inter•noise 96
25th Anniversary Congress – Liverpool
INCE: 71.1.9

IMPULSE NOISE MEASUREMENTS IN A FOREST DURING SUMMER AND WINTER CONDITIONS - AN OVERVIEW OF MEASUREMENTS

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1. INTRODUCTION

During the recently completed impulsive noise blast trials conducted during the summer and winter in Norway [1] over 30,000 individual measurements were successfully made. These measurements were gathered by numerous agencies from four countries. The types of measurements included: 1) time histories of pressure/noise [2], accelerations, and seismic waves [3], 2) peak noise, 3) surface acoustic impedance [4], 4) vegetation and snow characterization [5], and extensive weather measurements [6]. One benefit of this set of measurements is that they where spread across a wide area surrounding the impulsive noise sources which should provide an indication of the variation of sound propagation in the selected directions.

This paper will not discuss all of the measurements since they are so numerous and references to measurements not discussed herein are cited. Instead, this paper will concentrate on the measurement of the pressure/noise time histories. While the majority of pressure/noise measurements were accomplished with common Brüel & Kjær (B&K) instruments some combinations of new B&K equipment were used which could vary the results. Also, several unique techniques were used for this same measurement in attempts to validate each technique. A description and comparison of these measurements will be given.

2. SCOPE

There were five measurement stations nominally located 12 km apart. Each station had at least two or more B&K microphones located at various elevations. The center station also had the experimental gages located at the ground surface and at a 4 m elevation (other measurement elevations were used on the September trials but will not be discussed here).

3. TRANSDUCERS

General

While the acoustician prefers the use of microphones, the blast physicist prefers the use of pressure gages. The operational characteristics of these two measurement techniques can vary widely. Most of the measurements, on these trials, involved the use of B&K model 4147 microphones. This has been the standard microphone used during the recent past for impulsive noise measurements. However, B&K no longer makes this unit and today provides an 'equivalent' model 4193 microphone.

In an attempt to pacify the blast physicist, several commercially available semi-conductor gages were evaluated during the trials. A high sensitivity/"solid state microphone" - model Chaparral II, manufactured by Chaparral Physics Consultants of New Mexico, a modified differential pressure transducer - model P305D, manufactured by Validyne, a piezoresistive transducer - model XT-190, manufactured by Kulite Semiconductor Inc., and a piezoelectric transducer - model 132A41 'ICP Sensor', manufactured by PCB Piezotronics were fielded.

B&K Microphones

The changes from the B&K microphones from the model 4147 to the 4193 have some consequences. The 4147 has a frequency range from 'near' DC to 20 kHz. The 4193 has a frequency range between 70 mHz to 20 kHz. However, by implementing a Low Frequency adapter the lower cut-off frequency will be reduced down to 0.1 Hz. But, the inclusion of this adapter reduces the sensitivity of the microphone by 16 dB.

In general, these microphones are limited in the operating environment and have a relatively high cost.

Chaparral Microphone

The Chaparral gage is a high sensitivity, low frequency (0.1 Hz) microphone. The gage has been typically used to measure infrasound (extremely low frequency) at ranges of thousands of km [7]. The pressure range is between a few tenths to several tens of Pascals.

This gage is limited in the operational environments similar to the B&K microphones. Due to the high sensitivity, wind is a problem causing high background noise. Wind shields can be used but the frequency range is then greatly reduced. The cost of these gages is very high.

Validyne Gage

The Validyne pressure gage utilizes a diaphragm in a chamber. The gages are designed to measure differential pressures. In order to measure dynamic changes in ambient pressure it is necessary to partially seal off the chamber on one side of the diaphragm to provide a volume of air at reference pressure. This partial seal is accomplished by adding a precision needle valve to the reference volume chamber. This valve is adjusted to provide a very slow leakage rate so that the gage responds to frequencies above 0.01 - 0.05 Hz. If completely sealed off, the gage would behave as an altimeter and barometer.

The sensitivity of the gage is dependent on the thickness of the diaphragm used, but with the thinnest diaphragms the sensitivity ranges near ± 5 Vdc at full scale (550 Pa). The frequency response of the gage is DC to 200 Hz flat. The gages are relatively low in costs and can operate in harsh environments.

Kulite Pressure Gage

The Kulite pressure gage is a piezoresistive transducer with a maximum overpressure ranges up to 206 MPa. The gages used during this effort had a maximum range of 13 kPa and a sensitivity of approximately 7.7µV/Pa, generally these gages have a frequency response between 10s and 200 kHz. The sensing area is small (~3mm), have a large operating range, are very linear, and can operate in harsh environments. The price of these gages is relatively small.

PCB Pressure Gage

The PCB type pressure gage family are piezoelectric transducers with some models sensing maximum pressures up to 689 MPa. One advantage of these gages is that they have a short time constant which allows for a precise definition of the rise time of the pressure pulse.

The gages used during this effort were of the ICP Pressure sensor group. This group is characterized by a small (~3mm) ceramic sensing element, a large environmental operating range, a very short time constant, and a maximum range of 69 kPa with a sensitivity of approximately 145.1 mV/Pa. The frequency response is good with the lower limits similar to the Kulite gage but the upper limit at nearly 500 kHz. The units are also relatively low in price

4. PRELIMINARY RESULTS

General

A large quantity of data was obtained, which when fully analyzed, will provide a greater understanding of blast propagation over forests from impulsive sources. Due to the volume of data, tens of months will be required to validate and correlate the data with the weather and surface conditions. All of the data will be assembled into a relational database, which will provide a detailed description of each measurement, as well as, the raw data (including time histories) and the analyzed data.

(Note: due to the time required to reduce the data from the last test series comparisons between data used for this paper is a combination between the summer and winter trial results.)

Comparisons
The data from the B&K microphones appears to very repeatable in terms of the measurement technique. Fig. 1 shows the recordings from 5 microphones up 30 meters at the center station. As one can see the measurements are very consistent. The measurements from this particular test (during the fall) were made with B&K 4147 microphones.

Fig. 2 shows a comparison between a 4193 B&K microphone, a Chaparral microphone, and a PCB ICP sensor. The 4193 and the Chaparral track very consistently. The major differences are that there seems to be some AC noise superimposed on the B&K signal and the Chaparral microphone saturates during the large negative period at about -13 Pa. The PCB gage shows only a slight response to the large negative portion of the wave and a very noisy signal at all times.

Fig. 3 shows another comparison between a 4193 B&K microphone, the Chaparral microphone, and a Validyne gage. Again, the B&K and the Chaparral tracking together nicely. The AC problem on the B&K is still apparent, but the Chaparral did not clip due to the lower amplitude of the wave. In this case the Validyne also shows a good comparison with the major features of the wave. However, the Validyne exhibits a nosier signal and shows some drift. The data from these last two figures was from the winter trials.

Even though it has not been shown here, the Kulite gage shows even a worse result than the PCB gages. In fact the Kulite has trouble resolving any pressures less than about 700 Pa.

4. CONCLUSIONS

The B&K and Chaparral microphones and the Validyne gage are all capable of measuring acoustic waves. The Kulite and PCB gages do not have the sensitivity to detect the acoustical wave. More work needs to be done to fully evaluate the signals such as examining the frequency spectra. This additional work is on going and will be presented in future publications.

Additional modifications to the Validyne gage, such as amplifying the signal (at the gage) to increase the signal-to-noise ratio, should improve its performance. If these improvements are successful and the frequency resolution is sufficient a new, rugged and low cost measurement technique may be available.

REFERENCES
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Fig. 1 Blast Pressure Data
B&K Microphones - Elevation Variation
Test 75

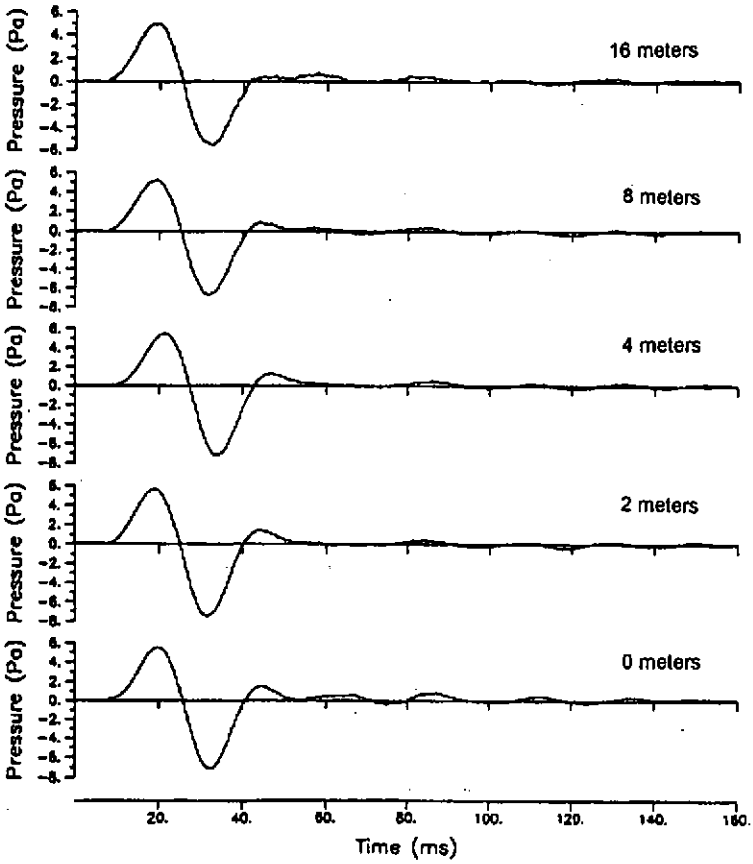

Fig 2. Comparison of Time Histories
Norwegian Winter Trials
Test 767

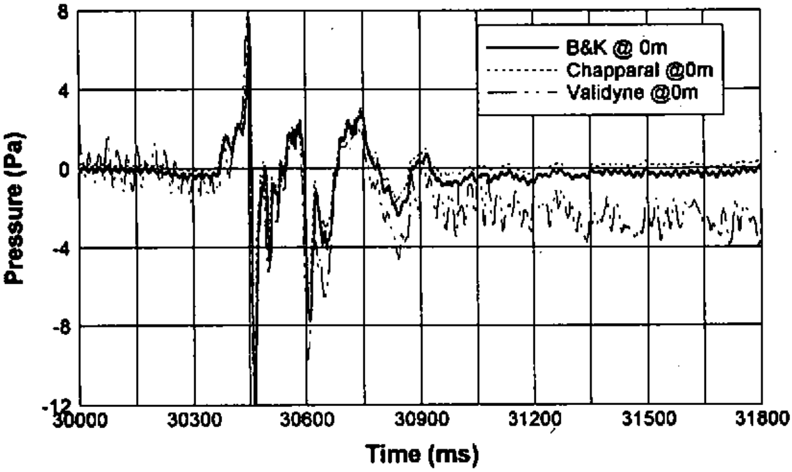

Fig 3. Comparison of Time Histories
Norwegian Winter Trials
Test 764