May 25, 1965 W. S. FILLER 3,184,955

EXPLOSIVE DRIVEN CONICAL SHOCK TUBE

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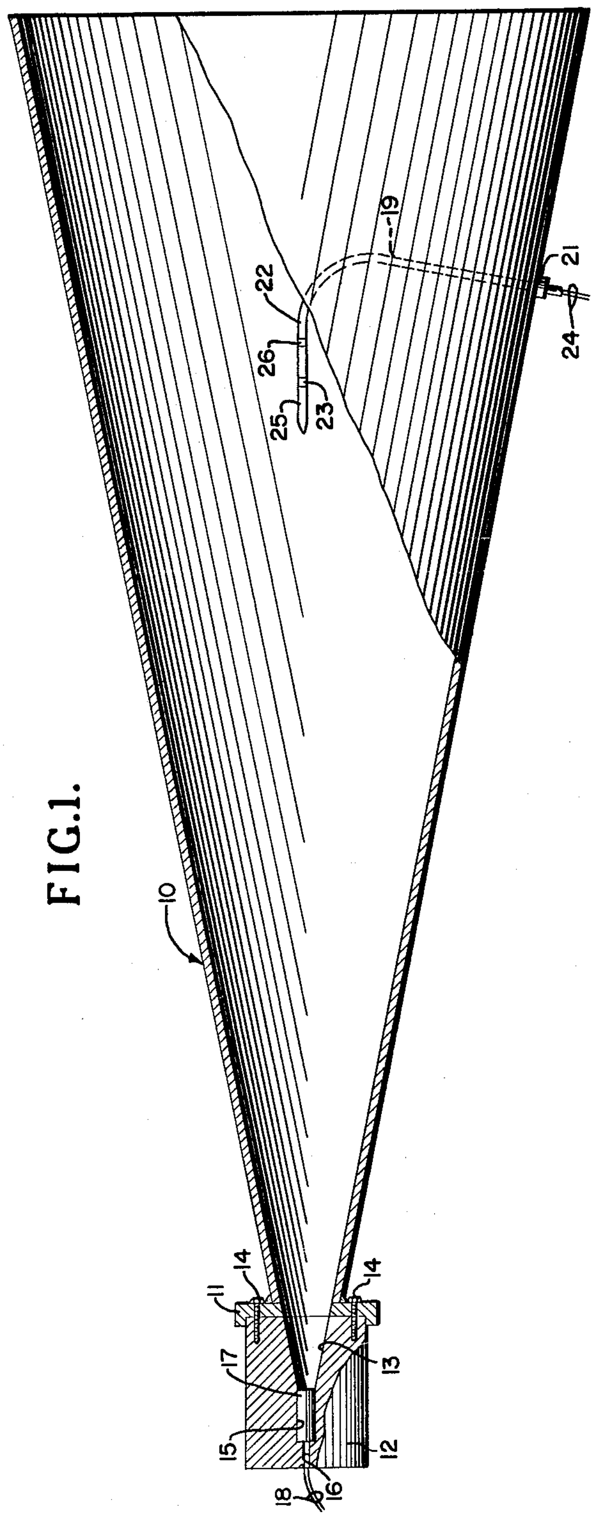

FIG.1.

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FIG. 2.

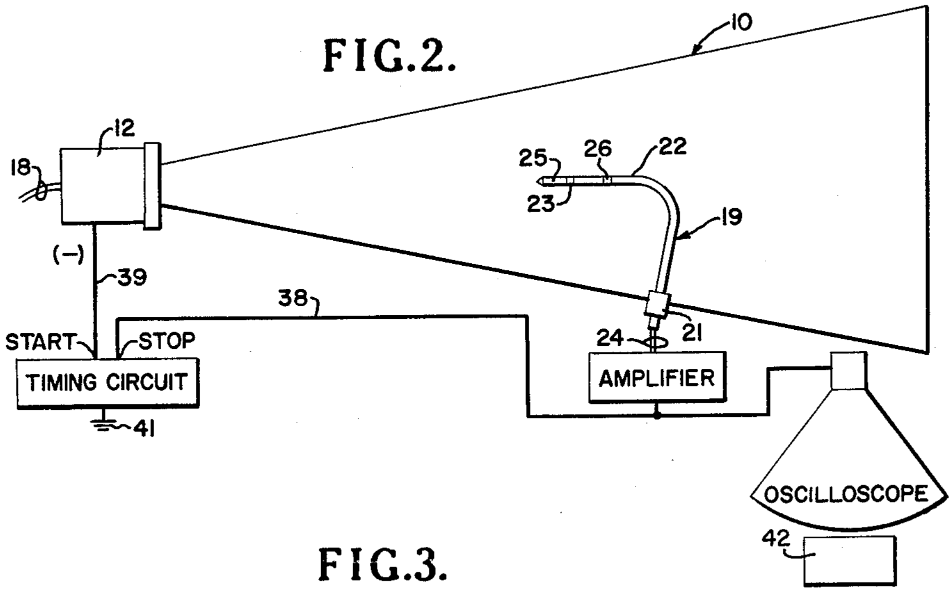


FIG. 3.

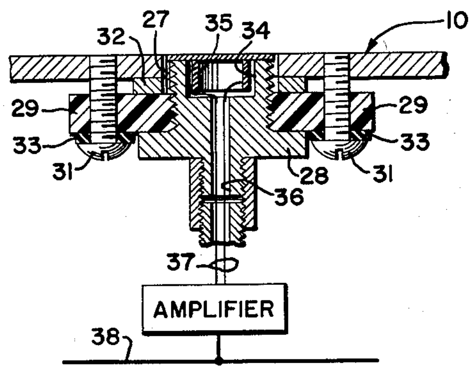
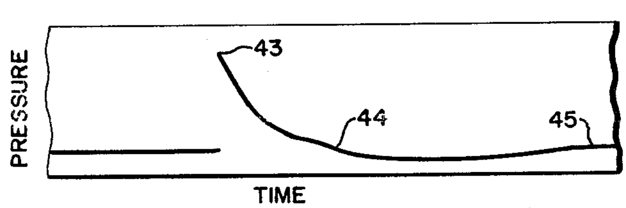


FIG. 4.



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EXPLOSIVE DRIVEN CONICAL SHOCK TUBE

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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a device for greatly amplifying the blast effect of a high explosive charge and more particularly to a test apparatus for generating a spherical blast wave from the explosion of a small amount of high explosive within a conical shock tube for the simulation of a spherical shock wave having a characteristic equivalent to the shock wave produced from a much larger quantity of explosive fired in the open.

High explosive detonations and the shock waves they produce in air have been the subject of extensive studies for several years. Such studies, however, have been hampered by the difficulty in obtaining experimental measurements of the blast wave and by adverse field conditions under which the wave was produced. A further disadvantage is the requirement of unusual facilities to manufacture, handle, and test-fire large explosive charges necessary to effect the blast intensity of the explosion at a selected distance from the source thereof. Various methods have been employed heretofore to generate spherical shock waves under convenient laboratory conditions. In one such method a brittle spherical container filled with compressed gas was ruptured. In another method a conical-shaped shock tube having a diaphragm separating high and low pressure sections at the small end thereof has been employed in such manner that rupture of the diaphragm causes a flow of gas from a high pressure chamber at the apex part of the tube which generates a shock wave comprising a sector of a spherical wave. In all of these methods which employ compressed gas as the driving means for generating the blast, only weak blasts were obtained.

According to the present invention only a small quantity of high explosive disposed within a firing chamber in communication with the small end of a conical shock tube is employed to generate a spherical shock wave within the tube of greatly amplified character and corresponding in blast intensity or strength to that of a much larger quantity of high explosive detonated in the free air at a selected distance from the point of measurement thereof. The amplification factor of the apparatus varies in an inverse ratio to the angle of the conical interior surface of the shock tube.

One of the objects of the present invention is the provision of new and improved means for greatly amplifying the blast effect of a high explosive charge at a selected distance therefrom as the charge is fired.

Another of the objects is the provision of new and improved means for generating spherical blast waves and amplifying the blast effect thereof at a selected distance from the wave source.

Still another object is the provision of means for generating a spherical blast wave and greatly amplifying the blast effect thereof at a selected distance from the source of the wave and measuring the time of transit of the wave from the source to the point of measurement thereof.

A still further object is to provide a new and improved test apparatus for greatly amplifying the explosive effect of a small high explosive charge disposed therein in which

a pressure sensing element arranged within a conical shock tube at a selected distance from the explosive source is employed to control the recordation of a pressure-time record of the spherical wave sensed thereby and to effect a control for indicating the precise minute interval of time corresponding to the time of travel of the pressure wave from the source thereof to the sensing element.

Various other objects, advantages and improvements will be more readily apparent upon consideration of the following specification taken in connection with the accompanying drawings of which:

FIG. 1 is a view partially in section and partially broken away of a conical shock tube employing the instant invention in accordance with a preferred form thereof;

FIG. 2 is a diagrammatic view of the device of FIG. 1 and a system suitable for use therewith;

FIG. 3 is a greatly enlarged view partially in section of a fragmentary portion of the shock tube and a pressure sensing element secured thereto substantially flush with the inner surface thereof; and

FIG. 4 illustrates a time-pressure record of the instantaneous value of the pressure of the shock wave sensed by the pressure sensing means.

Referring now to the drawings for a more complete understanding of the invention on which like numerals or references are employed to designate like parts throughout the several views, there is shown in FIG. 1 thereof a shock tube of frusto-conical configuration indicated generally by the numeral **10** and having a flange **11** welded thereto substantially as shown. A cylindrical firing block **12** having a conical recess **13** therein continuous with the inner conical surface of shock tube **10** is bolted to flange **11** as by the bolts **14**.

There is provided within the cylindrical firing block **12** a circular bore **15** in communication with the conical recess **13** and a second bore **16** coaxial therewith. Disposed within the circular bore **15** is an electro-responsive detonator **17** having a pair of leads **18** connected thereto and protruding from bore **16** to establish an electrical firing circuit to the detonator. The detonator is preferably provided with a non-metallic casing such, for example, as a plastic casing suitable for the purpose, to prevent interference with the spherical shock wave or pressure sensing apparatus as the result of flying metal fragments as the detonator is exploded.

There is also provided within the shock tube a hollow tubular support **19** secured to the casing of the shock tube by a resilient mounting member **21** through which the tubular support extends, substantially as shown. The support **19** is provided with a portion **22** formed at an angle preferably with respect to the part of the tube protruding through the mounting member **21** in such a manner as to be directed toward the explosive charge which, in the illustrated embodiment, is a detonator. There is also provided a pressure sensing element **23** preferably comprising a tube of lead zirconate, the dimensions of which are preferably ¼ inch in diameter and the length thereof ⅛ inch. To this pressure sensing element or gage are secured a pair of conductors **24** disposed within the tubular support **19** for establishing an external electrical connection thereto. The sensing element **23** is provided with a nose portion **25** having a length substantially eight times the diameter of the gage to minimize disturbing effects of the sensing element as a result of the flow of the gases past the gage. The gage **23** is secured to the portion **22** of mounting member **21** preferably by a resilient coupling member **26** which, together with member **21**, effectively prevents vibratory or oscillatory movement of the sensing as a result of vibrations transmitted longitudinally through the material of which the shock tube is composed. Spurious pressure indications of pressure received by the sensing element **23** are thus substantially eliminated. An arrangement is thereby provided in which the sensing element is maintained in a predetermined position within the shock tube at a selected distance from the source of the explosive blast.

The shock tube 10 is also provided with a plurality of apertures 27 therein at different selected distances from the detonator, each of which is adapted to receive a fitting 28 threadedly secured to an annular resilient support 29 composed of non-conducting electrical material and clamped to the shell of the shock tube as by screws 31, a resilient washer or packing member 32 of annular configuration being disposed between the support 29 and the casing of shock tube 10, which together with resilient washers 33 arranged beneath the heads of the screws 31 effectively prevent the transmission of longitudinal vibrations through the shell of shock tube 10 to the fitting 28. The fittting 28 is preferably recessed as at 34 to receive and support a wall-type piezoelectric gage 35 in substantial flush relation with respect to the adjacent inner portion of tube 10. The fitting 28 is also provided with a bore 36 within which are disposed a pair of conductors 37 for establishing an external electrical connection to the gage 35. The apertures 27 within which a piezoelectric gage has not been installed, are each covered by a suitable plate secured thereto as by the screws 31 and having an upraised circular portion of sufficient height to present a substantially unbroken continuous surface to the portion of the interior of the shock tube 10 immediately adjacent thereto when the plates are secured to the tube.

On FIG. 2 is shown a complete system suitable for use with the shock tube device of FIG. 1 with particular reference to a pressure sensing element supported by tubular support 19 and having the pair of conductors 24 thereof connected to an amplifier. The output of the amplifier is connected to an oscilloscope substantially as shown and to the stop terminal of a timing circuit as by conductor 38. The start terminal of the timing circuit is connected as by conductor 39 to the firing block 12 for the purpose which will be more clearly apparent as the description proceeds. The timing circuit is connected to ground at 41. The oscilloscope is arranged in the field of vision of a drum type recording camera 42 in such a manner that a record is made on a time axis of the image appearing on the oscilloscope corresponding to the pressure wave sensed by the sensing lement 23.

On FIG. 4 is shown on a time axis a pressure wave sensed by the pressure sensing element as the element is enveloped by the pressure wave of a blast received from the detonator. As shown on FIG. 4 the pressure rises suddenly to a maximum value at 43 as the front of the pressure wave envelops the sensing device. The wave thereafter drops to a zero value at 44 and thereafter becomes slightly negative until the point 45 of the trace is reached. This graph is characteristic of a spherical pressure wave by exhibiting an explosive blast pressure wave having a well known discontinuous shock front followed by rapid decay and which returns to ambient pressure in about 500 microseconds. A drum camera suitable for the instant purpose is one which is capable of providing a one millisecond per inch time resolution of the film.

When firing impulse is applied to the firing leads 18 causing operation of detonator 17, the resulting explosion of the detonator is accompanied by an ionization of gas which causes a negative electron flow away from the ionized gas region. This negative flow causes a negative start impulse to be applied to conductor 39 sufficient to set the timing circuit into operation. When the pressure wave sensed by the sensing element reaches point 43 of the graph of FIG. 4, a stop impulse is applied by way of conductor 38 to the timing circuit thereby giving an indication of the time of travel of the explosive wave from the detonator to the sensing element.

It has been found by actual test that when the angle of the shock tube is 22 degrees, the amplification thereof

is 62. Thus, when a high explosive charge of 0.5 gram, for example, is employed in the firing block 12 as a source of high pressure wave blast, the strength of the blast measured at the sensing element is equivalent to the blast received in free air from 31 grams of explosive at the same distance from the source of the explosive blast.

A suitable method of calibrating the blast gages employed with the present invention is to expose them to shock waves whose peak pressures were accurately known. This was done by means of free-field firings of a standard explosive. Sensitivity of the gage could be determined from recordings of the shock wave obtained with a particular gage.

Quantitative evaluation of the performance of the shock tube may be obtained by measuring the peak pressure (P), positive impulse (I), positive duration (T) of the shock wave (FIG. 4) that was recorded at several distances from the apex of the cone. The positive impulse of the shock wave is defined by the expression

$$I=\int_0^T p\,dt$$

were p=pressure and t=time.

This integral is evaluated numerically by determining the area under the pressure-time curve such, for example, as shown on FIG. 4.

The pressure sensing arrangement of FIG. 3, it will be noted, comprises a pressure sensing element or pressure gage 35 connected as by the conductors 37 to an amplifier and thence to an oscilloscope generally in the manner of FIG. 2, the timing circuit being connected by conductor 38, if desired, to the output of the amplifier in the manner of FIG. 2. Furthermore, whereas on FIG. 2 is shown but a single sensing element 23 in substantial alignment with the axis of the cone, additional sensing elements 23 may be provided, each on its support 19 at different selected distances from the explosive charge and not necessarily on the axis of the cone but each pointing in the direction of the source of the explosive blast. Also, if desired, additional pressure gages 35, FIG. 3, may be employed, if desired, or a combination of sensing elements 23 and 35 may be employed to obtain a desired result.

The angle of the cone shaped shock tube 10 may be other than the 22-degree angle illustrated. For example, a cone having a two-degree angle possesses a theoretical amplification factor of 10,000. Actual test of a two-degree cone indicated an actual amplification of 3,000 which, although corresponding to an efficiency of about 30% with this cone, a truly spectacular degree of amplification was made possible by its use.

While the invention has been described with reference to two embodiments thereof which give satisfactory results, it will be obvious to those skilled in the art to which the invention appertains, after understanding the invention, that the same is susceptible of additional embodiments, modifications and variations thereof without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. Test apparatus for greatly amplifying the blast effect of a small high explosive charge comprising a rigid frustoconical tube for amplifying a shock wave, a firing block having a firing chamber therein in communication interiorly with said tube and disposed in abutting relationship with the small end thereof, and a small solid high explosive detonating charge disposed within said chamber for generating a shock wave upon detonation and having a pair of firing leads connected thereto and extending through said block, and a piezo-electrical air blast pressure gage disposed within said tube at a selected distance from said charge for sensing the blast effect from said high explosive detonating charge.

2. Test apparatus according to claim 1 including means connected to said gage for amplifying and recording the

signal therefrom as a blast wave from said charge envelopes the gage.

3. Test apparatus according to claim 2 including a counter timer having means for indicating precise minute intervals of time, means interconnecting said counter timer to said block in a manner to apply an electrical start impulse thereto at the instant the charge is fired, and means interconnecting said counter timer to said recorder in a manner to apply an electrical stop impulse thereto as a signal from the blast gage is received.

4. Test apparatus according to claim 1 in which said air blast pressure gage comprises a pressure sensing element disposed within said tube substantially along the axis thereof.

5. Test apparatus according to claim 1 in which said air blast pressure gage is directed toward said charge.

6. Test apparatus according to claim 1 in which said air blast pressure gage is secured to said tube in substantial alignment with a portion of the inner surface thereof.

7. Test apparatus according to claim 6 in which means are provided for yieldably securing the gage to the tube in a manner to prevent vibratory motion thereof in response to longitudinal vibrations of the tube as the charge is fired.

8. A device for greatly amplifying the blast effect of a condensed solid high explosive detonating charge which comprising a shock tube means of frusto-conical configuration for amplifying the shock wave, a firing block having a recess therein secured to and communicating with the interior of said tube and disposed in abutting relation with the small end thereof, a high solid explosive detonating charge for generating a shock wave upon detonation disposed within said recess and having a pair of

leads for establishing a firing circuit thereto, and means disposed within said tube for sensing the instantaneous value of the pressure of the shock wave caused by the firing of said explosive charge and sensed by said sensing means.

9. A device according to claim 8 including means connected to said firing block and said sensing means for rendering manifest the time of transit of the pressure wave from the charge upon explosion thereof to said sensing means.

10. A device according to claim 9 including means coupled to said sensing means for indicating the pressure of the pressure wave at the instant of envelopment with the sensing means.

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