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DESIGN AND TESTS OF A MECHANICAL DEVICE THAT PRODUCES SYNTHETIC GAS-AIR EXPLOSION PRESSURES

S. SILVER

CANADIAN EXPLOSIVE ATMOSPHERES LABORATORY
ENERGY RESEARCH LABORATORIES

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ABSTRACT

Pressure transducers (the spark plug types) are used to measure the peak explosion pressures developed inside flameproof electrical enclosures during gas-air explosion testing. These explosion tests are conducted when investigating electrical enclosures for certification purposes if they had not been previously tested by other certifying authorities. These pressure transducers normally undergo periodic re-calibration to ensure that the explosion test results are valid. To assist this procedure a special mechanical device was designed here that allows operators to calibrate and check the specifications of such transducers with increased accuracy and efficiency.

The mechanical features of this device are:

a) to change the pressure on the diaphragm of the transducer from one level to another, and

b) to control the rates of this pressure change.

This report provides a brief description and the operational technique for this device. Also some of the problems that were encountered during its preliminary trials and their solutions are discussed. A typical example is given for the re-calibration, as well as the amplitude and frequency response check for one transducer.

INTRODUCTION

The determination of peak explosion pressures attained inside enclosures due to the ignition of internal gas-air mixtures is an essential component of certification testing of flameproof enclosures for use in coal mines or other hazardous areas. To obtain this data, spark plug type pressure transducers (either piezo or strain wire) are spotted in several different locations on the enclosure walls.

After many years of explosion testing of enclosures, the collected results from pressure transducers indicated that the peak pressure values obtained varied considerably due to any one or combinations of, the following factors:

a) location and source of ignition
b) location and type of transducer
c) variation in ratios of gas to air for the explosive mixtures
d) surface to volume ratio of enclosure
e) enclosure partitions and shapes
f) area of pressure relief available
g) volume of internal electrics or protrusions
h) presence and amount of moisture inside enclosures

As a consequence of this, it was found difficult to predict with any accuracy these peak explosion pressures and therefore the empirical technique using pressure transducers has to be employed.

The reliability of these transducers would of course, depends on how often they are re-calibrated (strain-wire types are known to fatique with usage) as well as the method of calibration. The method suggested by the instruction manuals involves the comparison of the transducer outputs to that of a known static pressure. To take account of the frequency response to dynamic pressures, one often had to rely on the written specifications in the transducer manual.

Thus, in order to obtain assurance that the frequency response of a particular transducer is in fact satisfactory and that it remains so after usage, a special mechanical device described in detail in the body of this report, was constructed for this purpose.

This device can be preset to generate dynamic pressure pulses (repeatedly and without degradation) of known amplitudes and rise times which are in the general ranges of the usual internal explosion pressures experienced by flameproof enclosures.

Description of Device

The three main elements of this device are:

1. A large air reservoir with precise pressure control.
2. A piston-cylinder assembly which is capable of transferring the air pressure from the reservoir to the transducer.
3. A number of "pressure-drop" discs that can control the pressure rise time in the small air pocket where the transducer is located.

The assembled device is shown in figure 1. The general description of each part is as follows:

1. Air Reservoir Chamber: a steel enclosure, all joints welded, internal volume, 1 cubic foot.
2. Pressure Transfer Mechanism consisting of:
    a) cylinder, 2 1/4" internal diameter
    b) piston
    c) piston rod
    d) handle on piston rod
3. Pressure-Drop Mechanisms: thin brass discs with different aperture sizes.
4. Air Pressure Gauge: Burbon type, for measuring the pressure in the air reservoir.
5. Air Pressure Regulator: for regulating the pressure in the air reservoir.
6. Control Valve: for charging and discharging the air in the reservoir (3-way valve).
7. Piston Control Lever: a notched lever with a "stop" position that holds the piston from moving when under a differential pressure of up to 100 psi, and a "go" position that can release the piston to move freely.
8. Guide: to guide the movement of the piston and act as a stop.

Operation of the Device

After the apparatus is assembled as shown in figure 1, the pressure transducer under test and one "pressure-drop" disc are threaded securely into the

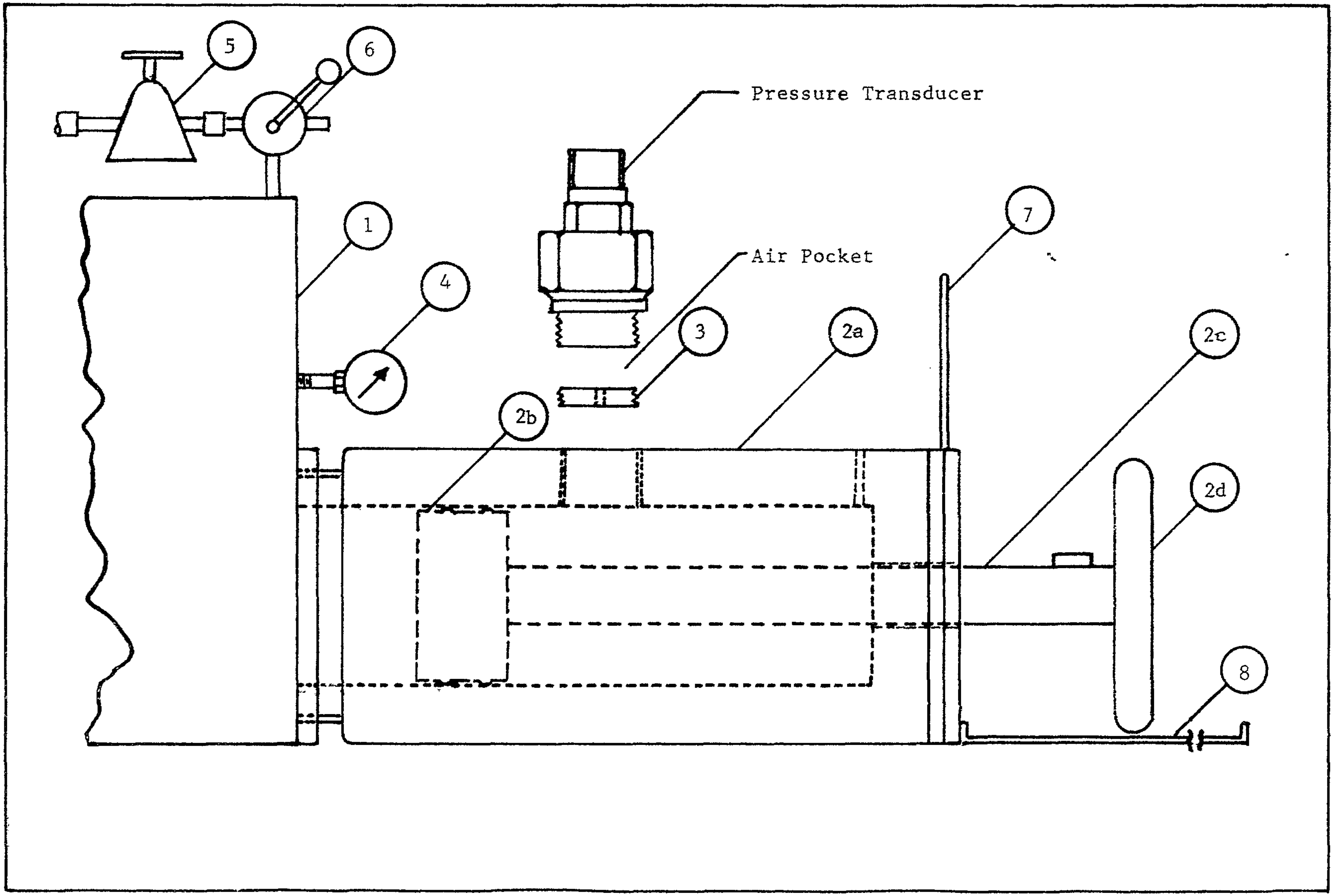


Fig. 1: Device for Generation of Synthetic Explosion Pressures

device. Then the piston (2b) is moved to its extreme left hand position via the handle attached to the piston rod (2c), and the assembly locked with lever (7) by placing it in its "lock" mode. The reservoir (1) is then charged to a selected air pressure level, via air control valve (6) and the preset air regulator valve (5) - the pressure value being recorded by the Burbon pressure gauge (4). The generation of a pressure pulse in the area of the pressure transducer air pocket is obtained by positioning lever (7) back to its "go" mode, to unlock the piston assembly and allow it to move freely to the right under the differential pressures acting on its surfaces. As the piston completely clears the aperture in the pressure-drop disc, the air pocket above it (where the transducer is located) is pressurized under control by the static pressure in the reservoir (reservoir pressure minus aperture pressure drop) i.e. at time zero, pressure-drop is a maximum for maximum air flow, and at time x seconds later, when air flow is zero, the pressure-drop is zero to make the air pocket pressure equal to the static pressure of the reservoir.

Tests

Preliminary tests on this device were conducted using one of the medium sized apertures for the pressure-drop disc, and static pressures of 30 and 60 psi in the air reservoir. The pressure-time traces are shown in figures 2(a) and 2(b). After the noise problems were overcome (see next section) the next tests were conducted with the largest aperture size disc in place. The pressure-time traces under these conditions (static air pressure kept at 80 psi) are shown in figure 3(a) for a strain-wire type transducer and 3(b) for a piezo type transducer. The damped oscillation noise which occurred at the peak pressures was eventually eliminated by a design change in the cylinder (see next section) after numerous other parameters were investigated.

In the next series of tests, a Norwood pressure transducer was calibrated with one of the medium sized apertures for the pressure-drop disc (rise time, approximately 30ms) and the static pressure in the air reservoir adjusted to four different levels, i.e. 30, 60, 80, and 100 psi. The pressure-time traces are shown in photograph 4(a). This same transducer was re-calibrated with one of the largest aperture sized disc at a static pressure of 80 psi. Then, without further adjustment to the static pressure (constant at 80 psi), the pressure discs were changed in steps from the largest aperture size to the smallest to give rise times of 2, 25, 60, 110 and 170 milliseconds. The pressure-time traces for these test series are shown in figure 4(b).

SOLUTION TO NOISE PROBLEMS

The noise signals observed in photograph 1(a) and 1(b), were found to originate from the movement of the handle (attached to the piston rod) which scraped along its metal guides during a pressure pulse generation. The handle was slightly modified so that at the beginning of its travel, the guides would not interfere with the handle movement. After this adjustment was made, this noise signal disappeared from the pressure trace.

A second interfering signal, a damped oscillation, was observed when the rise times of the pressure pulses were less than 5 milliseconds, see photographs 2(a) and 2(b). After many false interpretation for this phenomenon, it was deduced that the cause was due to several experimental openings in the cylinder wall beside the transducer location. As soon as these small air pockets were filled, this type of oscillations on the pressure trace was eliminated.

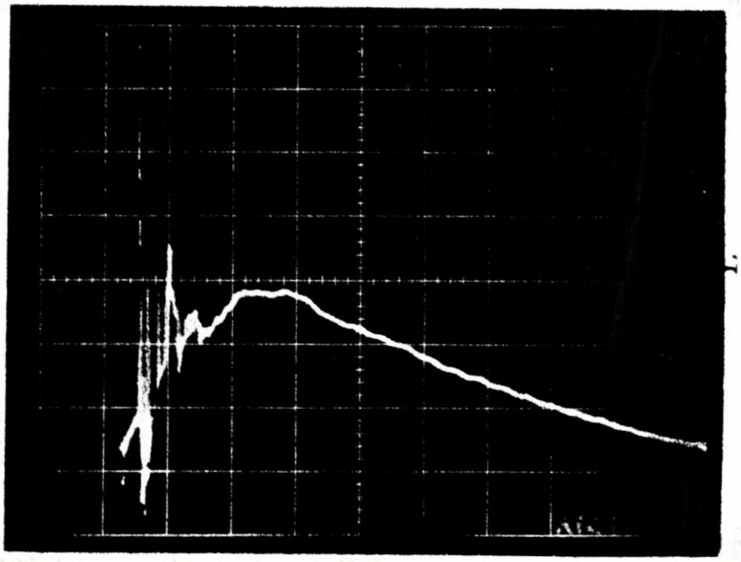
DISCUSSION OF RESULTS

The preliminary tests on this device indicated that the principles on which it was constructed were correct , but some interfering signals were superimposed on the outputs. The noise signals were found to originate from the scraping action of the piston roof handle againsts its metal guides. The damped oscillation signals which were superimposed on the peak of fast rising pressures, were due to small air pockets adjacent to the transducer location. Both types of interfering signals were eliminated by slight alterations in the basic design of the device.

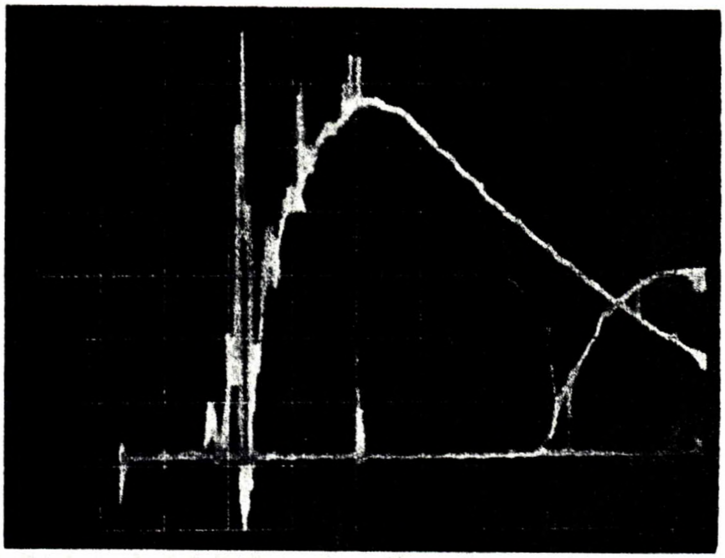
By means of only two controls on this device, (1) the static pressure in the reservoir and (2) the aperture size of the pressure-drop discs in the cylinder, sufficient variety of dynamic pressure pulses were generated to successfully calibrate and check the linearity and frequency response of a pressure transducer.

CONCLUSION

This device, based on simple concepts, can generate repeatedly, various types of dynamic pulses that are suitable for calibration and specification checks on spark plug type pressure transducers.

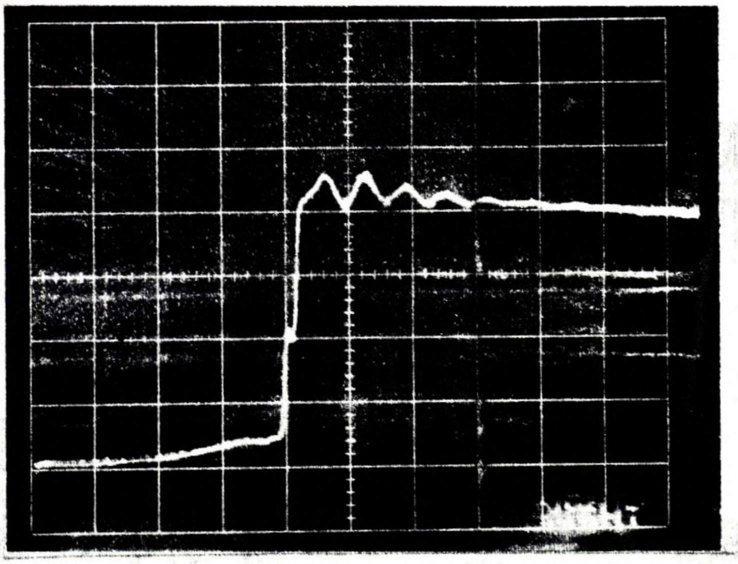


(a) Single Pressure-Time Trace

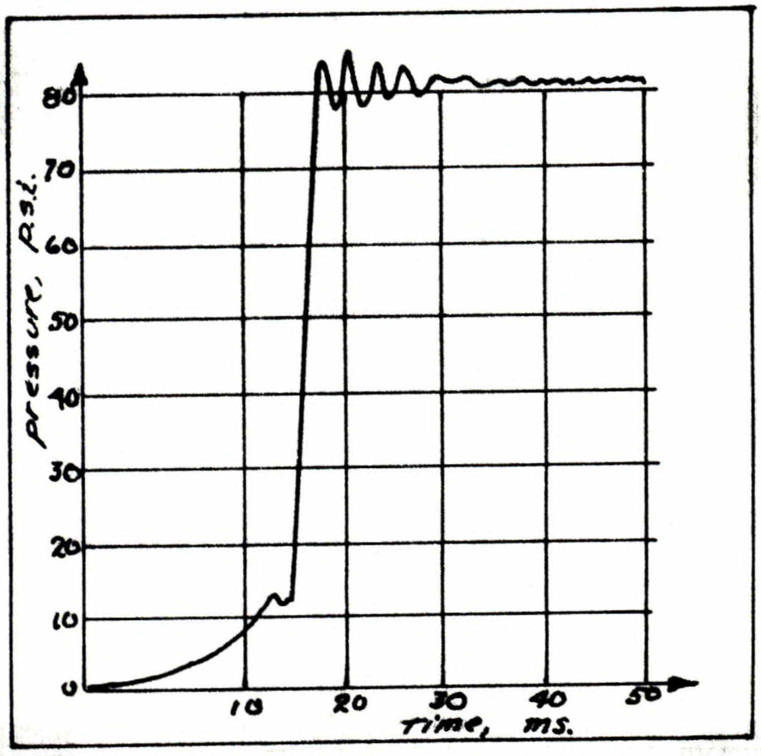


(b) Multiple Pressure-Time Traces

Fig. 2: Observed Noise Pick-up on Pressure-Time Traces

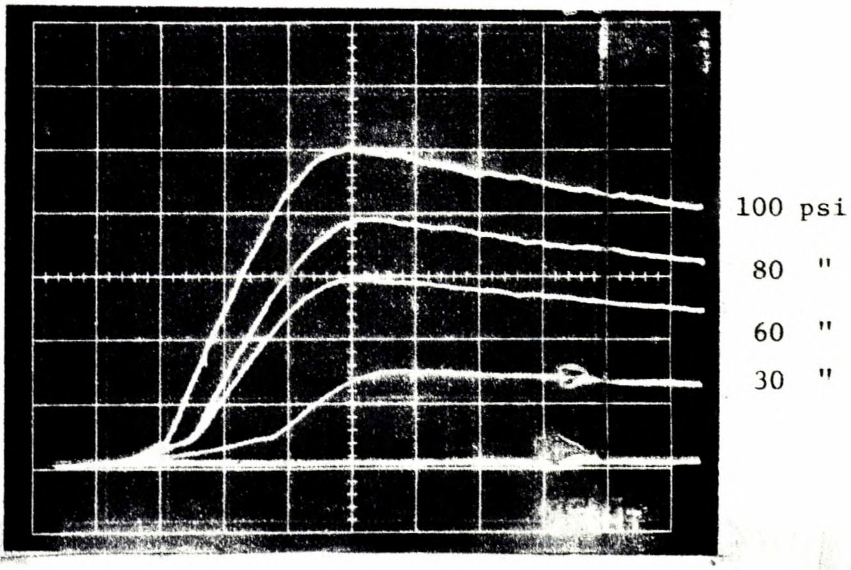


(a) Pressure-Time trace for Strain-wire Transducer

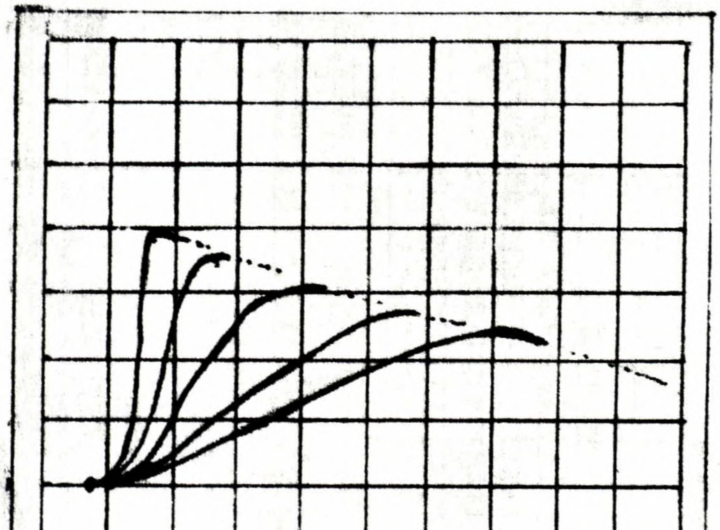


(b) Pressure-Time Trace for Piezo Transducer

Fig. 3: Observed Damped Oscillation on Pressure-Time Traces



(a) **Amplitude Response, with Calibration at 30 ms.**
(one aperture opening only, pressure varied)



(b) Frequency Response, with Calibration at 3 ms.
(constant 80 psi pressure, aperture openings varied)

Fig. 4: Calibration plus Amplitude and Frequency Response Checks of a Strain-wire Transducer.