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METHOD FOR THE TESTING OF DETONATING FUSE

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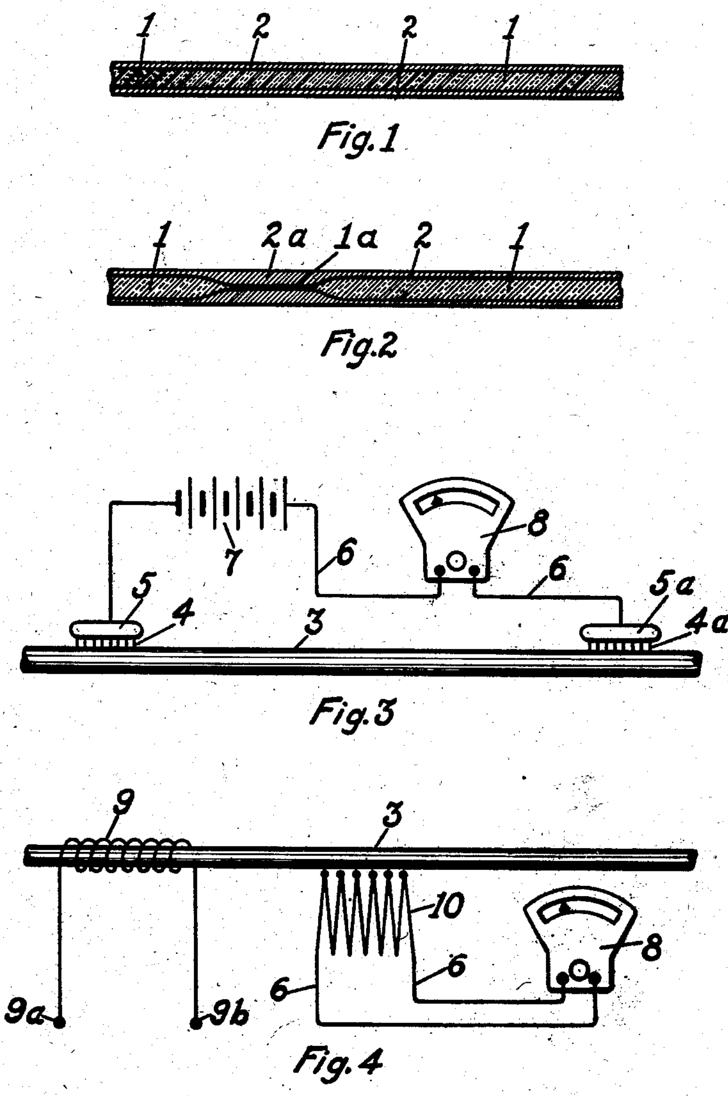


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## METHOD FOR THE TESTING OF DETONATING FUSE

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My invention relates to improvements in methods for the testing of detonating fuse, and more particularly relates to improved means for the testing of the cross-sectional area of the inner core of explosive material present in detonating fuse of the type known as cordeau. The principal object of my invention is to provide non-destructive means for determining the detonable continuity of the explosive or detonable core of detonating fuse, in connection with the manufacture of such fuse and as a means of testing and checking the functionability of cordeau prior to its actual use.

Cordeau or detonating fuse consists essentially of a core or "train" of a detonable explosive material such as trinitrotoluene, picric acid, nitropentaerythrite, trinitrophenyl-methyl-nitramin, or like substance or mixture of substances capable of transmitting a detonating wave at a very high velocity, this train of detonable material being encased in a tube of lead, tin, or other suitable protective metal or alloy. It is widely used in the explosives art as a means of transmitting detonation from one point to another, and particularly as a means for bringing about the practically simultaneous detonation of a large number of separated charges of explosive. The type of cordeau in most common use at the present time contains a core of trinitrotoluene in a casing of lead, and this type of cordeau transmits a detonating wave at a rate of approximately 5300 meters per second, or roughly three miles per second.

For the purpose for which cordeau is technically used, it is highly important that it should function with absolute reliability. The failure of any portion of a length of cordeau to transmit a detonating wave to other portions of the blast in which it is used as a connecting means is usually followed by serious consequences, and in addition to the expense which is involved in such a failure to properly function, there is also an element of hazard in the subsequent handling of the missed holes which it is very desirable to avoid.

In the manufacture of cordeau a tube of malleable metal is first filled with the detonable agent in molten or semi-molten condition, and after the detonable agent has cooled and wholly or partly solidified the metal tube with the contained core of detonable agent is subjected to a drawing, rolling or swaging operation, to increase its length and decrease its diameter to form cordeau of the desired final size. It has long been known that any cavitation caused by the presence of air bubbles in the fluid or semi-fluid trinitrotoluene or other detonable material used to fill the initial tube is very likely to result in the final cordeau being defective, this being due to the fact that although such a detonable agent as trinitrotoluene, for example, possesses very great explosive strength, it is quite incapable of jumping any considerable air gap or of detonating through a column of very small diameter. The outside diameter of commercial cordeau is usually 6 mm., and the wall thickness of the lead tube is 0.8 mm., so that accordingly the actual diameter of the cylindrical detonable core of trinitrotoluene is normally but 4.4 mm. Although a continuous core or train of trinitrotoluene 4.4 mm. in diameter will transmit a wave of detonation for indefinite distances, careful tests have shown that an air gap of but eight millimeters in such a column of trinitrotoluene makes the functioning of the cordeau very doubtful, while an air gap of ten millimeters or more inevitably results in the failure of the detonating wave to pass such space or gap. Similarly, any marked (and particularly any irregular) reduction in diameter of the core of trinitrotoluene is likely to result in failure of detonation to continue through the entire column of detonable material.

Manufacturers of cordeau have recognized the extremely serious consequences of any cavitation in cordeau, and it has long been known that the presence of air bubbles, open spaces or reduction in diameter of the core in a line of cordeau would entirely prevent the proper functioning of such material. Due to the fact that trinitrotoluene shrinks very greatly on solidifying, the possibility of shrinkage openings or cavities is a serious one, and many ingenious methods have been suggested and used for the purpose of insuring the complete filling of the lead tube with explosive, and for the purpose of avoiding the presence of any air bubbles, open spaces or lengths of explosive core of constricted diameter within the finished cordeau. Notwithstanding the great care which has been taken by manufacturers of cordeau to insure the absence of any open spaces or air bubbles within the column of trinitrotoluene in cordeau it has been found difficult to prevent the occasional presence of lengths of core of constricted diameter in the finished product.

Up to the time of my present invention no method had been found for the commercial testing of the detonable continuity of the normally hidden or invisible inner core of explosive material present in cordeau. Although manufacturers of cordeau have developed a number of excellent tests for the purpose of showing the proper functioning of cordeau, all of these tests depend upon the detonation of the cordeau and thus destroy the material in the course of making the test. The most common test for cordeau is known as the "zigzag" test, and consists in fastening together a number of short lengths of cordeau at right angles to each other by approved splices or connections, and then initiating a detonating wave at one end of the "zigzag" thus formed. Cordeau of satisfactory sensitiveness detonates satisfactorily through the successives splices or connections represented by the "zigzag" and cordeau represented by samples which passes this test is assumed to be of satisfactory grade for use, although careful consideration of this test will of course show that it does not and cannot prove the detonable continuity of the core of any portion of the cordeau except the portion actually used in the test, and which is destroyed in the course of making the test.

My invention provides means for the accurate determination of the cross-sectional area of the detonable core of trinitrotoluene or other agent in cordeau by an entirely non-destructive method of testing, and enables the manufacturer of cordeau to detect the presence of lengths of material of constricted core diameter within a column of cordeau without actually detonating the cordeau or opening the lead tube or otherwise injuring or destroying the material.

When a metal tube containing a uniform filling charge of a detonable agent is rolled, drawn or swaged to form cordeau, there is a definite relationship between the lengthening of the metal tube, the wall thickness of the resultant smaller tube, and the cross-sectional area of the explosive core. As the metal tube is increased in length and reduced in diameter the pressure which is applied in performing these operations compresses both the metal tube and the contained core charge, and the resistance to compression which is offered by the contained core charge determines the wall thickness of the metal tube. If an open space or cavity exists in the core charge, however, there will not be at such point any resisting means to prevent the thickening of the wall of the metal tube, and at such point the wall thickness of the metal tube will greatly exceed the normal wall thickness present at other portions along the length of the tube. My invention relates primarily to means for determining the cross-sectional area of the contained core of detonable material through non-destructive methods of measuring the wall thickness of the outer casing or sheath of cordeau by means of electrical effects produced within such metal tube.

In the drawing forming part of this application Figure 1 is a plan view of a section through a piece of cordeau of normal structure. Figure 2 is a corresponding section through a length of cordeau in which an air bubble originally existed. Figure 3 is a diagrammatic representation of one form of apparatus suitable for the practice of my present invention. Figure 4 is a diagrammatic representation of another form of apparatus suitable for the practice of my present invention.

In Figure 1, 1 is the detonable column of trinitrotoluene or other detonation-transmitting explosive material in a normal piece of cordeau and 2 is the tube or sheath of lead or other casing material. In Figure 2, 1 is the detonable column of explosive material as it normally exists throughout the length of the cordeau when no openings or cavities are present in the initial filling material, while 1*a* shows a constriction such as occurs after the cordeau has been subjected to a rolling, drawing or swaging operation, from the presence of a small bubble of air in the initial filling charge. 2 is the lead tube showing the normal wall thickness, while 2*a* shows the greatly thickened wall at a point where the inner detonable core is constricted because of the original presence of an open space or an air bubble in the initial tube before being reduced to its final diameter.

In Figure 3, 3 is a length of cordeau undergoing test in accordance with one form of my present invention. 4 is an electrode consisting of a number of tufts of wire or other electrically-conducting material suitably encased in an electrode holder 5. 6 is a wire connecting electrode holder 5 with battery 7 and ammeter 8. 4*a* and 5*a* are a wire brush and an electrode holder respectively, corresponding to the electrode 4 and the electrode holder 5.

In Figure 4, 3 is the length of cordeau undergoing test, 9 is a solenoid energized by alternating current of high frequency applied at the terminals 9*a* and 9*b* from any suitable source, 10 is a thermo-battery or plurality of thermo-couples, each thermo-couple having one junction adjacent to the line of cordeau 3 and 8 is an ammeter or other instrument for measuring the electric current or electrical potential produced in thermo-battery 10, the thermo-battery 10 being connected to the electrical measuring instrument 8 by the wire or conductor 6.

In the operation of testing apparatus as shown in Figure 3 the cordeau is continuously passed between the two electrodes 5 and 5*a*, contact being effected with the brushes 4 and 4*a*. A difference of electrical potential created by battery 7 causes an electric current to flow in the closed circuit existing within the system, the cordeau forming the return portion of the circuit. As long as the wall thickness of the lead tube remains constant the conductivity of the system when considered as a whole will similarly remain constant, and ammeter 8 will indicate a definite amount of current passing through the system, the exact quantity of current depending of course upon the electrical resistance of the various elements of the circuit and the electrical difference of potential created by battery 7. When a portion of cordeau having a constricted core of detonable material passes through the testing apparatus, however, ammeter 8 will momentarily show a greatly increased current within the circuit at the time that the portion of the cordeau having thickened walls passes between the brushes connected to electrode 5 and electrode 5*a*.

It will of course be evident that the apparatus as described represents a device intended primarily for the purpose of illustrating the principle of the present invention of employing the electrical characteristics of the thickened lead walls of cordeau at a point in which a constriction of the detonable core exists as an indirect means of detecting or of indicating the existence of such a hidden defect within the cordeau. Instead of a battery any suitable source of electrical potential may be employed, and either direct or alternating current may be used. Instead of electrodes actually entering into contact relationship with the cordeau being tested coils may be employed to induce electrical effects within the line of cordeau being tested and the electrical effects so produced may also be measured indirectly and without actual contact with the line of cordeau by means of suitable pick-up mechanism consisting of a solenoid and measuring apparatus of known type. In one convenient form of apparatus the line of cordeau is progressively passed through two closely adjacent solenoids through which alternating currents of high frequency are passing in balanced circuits, such as two coupled oscillating dynatron circuits for example. Any inequality in the thickness of the explosive core will be indicated by a lack of balance in the oscillating circuits when the portion of the metallic sheath having walls of excess thickness passes between the two solenoids and this lack of balance of the oscillating circuits can be indicated by "beats" and "squeals" in an inductively connected loud speaker or in any other of the well known methods of indicating variations in current flow in high frequency oscillating circuits. In still another form of apparatus the line of cordeau may be passed progressively through two closely adjacent solenoids through only one of which an oscillating current is passing. This oscillating current will produce eddy currents within the metal of the sheath, and the magnitude of these eddy currents will be materially modified when portions of the cordeau having a constricted diameter of explosive core, and a correspondingly thickened portion of metallic sheath, passes through the solenoid energized by the oscillating current. The adjacent but electrically disconnected solenoid will be influenced by the magnitude of the eddy currents within the metallic sheath, and will "pick up" an oscillating electric current the magnitude of which will be proportional to the eddy currents themselves, and this secondary current can be utilized in any of the known forms of electrical devices as a means of indirectly determining the uniformity of the explosive core.

Instead of ammeter or voltmeter 8 as shown in Figures 3 and 4 a wide variety of current actuated devices may be used, such for example as a relay which will remain in one position when such minimum of current is passing as corresponds to the passage of tubing of normal wall thickness, but which will be actuated or moved to a second position by the increased current which passes when cordeau having a constricted column of a detonable material and consequently thickened metal walls passes through the apparatus.

The apparatus shown in Figure 4 represents an embodiment of my present invention in which no actual contact exists between the electrical testing apparatus and the cordeau to be tested, 9 being a solenoid through which an oscillating current of high frequency is sent. This oscillating current creates eddy currents within the metal sheath of the length of cordeau 3, and in the absence of any means for removing or utilizing these eddy currents within the metal, they are transformed into heat, slightly increasing the temperature of the metallic sheath. The thermo-battery 10 creates a constant difference of potential which is proportional to the temperature of the cordeau, and this difference of potential is measured by voltmeter 8. If the line of cordeau is passed through the apparatus from left to right at a constant rate, measuring instrument 8 will remain constant, but upon any portion of cordeau having a restricted diameter of explosive core passing through the apparatus it will show a fluctuation, due to the difference in temperature created by the modified eddy currents resulting from the thickening of the metal walls of the cordeau at the portion where the explosive core is constricted in diameter.

As means for creating acoustical, actinic, electrical and mechanical effects from any given change of electric flow are well known in the art I will not attempt to enumerate the many embodiments of my invention which are possible by the use of well known equivalents for the forms herein described, but it will be evident to those familiar with the art that instead of the use of a galvanometer, ammeter, or voltmeter as a means of measuring or indicating the secondary electrical effects produced in accordance with my invention, lights may be flashed, bells may be sounded, horns may be operated, or control apparatus for the purpose of marking the portion of cordeau which is defective, or of stopping the further motion of the testing apparatus, may be actuated, or any other suitable visible, audible or operative device may be set in motion or operation, in accordance with well known inspection methods.

As it will be evident that many modifications may be made without departing from the principles of the disclosure as herein made, no limitations are to be placed upon my invention except such as are indicated in the appended claims.

I claim:

1. The process of testing the continuity of the core of detonable material in cordeau which comprises establishing electrical forces within a metallic sheath surrounding such core and measuring the intensity of such electrical forces.

2. The process of testing the continuity of the core of detonable material in cordeau which comprises establishing a flow of electricity within a metallic sheath surrounding such core and measuring the intensity of the resulting electric current.

3. The process of testing the continuity of a core of a detonable material compressed within an associated metallic sheath of a malleable metal which comprises establishing an electro-magnetic field adjacent to the metallic sheath and measuring the electrical effect produced by the action of such electro-magnetic field upon the metallic sheath.

4. The process of testing the uniformity of cross-sectional area of a core of a detonable material encased in an associated metallic sheath which comprises creating a difference of electrical potential at two points along the length of the metallic sheath and measuring the intensity of the electrical flow thereby created.

5. The process of testing the uniformity of cross-sectional area of a core of a detonable material encased in an associated metallic sheath which comprises establishing a flow of electric current within the metallic sheath and measuring the intensity of such electric flow as a measure of the cross-sectional area of the explosive material.

6. The process of testing the uniformity of cross-sectional area of a core of a detonable ma-

terial encased in a metallic sheath which comprises creating eddy currents within the metallic sheath by the action of an oscillating electric current exterior to the metallic sheath and using the intensity of such eddy currents as a measure of the cross-sectional area of the explosive material.

7. The process of testing the uniformity of cross-sectional area of a core of a detonable material encased in a metallic sheath which comprises creating eddy currents within the metallic sheath by the action of an oscillating electric current exterior to the metallic sheath and electrically insulated from same and employing the intensity of such eddy currents as a measure of the cross-sectional area of the explosive material within the metallic sheath.

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