United States Patent

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[73] Assignee **The United States of America as represented by the Secretary of the Navy**

[54] ULTRAVIOLET TARGET HIT SCORING SYSTEM

3 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** .... **250/83.3 UV,** 89/41.7, 250/83.3 H, 250/222 R, 250/237 R, 273/102.2, 340/25, 340/228 S
[51] **Int. Cl.** **G01j 1/06**
[50] **Field of Search** .... 250/83.3 UV, 83.3 H, 83.3 R, 222 R, 237 R; 73/167; 340/25, 258 B, 228 S; 89/41.7 L; 343/15; 324/178, 706; 273/107.2 X

[56] **References Cited**

UNITED STATES PATENTS

2,237,193	4/1941	Mobsby	89/41.7 (L) (UX)
3,205,361	9/1965	Albus	250/237 X
3,475,029	10/1969	Hyman	250/222 X

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ABSTRACT: A scoring system for a nonmaterial target is provided by directing ultraviolet light across the face or front of the target in such manner that a projectile striking the target must pass through the ultraviolet light. Photoelectric sensors are arranged to detect ultraviolet light reflected from projectiles passing through the light and striking the target. The light passes through coded masks associated with each sensor. The coding of the masks is such that the sensors respond discretely to indicate the position of the projectile with respect to the target and thus a "hit" or a "miss."

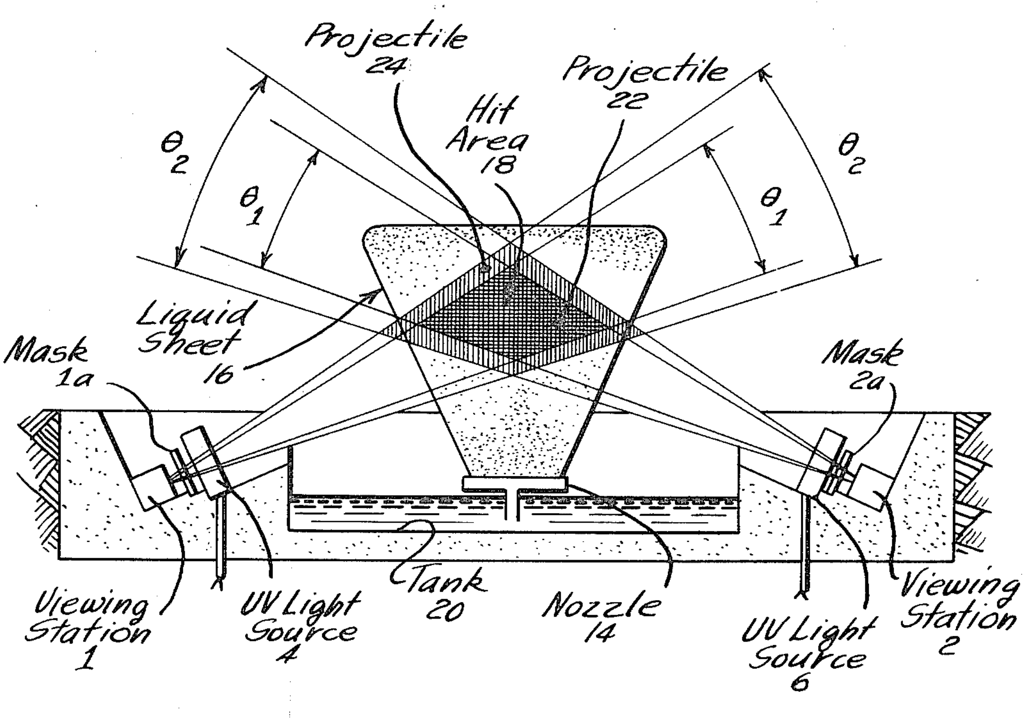

Fig. 1

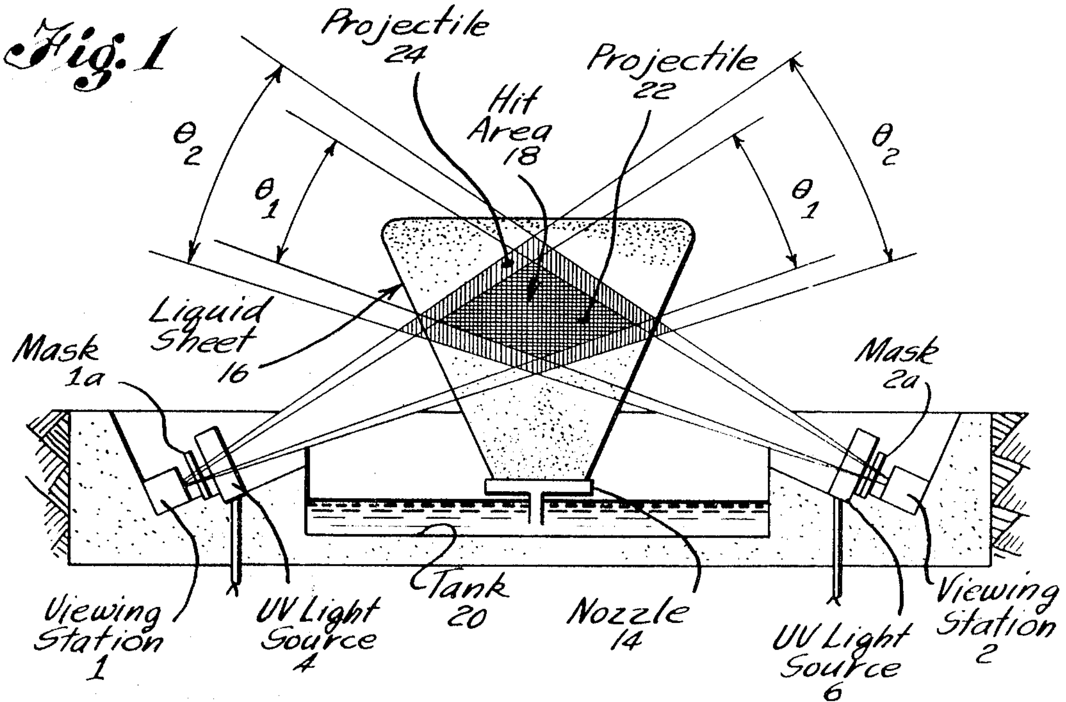

Fig 2

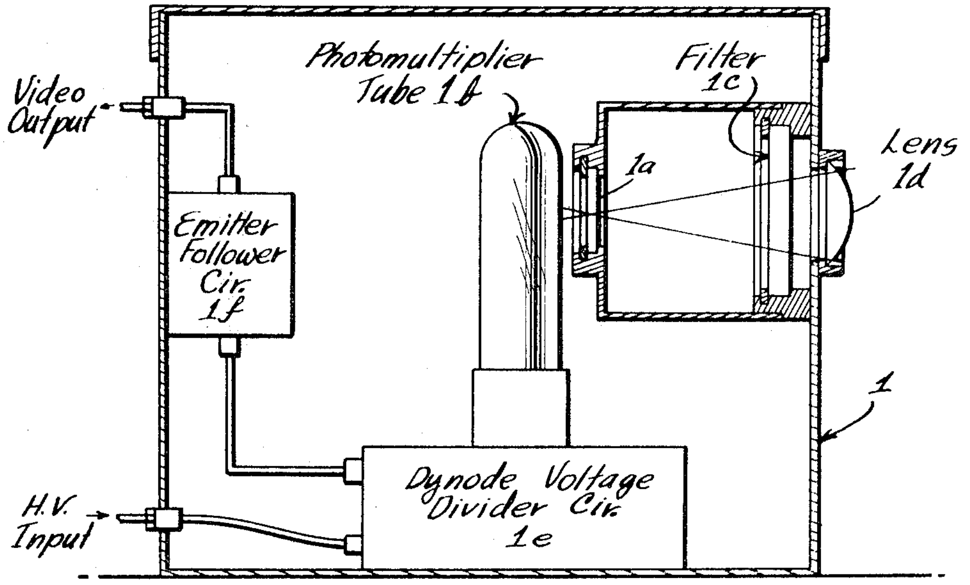

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Fig. 4

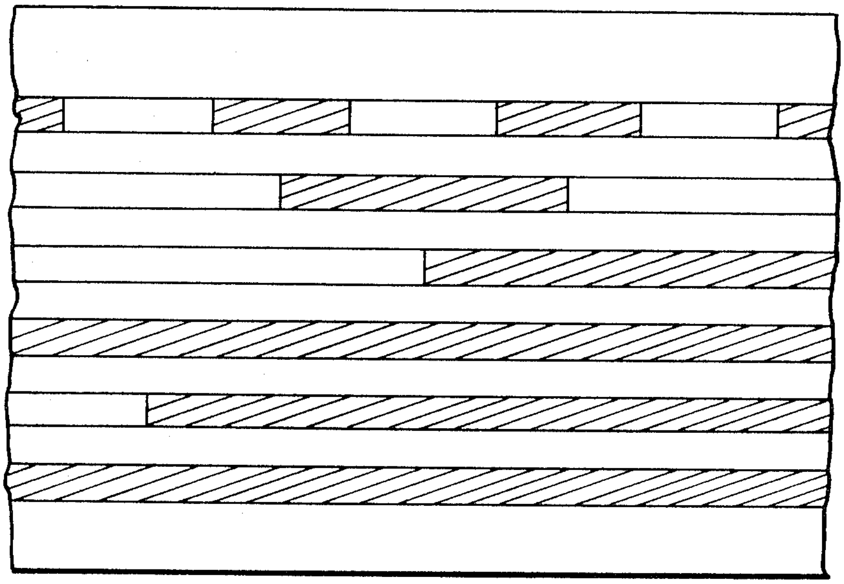
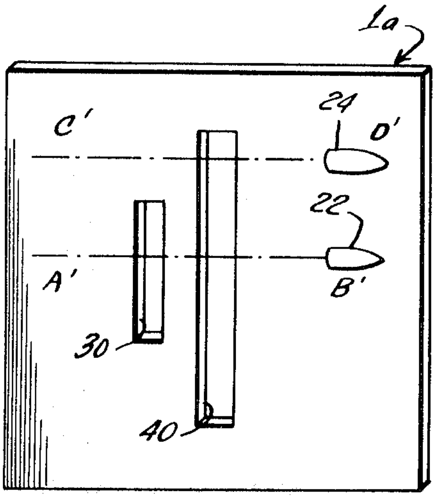


Fig. 3



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ULTRAVIOLET TARGET HIT SCORING SYSTEM

BACKGROUND OF THE INVENTION

The invention is in the field of target scoring. In the past various devices have been used to score hits on targets. Various mechanical and electronic arrangements including sonic, photoelectric, capacitive, inductive, and infrared devices have been developed which will register and in some cases evaluate hits on conventional targets. Recently a great deal of experimentation with nonmaterial targets has taken place. Prior art scoring devices have not proven completely suitable for use with nonmaterial targets for various reasons. The present invention avoids the difficulties encountered in scoring nonmaterial targets with prior art devices by using scoring techniques which are independent of target structure.

SUMMARY OF THE INVENTION

Ultraviolet light of a selected wavelength is directed across an area or a plane adjacent a nonmaterial target in such manner that a projectile striking the target must pass through the ultraviolet light. A plurality of lens are arranged to focus light reflected from a projectile passing through the light on respective digitally coded masks. Filters are provided to reject light energy of other than the selected wavelength. Light passing through particular slots in a mask activates a photoelectric sensor. Output signals from the sensors are decoded to indicate the path of the projectile with respect to the target. The phrase "ultraviolet light" is commonly used in the art and is used here for convenience. Ultraviolet radiation is outside the visible spectrum.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 shows the invention.

FIG. 2 shows the several elements comprising a viewing station such as station 1 in FIG. 1.

FIG 3 shows one example of a coded mask which is one element of a viewing station.

FIG. 4 shows an example of a more complex coded mask usable with a viewing station.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The apparatus of the invention is shown in FIG. 1. Two ultraviolet light sources **4** and **6** are arranged to illuminate a plane in front of a "nonmaterial" or nonsolid target which may be formed by, for example, a sheet of colored liquid **16**, or a lighted area on sheet **16** such as might be formed by a spot of light. Two viewing stations **1** and **2** comprise photoelectric sensors having respective coded masks **1***a* and **2***a* interposed between the sensors and the ultraviolet light in front of target **16**. The masks **1***a* and **2***a* contain slots which are arranged to pass light reflected from a projectile such as **22** or **24** when the projectiles pass through the areas defined by angles θ_1 and θ_2 originating at each of stations **1** and **2**. A hit area shown as the shaded area **18** on target **16** is formed by the intersection of the projections of angles θ_1. A projectile such as **22** passing through the shaded area **18** will be sensed at the viewing stations **1** and **2** and registered as a hit. A projectile passing outside of the area **18** but inside the area bounded by the sides of θ_2 such as projectile **24**, would be sensed to register a miss or a lower valued hit. A projectile passing outside the area θ_2 would not register. The nonmaterial target may be of any description but is shown here as a sheet of colored liquid **16**. The liquid may be pumped by a pump not shown through a perforated pipe or nozzle **14** to create the sheet of liquid **1** which is visible as a target. A tank **20** catches the liquid and forms a reservoir for the pump. Nonmaterial is used to distinguish targets of liquid, smoke, light, etc., from conventional targets made from solid materials such as wood, cloth, paper, etc., which require replacement after receiving a number of hits. All of the elements shown in FIG. 1 are protected from hits by being placed in a pit below ground level, as shown. Light sources **4** and **6** are offset in a different plane to avoid blocking viewing stations **1** and **2**.

The elements in a viewing station such as **1** and **2** are shown in FIG. **2**. An imaging lens **1***d* and a filter **1***c* are interposed in the optical path between a projectile and mask **1***a*. Slots in **1***a* pass light to the photoelectric sensor, photomultiplier tube **1***b*. A high voltage input is processed in a dynode voltage divider circuit **1***e* to supply tube **1***b*. The video output of tube **1***b* is buffered by emitter follower circuit **1***f*. The output of emitter follower **1***f* is taken through an amplifier to an indicating counter not shown, to register hits.

Lens **1***d* is used to focus a reflected projectile image at mask **1***a*. Filter **1***c* is used to filter out sunlight and skylight which, if permitted to reach tube **1***b*, would produce high photocurrents with considerable random noise due to shot effect. This can be expressed as $i_{noise}=k\sqrt{i_c\cdot F\cdot F}$ is the system bandwidth and i_c is the cathode photocurrent. Because of the high speed of projectiles such as bullets which may have speeds of up to 5,000 feet per second, a relatively high bandwidth of about 20,000 Hertz is required. This value is obtained by considering the rise time of reflected light from a bullet as it passes an edge. A one inch bullet traveling at 5,000 feet per second (60,000 inches per second) would pass an edge in 16.7 microseconds. From the relationship $F=0.35/T$ where T is the rise time and F is the bandwidth, a bandwidth of about 20,000 Hertz is obtained. While the photomultiplier can accommodate this bandwidth, the value of i_c must be kept low if noise is to be minimized.

Since the target scoring system is designed to be used in daytime, filter **1***c* is especially designed to block ambient light comprising sunlight and skylight and to admit ultraviolet light of a selected wavelength. It comprises a first order interference filter, a second order interference filter, and a blocking filter, and is designed to pass a maximum of energy at a wavelength of 253.7 millimicrons. This is the wavelength of UV light sources **4** and **6**. Sources **4** and **6** were selected after lengthy analysis of the spectrum of sunlight, testing of the effectiveness of various filters for various wavelengths, and testing the responsiveness of various sensors. It was found that the spectral output of the sun effectively starts at wavelengths of around 300 millimicrons, rises rapidly to about 450 millimicrons, then falls off gradually to 1.4 microns, where water vapor absorption has a considerable effect. Therefore a light source is used having a frequency outside this spectrum to obtain a maximum signal-to-noise ratio. The infrared region was rejected because of a lack of suitable infrared detectors. A known germicidal lamp which generates ultraviolet light having a wavelength of 253.7 millimicrons was selected for light sources **4** and **6**. Sources **4** and **6** are provided with DC current to avoid flicker in the light output. Filter **1***c* transmits 6.7 percent of the available light energy having a wavelength of 254 millimicrons and effectively blocks light energy of other frequencies. Therefore it is possible to obtain a good signal-to-noise ratio in the output of photomultiplier tube **1***b* even when the target system is operated in sunlight.

A simple example of a mask such as **1***a* or **2***a* is shown in FIG. 3. Here mask **1***a* is shown containing a short slot **30** and a longer slot **40**, arranged as shown. A projectile passing within the angle θ_1 and projecting an image along path A'B', will reflect light through slots **30** and **40**. A projectile passing within the angle θ_2 but outside of angle θ_1 and projecting an image along the path C'D' will reflect light through slot **40** only. Photoelectric sensor **1***b* is positioned to respond to light passing through slots **30** and **40** and will therefore develop two output pulses when a projectile such as **22** passes through angle θ_1. These output pulses can be counted by a counter to indicate a hit. Thus if the counters for stations **1** and **2** each receive two pulses a projectile such as **22** of FIG. **1** has passed within the angle θ_1 of both viewing stations, shown as target area **18**, to score a hit. A projectile such as **24** which is within angle θ_1 of viewing station **2** but outside of θ_1 and inside of θ_2 of viewing station **1** would cause one pulse to be registered on the station **1** counter and two pulses to be registered on the station **2** counter to indicate a miss or a lower valued hit. A lesser number of pulses can indicate a miss. A projectile passing outside of both angles θ_2 would not register. The optical axes of stations 1 and 2 are at a known angle to each other, e.g., a right angle, therefore two viewing stations make it possible to locate a projectile path by triangulation.

The coded mask 1*a* of FIG. 3 is shown by way of example only. In practice a more complex coded mask having a plurality of coded slots could be employed. In some cases, depending on the nature of the coded masks, a plurality of photoelectric sensors might be required to handle the inputs from the several slots. FIG. 4 shows one example of a coded mask which might be used. A more complex mask makes it possible to pinpoint the location of a hit within the target area and to assign a range of values to hits nearer to or farther from the center of the target. The two counters associated with viewing stations 1 and 2 could be interconnected with a decoding circuit to indicate the value of a particular hit. Such a decoding circuit could form an input to a register or recorder arranged to add the values of several hits and store the sum to keep the scores of several marksmanship trainees. Circuitry for decoding coded masks is well known and commercially available. See for example chapters 8 and 9 of "Digital Techniques for Computation and Control," by Klein, Morgan, and Anderson, published by Instruments Publishing Co., Pittsburgh, Pa. Chapter 8 discusses theory of conversion. Chapter 9 lists manufacturers and briefly describes several decoders. See also chapter 11 of "Digital Computer Components and Circuits" by Richards, published by D. Van Nostrand Co., Inc., New York. The synthesization of a mask and decoder to digitize a particular quantity is within the skill of the art.

I claim:

1. In a target scoring system, the improvement comprising:

a target, means for lighting a space adjacent said target, said lighted space being positioned so that a projectile striking said target must pass through said lighted space, and sensor means responsive to reflected light for detecting the passage of a projectile through said lighted space,

said target comprising nonmaterial target means,

said sensor means being arranged to respond to the passage of a projectile through said lighted space in a manner determined by the path of said projectile with respect to said target, whereby the area of said target struck by said projectile may be identified,

said means for lighting comprising ultraviolet light sources for generating ultraviolet light energy of a selected wavelength,

filter means positioned before sensor means in a light path between a projectile and said sensor means, said filter means being adapted to permit light energy of said selected wavelength to reach said sensor means and to prevent light energy of other wavelengths from reaching said sensor means,

coded mask means located between said filter means and said sensor means, whereby said sensor means are caused to respond discretely to the passage of a projectile through a particular area of said lighted space,

lens means for focusing light reflected from a passing projectile on said coded mask,

said coded mask containing a plurality of slots for transmitting light from a passing projectile to said sensor means, said slots being arranged to pass light in accordance with the position of said passing projectile, whereby said sensor means are caused to produce a number of output signals determined by the location of the path of said passing projectile.

2. The apparatus of claim 1, said sensor means comprising photoelectic means arranged to subtend an area in said lighted space in such manner that light will be reflected from a projectile passing through said area to more than one of said photoelectric means through a respective coded mask, the arrangement being such that said photoelectric means produce a number of output signals peculiar to the position of said projectile in response to said reflected light.

3. The apparatus of claim 2, said selected wavelength being about 253.7 millimicrons.

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