Fire Research Note No 988

GAS EXPLOSIONS IN BUILDINGS
PART V. THE MEASUREMENT OF SOUND LEVELS AND PRESSURES OUTSIDE A VENTED GAS EXPLOSION CHAMBER

by

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SUMMARY

The methods of measuring the external pressure and sound levels resulting from vented gas explosions in experiments by the Fire Research Station at Cardington are described, together with the methods of calibration. Examples of the oscilloscope traces for sound and pressure are given.

Department of the Environment and Fire Offices' Committee
Joint Fire Research Organization

FOREWORD

Following the Ronan Point disaster and the report of the Investigating Tribunal it was decided that the Fire Research Station of the Building Research Establishment would undertake a study of gas explosions in large compartments. In particular, the study would cover the factors affecting the development and severity of the explosions and the extent to which the pressure obtained could be relieved by venting.

In the context of the problem as a whole, the study is intended to provide the basic data on the form and magnitude of the transient stresses, likely to be experienced by buildings, in the event of gas explosions involving one or more compartments. This information is required as a guide for safe structural design and for any re-appraisal of the relevant parts of Building Regulations 1972, Part D, England, or Building Standards (Scotland) (Consolidation) Regulations 1971.

The study has begun with explosions in a single compartment volume 28 m^3 (1000 ft^3) provided with a single opening of simple configuration, the size of which can be varied and which can be closed with panels having a range of bursting pressures.

In view of the progressive change of domestic fuel gas to natural gas, which is much lighter than air, and the probable circumstances of the Ronan Point explosion, special emphasis has been placed on the explosion of buoyant layers of gas/air mixtures and the effects of layer depth, composition and point of ignition.

The principal measurements consist of high-resolution pressure-time records at points both inside and outside the compartment. In general, these pressure records are complex, including both positive and negative pressures, and attention needs to be given to the exclusion of spurious effects due to mechanical vibration and transient heat pulses accompanying explosion.

The study is to be extended to gas explosions in multiple compartments communicating by door openings and corridors, in which particular attention will be given to the effects of turbulence generated at openings, bends and obstacles and the possibility of increasing pressures as an explosion propagates from one compartment to another.

This is one of a series of notes comprising detailed accounts of phases of the work as it proceeds. A project of this magnitude necessarily involves a considerable amount of preliminary work in the development of equipment and procedures all of which needs to be placed on record, but, in isolation, may sometimes appear somewhat remote from the objectives. This foreword is intended to facilitate the presentation of the detailed material with a minimum of introductory matter - no more than is needed to indicate the place of the particular work reported in the project as a whole. Reports of results and conclusions from this study will be included in the series at appropriate stages as the work proceeds and, correspondingly, these will need to contain a minimum of experimental detail.

Reports preceding the present one in the series are:

FR Note 984. Part I - Experimental explosion chamber. By P S Tonkin and C F J Berlemont.

FR Note 985. Part II - The measurement of gas explosion pressures. By S A Ames.

FR Note 986. Part III - A rapid, multi-channel, automatic chromatographic gas analysis system. By R N Butlin, S A Ames and C F J Berlemont.

FR Note 987. Part IV - Strain measurements on the gas explosion chamber. By M Senior.

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INTRODUCTION

Measurements have been made of pressures developed within the experimental explosion chamber at Cardington during explosions of natural gas/air mixtures in a research programme concerning the venting of gas explosions in buildings[1]. Methods of measurement of internal pressure together with the precautions which had to be taken to eliminate interference from vibration and radiation heat transfer have been described[2].

It is also important to assess the pressures developed outside the compartment and to determine the laws of attenuation of pressure with distance, and to this end a suitable programme of tests in which external pressures and sound level measurements were made has been completed. The results from such tests should enable predictions to be made of the effect of pressure and rarefaction waves in a vented explosion in a building on nearby property and should also establish the relevance of pressure differentials on the surfaces of the building in which the explosion took place.

The laws of decay of pressure are closely linked theoretically with those of the decay of sound level. The laws of decay of sound level and pressure have been established for blast waves arising from solid explosives[3]. However, their use with gas explosions (on an energy equivalence basis for example) assumes identical pressure phenomena for both gas and solid state explosions, for which there is, as yet, no experimental evidence. Sound intensities arising from gaseous explosions have been measured, together with pressures outside the chamber to establish the relationship between pressure and sound intensity levels. This note describes the method of measurement of external pressures and sound intensities; the significance of these measurements will be considered in later reports.

EXTERNAL PRESSURE MEASUREMENT

Quartz piezo-electric pressure transducers used in this work have an output of approximately 150 pico-coulombs per atmosphere, identical to those used for internal pressure measurement[2]. The electrostatic charge developed across the face of the quartz crystal was fed to a high impedance (10^{14} ohms) DC charge amplifier with capacitative negative feedback. The resulting DC output signal was monitored using a cathode ray oscilloscope fitted with a Polaroid film camera, triggered from the ignition circuit and used in the single sweep mode with a sweep of 2 s (200 ms/cm). An example of the output from two such transducers positioned on a line normal to the face of the chamber containing the vent is given in Fig 1. The maximum pressure generated by the explosion was measured by the peak height on the pressure trace, and the velocity of the pressure waves in the explosion was determined from the time intervals between peaks at consecutive stations.

It is imperative to mount pressure transducers so as to avoid vibration and thermal radiation which affect their output. The method of mounting the transducers in the explosion chamber, to avoid the effects of vibration is described in a previous note[2], was not appropriate for external sites, for which the transmission of vibration would occur mainly through the concrete floor of the building in which the explosion chamber was situated. The damping by the floor attenuates vibration at the transducer sites. The transducer was therefore secured in a collar of flexible foamed plastic, which acted as a vibration damping medium, and mounted on a steel bar cast into a concrete conical base weighing approximately 4.5 kg, (Figure 2). Negative signals, produced by radiation from the explosion flame, were avoided by covering the face of the transducer with a layer of black silastomer as was used when making pressure measurements within the chamber, and by siting the transducers so that their faces were at right angles to the face of the explosion chamber containing the vent. Such mounting also served to reduce the effects of vibration, as the vibration would not be applied to the most sensitive axis of the transducer.

The sensitivity of the transducers used in this work was maintained at a constant value by frequent calibration with the apparatus shown in Figs 3 and 4. In this apparatus the air pressure in a reservoir of 10 litres capacity was maintained at a constant value by an air pump and bleed valve[2]. The pressure was measured by a commercially available mercury manometer. Transducers were calibrated by fitting them to the T-piece A and operating the solenoid valve B which connected the T-piece with the reservoir C, Fig 4.

The volume thus added to that of the reservoir was small, and did not significantly reduce the pressure. The output from the transducer charge amplifier was measured on an oscilloscope.

MEASUREMENT OF SOUND LEVELS

The short duration of the vented gas explosions producing the sound levels to be measured requires the measurement of impulse sound. Articles have appeared in the technical literature in recent years concerning both the methods of measurement and the physiological effect of impulse sound[4-7]. An impulse sound level meter is one which will produce a meter reading which approximates to a subjective impression of a sound of short duration (1 to 1000 milliseconds). The meter response characteristic should be such that it closely approaches the rise time of the human ear, and stores, and averages, the short duration signal in a way similar to the human brain.

Two Bruel and Kjaer, Type 2209 impulse sound level meters, Fig 5, were used in this investigation. Sound levels were measured with the meters coupled to a 25 mm (one inch) Bruel and Kjaer type 4145 capacitative microphones, Fig 6 , with a standard sensitivity of 50 mV per N/m^2 and with operating characteristics of high stability, reasonably high sensitivity and linear response over a frequency range of 1.5 Hz to 18 k Hz. The microphones were mounted about 1 m from the ground at distances of 18.3 m and 36.6 m from the face of the explosion chamber. Plastic foam wind shield covers were used on the microphones, mainly to prevent the accumulation of dust on the microphone. To ensure accuracy of measurements, frequent checks on the calibration of the meters were made using a sound level calibrator which produced a 94 db signal at a frequency of 1 k Hz.

The meters were used with 'A' frequency weighting which approximates to the frequency response of the human ear. During the experiment the meters were set in the 'peak hold' mode so that the maximum intensity could be read after an explosion had occurred. These values were recorded and also the oscilloscope display of the sound intensity during the explosion was photographed, as for the pressure transducer outputs described earlier. An example of the traces of outputs from sound level meters during an explosion is shown in Fig 7. Such records may be used to examine the complete sound output from explosions.

It would be necessary to know the frequency distribution of the sound to determine the loudness of the impulse sounds resulting from vented gas explosions. It is possible in principle to make a series of tests with the sound level meters used in these investigations, because they are fitted with octave band frequency analysers which enable the individual contribution of series of frequency bands to the overall sound level to be measured. However, such measurements are not necessary in a correlation of pressure and sound levels, and would necessitate a large number of explosion experiments solely devoted to the establishment of a frequency spectrum. If such measurements prove to be of importance an alternative method would be to record the sound emitted by a gas explosion using a tape recorder and subsequently analysing the frequency spectrum.

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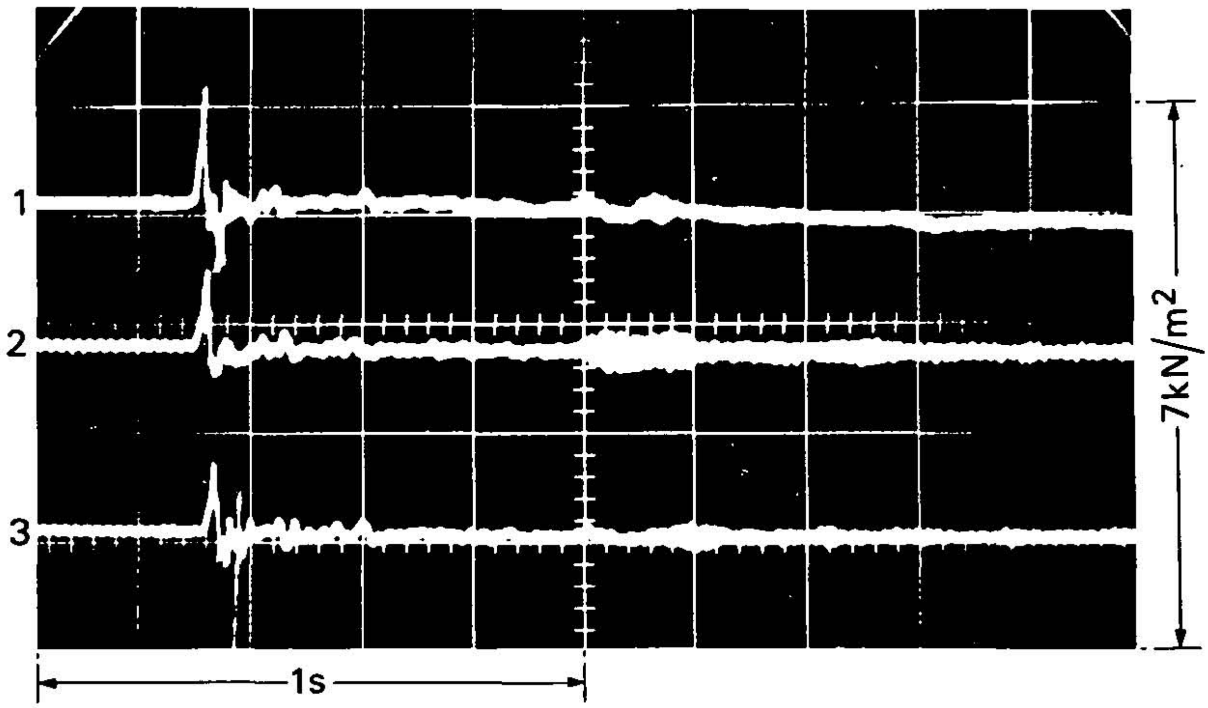


FIG. 1 OSCILLOSCOPE RECORD OF OUTPUT OF PRESSURE TRANSDUCERS

EFFECT OF DISTANCE AND ORIENTATION

Trace 1 : 9.1 m normal to explosion vent

Trace 2 : 9.1 m at right angle to explosion vent

Trace 3 : 18.3 m normal to explosion vent

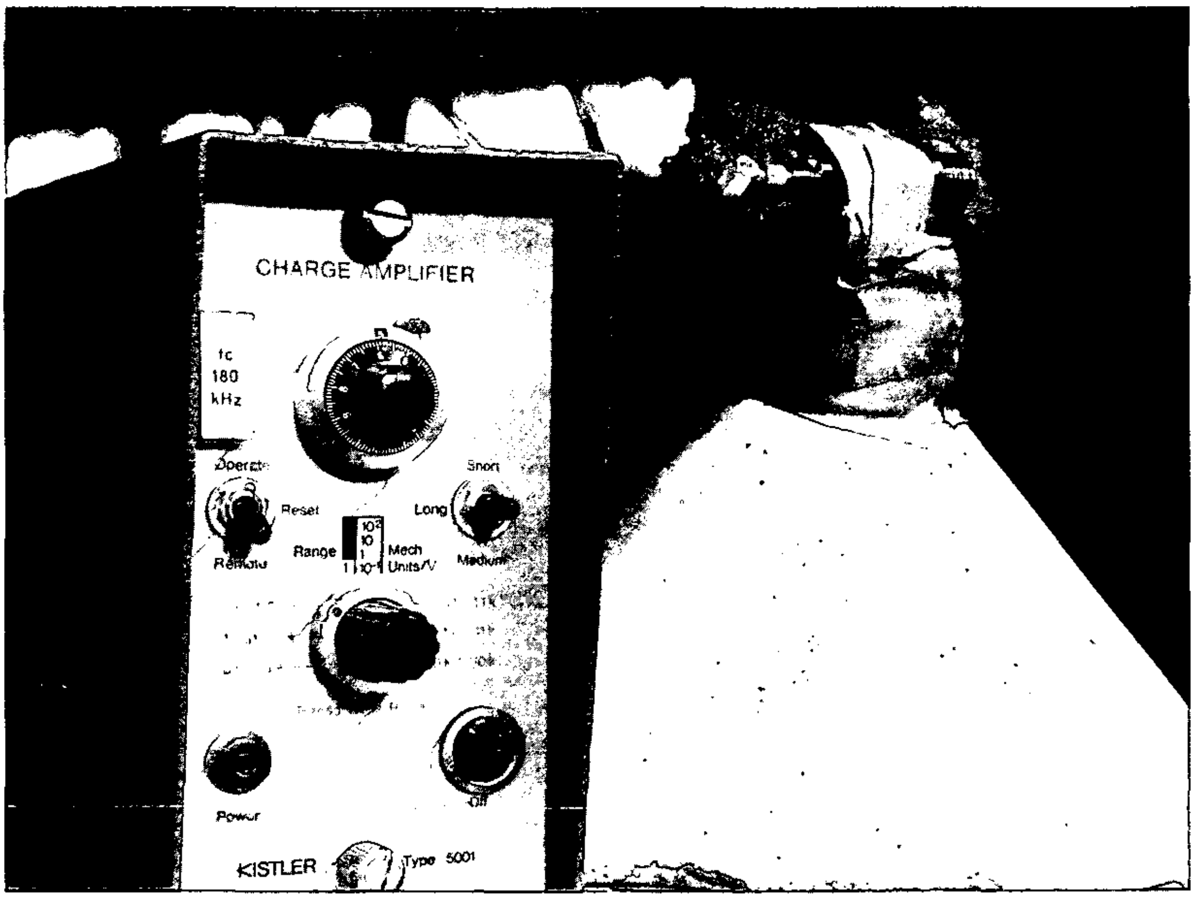
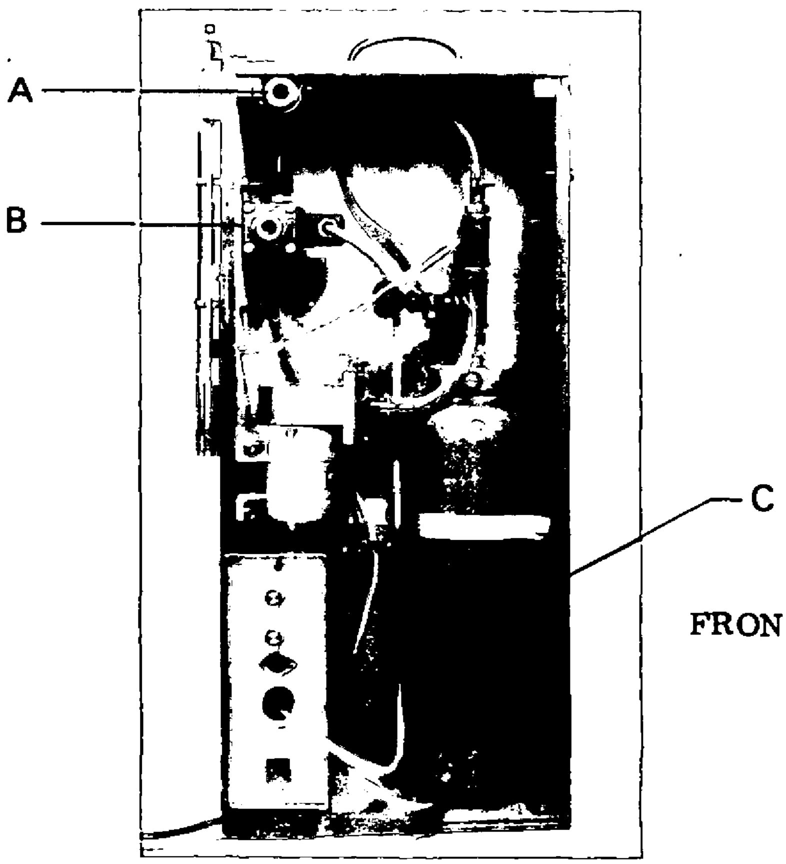


FIG. 2 MOUNTING OF TRANSDUCER

TRANSDUCER AND CHARGE AMPLIFIER

SIDE VIEW SHOWING MANOMETER

FIG. 3 PORTABLE APPARATUS FOR CALIBRATION OF PRESSURE TRANSDUCERS.



FRONT VIEW SHOWING RESERVOIR

FIG. 4 PORTABLE APPARATUS FOR CALIBRATION OF PRESSURE TRANSDUCERS.

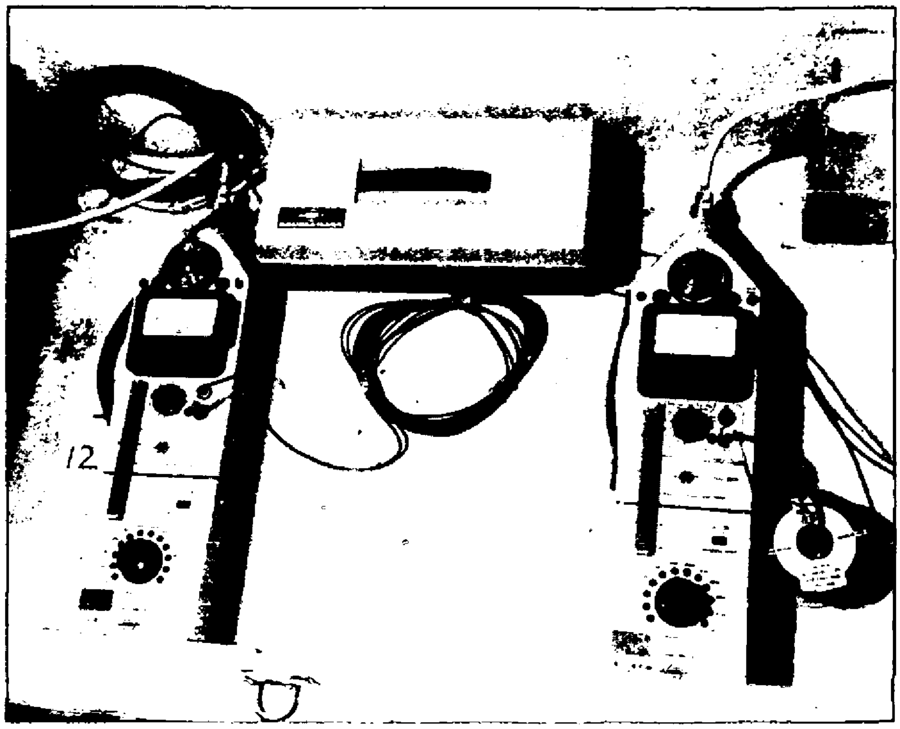


FIG. 5 SOUND LEVEL METERS

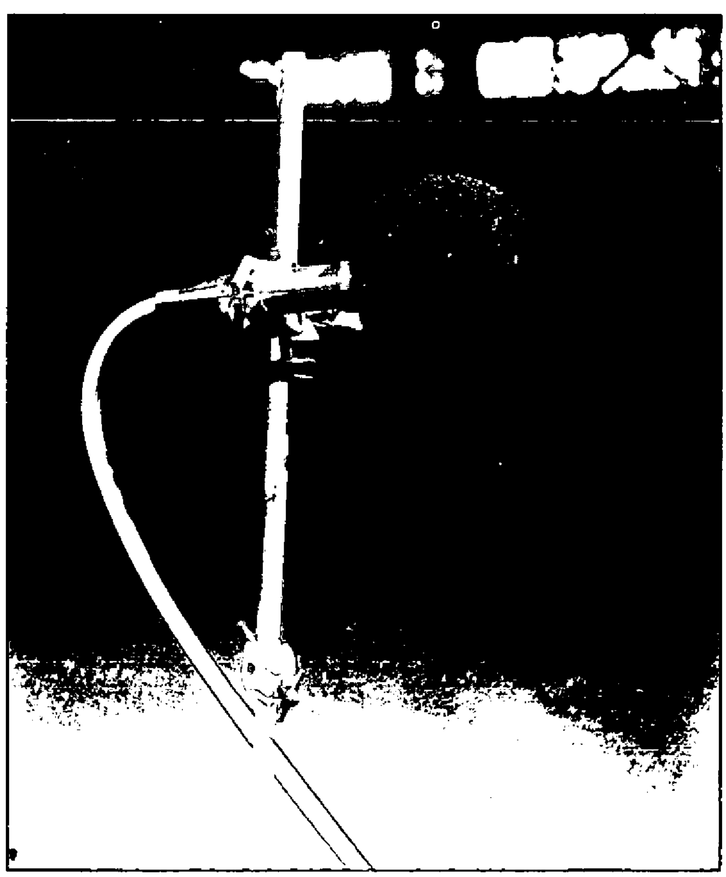


FIG. 6 MICROPHONE FOR SOUND LEVEL MEASUREMENT

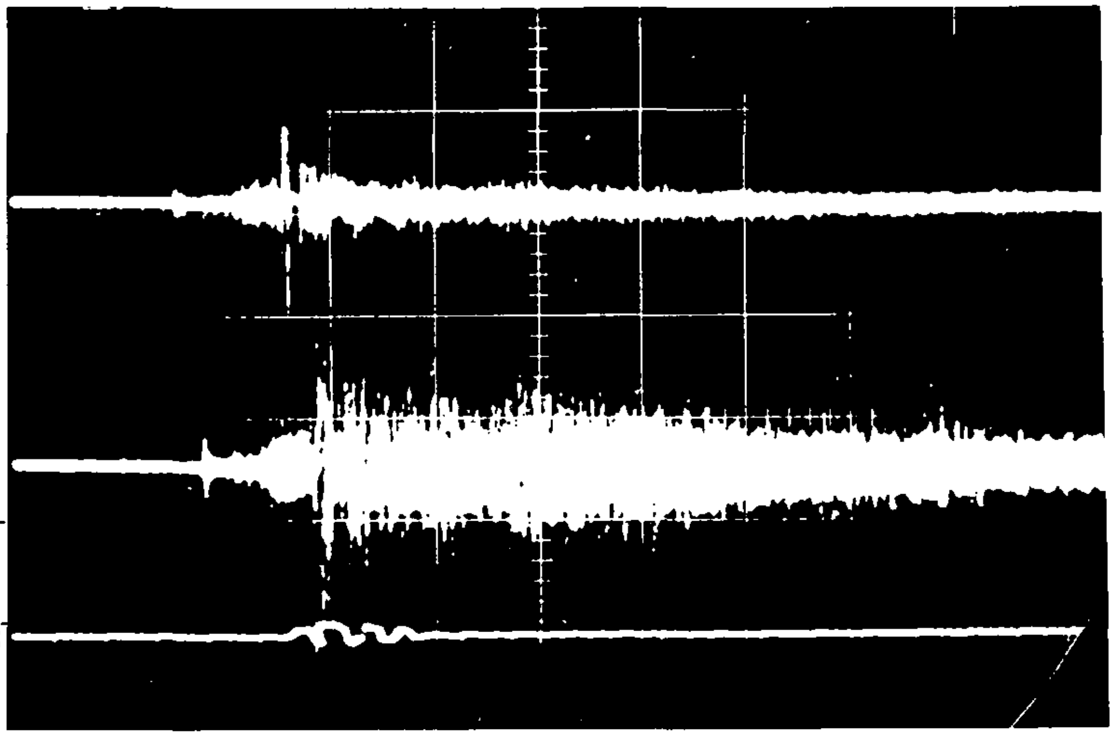


FIG. 7 OSCILLOSCOPE RECORD OF IMPULSE SOUND LEVELS

Trace 1 : Microphone output 36.6 m normal to explosion vent

Trace 2 : Microphone output 18.3 m normal to explosion vent

to explosion vent. 0.5 v RMS = 110 dB

Trace 3 : Timer output, 0.1 sec intervals

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