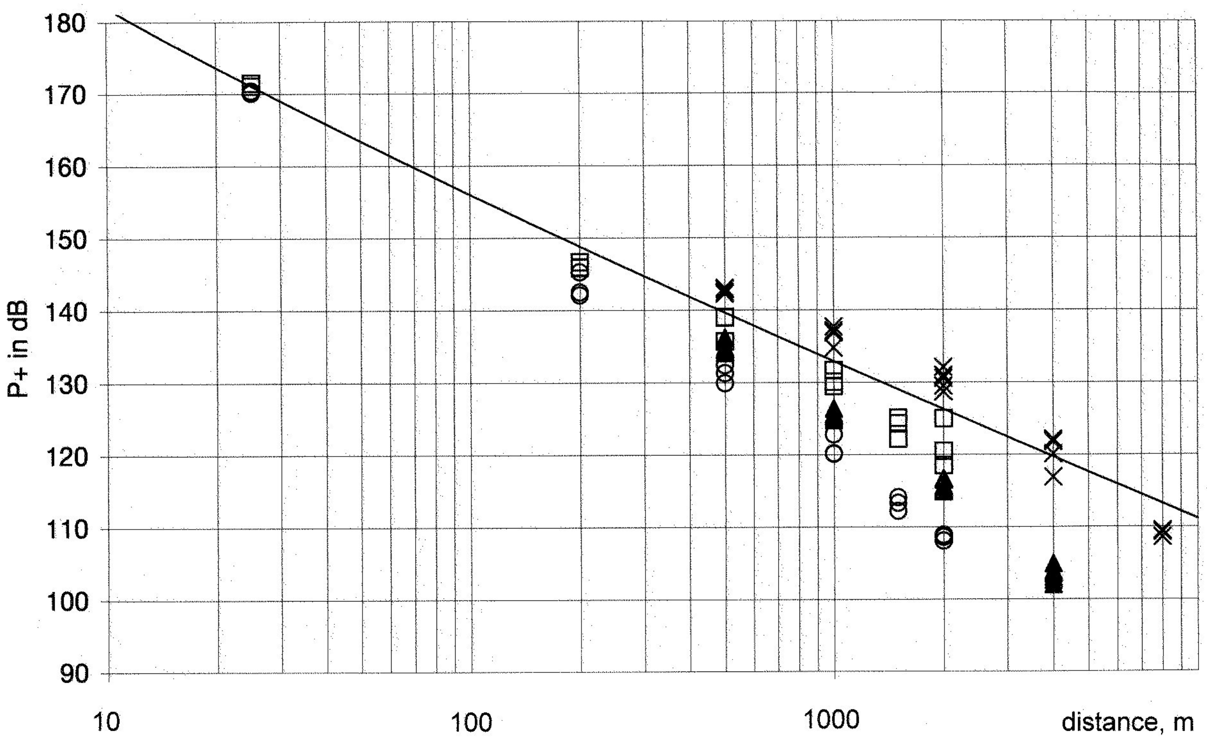

Figure 11: Propagation over concrete and sea for 1kg of PE4; × - propagation over sea, downwind; ▲ - propagation over sea, upwind; □ - propagation over concrete, downwind; ○ - propagation over concrete, upwind; — - ANSI Prediction.