DETECTION OF HITS ON TARGETS

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This invention relates to targets, and more particularly, to apparatus for detecting hits on targets during practice firing with weapons such as rifles and machine guns and the like.

To be used for training purposes, a target should be inert to climatic conditions and must have low weight combined with high rigidity. Materials recently developed and ideally suited for fabricating targets having these characteristics include the foamed plastics such as styrofoam and cellulose. However, conventional hit detector apparatus used with targets made from foamed plastic have proved to be deficient in a number of respects. Impact-type detectors, for example, utilize spring-loaded micro-switches, microphones or vibration detectors associated with the target, and are consequently extremely sensitive to near misses of the target. As a result, such detectors cannot reliably distinguish between hits and near misses. Short circuit-type detectors, on the other hand, are not responsive to near misses but give rise to other problems, an understanding of which will become apparent from a consideration of their construction and operation.

In conventional short circuit-type detectors, there is used on each side of a dielectric target (such as the foamed plastics referred to above) conductive laminates maintained at different potentials by a source of E.M.F. On passing through the target, a projectile will simultaneously contact both laminates causing a local short circuit. The resulting surge of current through an impedance connected with the source of E.M.F. may be detected by conventional means well known to those skilled in the art. Because a projectile must contact both laminates to cause a local short circuit, false detection of near misses is eliminated. However, it has been found that high velocity projectiles with blunt noses may actually pass through the target without being detected, particularly with targets of the foamed plastics. Investigation indicates that after the projectile pierces the outer conductive laminate, it pushes the dielectric target ahead of it and through the second laminate. Instead of contacting the second laminate to produce a short circuit which can be detected as a hit, the projectile emerges from the target surrounded by the dielectric material and thereby insulated from the second laminate. Furthermore, a concentration of hits in a small area may cause local disintegration of the target material allowing the laminates to come into contact. Not only does this situation appear as a hit, but it renders the system incapable of detecting hits for the duration of the short circuit. The possibility of the laminates contacting each other is increased if the target is subjected to vibrations during use. If the target is being used in the rain, the wet dielectric may act as a short between the laminates, thereby effectively preventing their detection of hits.

Much effort has been expended by those skilled in the art to develop an apparatus of the type described which does not suffer from the deficiencies outlined above, but so far as is known, no successful apparatus has yet been developed. Accordingly, it is an object of this invention to provide hit detection apparatus which may still detect hits even if the laminates are in actual contact or are shorted to the target. It is a further object of this invention to provide hit detection apparatus which does not require two conducting laminates to reduce sensitivity to near misses while successfully detecting a target hit. It is still a further object to provide hit detection apparatus which is operable when a single conducting laminate is pierced by a projectile and does not require batteries or other active components.

As a feature of this invention whereby the objects thereof are achieved, a conductive laminate which has a given capacitance with respect to an electrical ground is applied to one side of the target and electrically grounded through an impedance. A projectile passing through the laminate causes a change in the potential of the laminate with respect to the ground. This potential change does not require batteries or any other active components, but arises solely because of the interaction between the projectile and purely passive target elements. As a projectile passes through the laminate, a negative charge appears on the laminate. As in a conventional detector, a negative going pulse is formed which dies away exponentially. Such pulse can be detected across the impedance in a conventional manner. As a further feature of this invention, any A.C. pick-up by the laminate is eliminated from the detected signal by providing a second laminate on the target, and connecting the laminates to a differential amplifier which produces and output only when the laminates are at different potentials due to a hit on the target.

The more important features of this invention have been outlined rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will also form the subject of the claims appended hereto. Those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other structures for carrying out the several purposes of this invention. It is important, therefore, that the claims be granted herein shall be of sufficient breadth to prevent the appropriation of this invention by those skilled in the art.

In the drawings:

FIGURE 1 illustrates one form of the hit detection apparatus applied to a target about to be impacted by a projectile.

FIGURE 2 is a sectional view of the target of FIGURE 1 showing the projectile passing through the target.

FIGURE 3 illustrates another form of the invention applied to a target.

FIGURE 4 is a side view of the target of FIGURE 3.

FIGURE 5 is a schematic of the hit detector apparatus showing how a hit on the target may be displayed.

Referring now to FIGURE 1, there is depicted schematically a target 10 having a layer of electrically conductive material 11 bonded to one side of the target. Projectile 12 is about to pierce the target. Resistor 13 has end 14 electrically connected to material 11 and end 15 electrically connected to ground. The term "ground" as used in this application is broader than the usual meaning of the term, and includes any conductive mass or area similar in magnitude to the target. The essential feature of the "ground" is that the material 11 on the target exhibit electrical detection of the "ground." When the projectile pierces material 11, a pulse which is negative with respect to ground appears across resistor 13 and dies away exponentially from its peak negative value.

It has been found that the results obtained when the projectile travel is one inch are not substantially different from those obtained when the projectile travel is 50 yards. This indicates that the charge appearing on the
material does not arise because the projectile became charged during its passage through the air. Furthermore, it has been found that the results obtained outdoors in the rain and snow are not significantly different from those obtained on a dry day. It is believed, therefore, that the pulse arises because of the rapid deformation of material 11 by the projectile as it passes through the material. By way of explanation, it is pointed out that the material covering a target has some inherent capacitance which is a function of the relative permittivity and thickness of the material. This is represented in FIGURE 2 by capacitor 16. When the projectile impacts material 11, a negative charge appears thereon. This amounts to placing a negative charge on capacitor 16 with the polarity as indicated. The potential at lead 17 drops from ground potential to some negative peak value and then rises exponentially to ground potential. Capacitor 16 and resistor 13 thus forms a conventional differentiating circuit, and display of the shape of voltage $e_o$ on an oscilloscope confirms the above analysis.

A sharp negative pulse occurs for each hit. With a one-square-foot target covered with a conducting rubber laminate having a resistance of approximately 1,000 ohms per square and a load resistor of 10K ohms, output pulses having a magnitude of two millivolts and a duration of from 0.2 to 1.0 milliseconds have been obtained. While it has not been possible to produce a false trigger pulse by vibrating the target or by brushing the laminate with dielectric paint, the idea that charge is retained on, a considerable amount of A.C. pick-up or electrical noise under certain conditions is likely to be superimposed on the output pulse. Because a target for field use may have as much as 15 square feet of area, a conductive laminate that size would behave as an antenna and pick up considerable noise which could mask the output pulse or even produce false triggering. To eliminate this problem, the construction of FIGURE 3 may be restorted to.

In FIGURE 3, conductive laminates 18 and 19 are bonded to each side of target 20. Load resistor 21 has end 22 connected to laminate 18 and the other end 23 to laminate 19. Lamine 18 is considered to be the face of target 20 that is exposed to fire and which is first pierced by a projectile. Accordingly, end 22 of resistor 21 is connected to electrical ground 24 through ground resistor 25, thereby reducing the sensitivity of laminate 18 to the static electric field. The output pulse can be taken across both resistors or across only the shunt resistor 21.

The thickness of target 20 is exaggerated in the drawing to facilitate an understanding of the invention. In reality, the foamed plastic target is about 0.2 inch in thickness. After repeated hits in a small area, the foamed plastic disintegrates locally, permitting the laminates to contact. Were the laminates of an extremely high conductive material such as aluminum foil, local short circuits of the laminate would have a resistance which is a small fraction of the resistance of the laminate caused by charge on the laminate. The square resistance of a laminate is the resistance obtained by passing a current through the laminate and measuring the voltage drop across two parallel leads at a distance of 1 inch apart. The square resistance of about 1,000 ohms per square. A short between laminates of the type above described has an effective resistance of about 50K ohms. By making resistors 21 and 25 about 10K ohms each, a 50K shunt caused by a local short circuit reduces the load resistance and signal output amplitude only slightly. Since there is no voltage applied between the target laminates, a short itself does not produce a signal.

The equivalent circuit of the embodiment shown in FIGURE 3 is illustrated in FIGURE 4. Laminates 18 and 19 have certain capacitances with respect to ground which are equivalent to capacitors 26 and 28. The dielectric target material between laminates 18 and 19 causes the laminates to have a certain capacitance with respect to each other. When a projectile pierces laminate 18, capacitor 26 is charged with a polarity as indicated. When laminate 19 is pierced, capacitor 28 is charged with a polarity as indicated. This causes a short initial pulse of opposite polarity from the main negative pulse produced when laminate 19 is pierced. Because of the high voltage of the projectile and the short distance between the laminates, capacitors 26 and 28 are charged within an interval of a microsecond. Both capacitors discharge through resistors 21. The effect of the distributed resistance and capacitance of the laminates is to produce a negative going pulse whose maximum negative amplitude is reached in a few microseconds. Decay occurs over a period of several hundred microseconds. With a target constructed as above, a signal of about one milliwatt is developed between terminals 22 and 23.

Because of the large size of the target, a hit may occur on a static edge laminate 18 and 19 at a point extremely remote from the ends 22 and 23 of shunt resistor 21. Since the conductivity of laminates 18 and 19 must be limited for the reasons pointed out above, a substantial portion of the voltage generated when a remote hit occurs may be dissipated in the internal resistance of the laminate, thereby reducing the sensitivity of the laminate. This will not happen if the target dielectric is shot away, because the effective resistance of the resulting short circuit is very low compared with the 10K shunt resistor. This is most easily accomplished by painting the stripes in alternate paths so that they do not overlap which is clearly shown in FIGURE 3.

In the event that target 20 becomes wet, as for example, when the target is used in the rain, laminates 18 and 19 are shunted by a “rain jumper” 21 whose resistance is about 27K. By making shunt resistor 21 about 10K, the signal strength of the output is preserved. Were a larger resistor used, the output signal from a wet target would be significantly smaller than the output signal from a dry target.

When a projectile pierces laminates 18 and 19, differential amplifier 29 produces an output pulse which is fed into amplifier 29 through lead 30. However, electrical noise is picked up by both laminates and is applied to the differential amplifier such that the output at lead 30 is free from such noise. Amplification of the signal triggers multivibrator 30, which produces an output that may be used to operate relay 31 and signal a hit such as lighting lamp 32.

An actual target constructed in accordance with this invention has been tested. Over 1,500 hits have been detected successfully without a single near miss as close as ½ inch being detected. Firings were conducted under all climatic conditions with positive pulse detection not dependent upon a short being developed through the projectile, short circuiting of the laminates does not adversely affect performance. Furthermore, the projectile need touch only one laminate to be detected, thereby assuring detection of extremely high obliquity hits.

Those skilled in the art will now appreciate that this
invention provides a hit detection apparatus which does not depend upon the shorting of conductive laminates to prevent detection of near misses. Furthermore, this invention provides a hit detection apparatus which needs only one conductive laminate to positively detect hits, and does not require the use of active circuit elements such as batteries and the like. Detection appears to be a function of laminate material and projectile velocity so that stones thrown at a target are not detected even through the target is pierced.

What is claimed is:

1. An electrically scoring target comprising two layers of electrically conductive material, a dielectric separating said layers, a first resistor having one end electrically connected to one layer and the other end electrically connected to the other layer, and a second resistor having one end connected to one layer and the other end electrically connected to ground, said layers being at substantially the same electrical potential and means to measure the potential across the resistors.

2. A hit detector for a dielectric target comprising a layer of electrically conductive material on one side of the target, a layer of electrically conductive material on the other side of the target, a first resistor having one terminal electrically connected to one layer and the other terminal electrically connected to the other layer, a second resistor having one terminal connected to one layer and the other terminal electrically connected to ground, said layers being at substantially the same electrical potential and a differential amplifier connected across the terminals of the first resistor for producing a trigger pulse in response to a projectile piercing the layers.

3. The hit detector of claim 2 wherein there is provided an indicator means for producing an output in response to trigger pulses, and means for connecting the differential amplifier to said indicator means.

4. A method for detecting the passage of a projectile through a target comprising the steps of placing a single electrically conductive laminate on the target so that the projectile must also pass through the laminate, grounding the laminate through a resistor, and monitoring the potential across the resistor to detect changes caused by a static charge deposited on the laminate when the projectile passes therethrough.

5. A method for detecting the passage of a projectile through a single electrically conductive laminate comprising the steps of connecting the laminate to a grounded resistor, causing the laminate to exhibit a capacitance with respect to ground, connecting a device across the resistor which is responsive to a voltage drop across the resistor to produce a signal, and exposing the laminate to the projectile so that it impacts the laminate whereby said device produces a signal.

6. A hit detector for use with a target of dielectric material comprising two layers of conductive rubber laminates, one laminate on each side of the target, said layers being at substantially the same electrical potential, alternate stripes of highly conductive paint on each laminate, a first resistor connected said laminates, a second resistor connecting one laminate to ground, and a voltage sensitive device connected across the terminals of said first resistor, said voltage sensitive device being responsive to a difference in potential across the first resistor for producing a signal.

7. A passive circuit for detecting a hit by a high velocity projectile on a target having opposite surfaces at substantially the same electrical potential comprising, a layer of electrically conductive material on one surface of the target, an impedance having one end connected to said material and the other end connected to an electrical ground, said material caused to become charged relative to ground by the impact of a high velocity projectile on the material, the charge on the material flowing through said impedance to ground, and means for detecting the potential difference across the impedance caused by the charge flowing therethrough.

8. A target comprising a sheet of dielectric material, said sheet having opposite surfaces at substantially the same electrical potential, an electrically conductive laminate on one surface of said sheet, said laminate being grounded through an impedance, said laminate adapted to become charged relative to ground by a projectile which pierces the laminate, the charge on said laminate flowing through said impedance to ground, and means for producing an indication in response to a potential difference, said last named means being connected across said impedance for detecting the potential difference across the impedance caused by the charge on the laminate flowing through the impedance whereby a hit on the target is detected.

9. A target comprising a sheet of dielectric material, said sheet having opposite surfaces at substantially the same electrical potential, an electrically conductive laminate on each surface of said sheet, an impedance electrically connecting the laminates, one of said laminates being grounded through an impedance, said laminates adapted to become charged relative to ground by the piercing of the laminates by a projectile, said impedances being discharge paths by which the laminates become discharged, and means to detect the discharging of the laminates.

10. A method for determining if a high velocity projectile hits a sheet of dielectric material having opposite surfaces at substantially the same potential comprising the steps of applying on one surface an electrically conductive laminate that is electrically chargeable by the impact of a high velocity projectile on the laminate, grounding the laminate through an impedance, and monitoring the potential across the impedance to detect differences resulting when the laminate discharges through the impedance after a high velocity projectile impacts the laminate.

11. A method for employing high velocity objects to supply power to a load having one end grounded comprising the steps of connecting the other end of the load to an electrically conductive laminate attached to one side of a dielectric sheet that has no potential gradient from the one side to the other, and exposing the laminate to the objects so that they impact the laminate.

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