(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 034 441**
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **81300462.9**

(51) Int. Cl.³: **F 41 G 3/32**

(22) Date of filing: **04.02.81**

(30) Priority: **09.02.80 GB 8004425**

(43) Date of publication of application:
26.08.81 Bulletin 81/34

(84) Designated Contracting States:
AT BE CH DE FR IT LI NL SE

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(54) **Gun with optical means for monitoring the boreline direction.**

(57) A gun (4) is provided with an arrangement for determining the boreline direction of its muzzle during firing. The arrangement is particularly applicable to battle tanks having relatively long and massive barrels across which temperature gradients giving rise to thermal stresses can be developed. A reflector (5) is mounted on the muzzle (6) so as to reflect a beam of light from an optical source (8) mounted on the mantlet (10) to an optical detector (9) mounted along side the source. By this means the pointing direction of the muzzle relative to the cradle (11) within which the barrel is mounted can be accurately monitored.

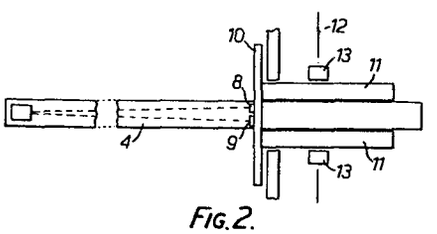

FIG. 2.

EP 0 034 441 A1

TITLE MODIFIED
see front page

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Improvements in or relating to guns

This invention relates to guns and is particularly applicable to guns having a relatively long and massive barrel such as a battle tank. The direction of travel of a shell fired by a gun depends on the boreline direction of the barrel in the region of the muzzle and even very small boreline errors can give rise to significant aiming errors at long range. It has been found that even when relatively sophisticated optical aiming sights are used to lay the gun on a target significant aiming errors can remain. These errors are at least in part due to uncertainties in the direction of the boreline of the muzzle and they can stem from the presence of temperature gradients across the diameter of the barrel which can cause the barrel to bend slightly. It has been proposed to compensate for this particular source of error by aligning the aiming mark of an optical sight with a reference image obtained via a reflector mounted on the muzzle of the gun, so that movement of the muzzle caused by distortion of the barrel can be detected. However, this error can only be detected when the optical sight is being used at unusually low optical magnifications and when the barrel is moved to a low angle of elevation, and thermal stresses set up in the barrel during firing cannot easily be taken into account. Moreover this ignores muzzle boreline errors caused by other factors.

The present invention seeks to provide an improved gun.

According to this invention a gun includes a barrel mounted so as to be rotatable in elevation; optical means for monitoring the boreline direction of the barrel in the region of its muzzle, said optical means including an optical detector arranged to receive an image from an optical source via a reflector mounted on the muzzle, and the optical means being mounted so as to be movable in elevation with said barrel.

When a gun is fired, the reaction of the shell produces a recoil, and in a tank gun the barrel is slidably mounted within a cradle so as to enable the recoil force to be safely dissipated. The cradle is rotatably mounted on trunnions by means of which the cradle and hence the barrel can be

rotated in elevation. The barrel is subject to violent shock, vibration, and acceleration when the gun is fired and for this reason it is not desirable to mount the optical means directly on the barrel.

Preferably the optical means is mounted on a member which moves with and is rigidly coupled to the cradle.

Preferably again the optical means is mounted on the mantlet of a gun. The mantlet is usually in the form of a strong metal plate and its function is to shield the elevation mechanism of the gun at all elevation angles, i.e. it closes what would otherwise be an exposed vertically arranged aperture within which the barrel moves in elevation.

The optical source may be arranged to generate visible light, or alternatively the light may be in a region of the spectrum which is invisible to the human eye, and conveniently the illumination is in the infra-red region.

The optical detector comprises a two dimensional receiving surface which is positioned so as to receive light via the reflector from the optical source with the optical detector being arranged to provide as an output an indication of the position of the received image on the receiving surface. The optical detector may therefore consist of a matrix of individual light sensitive devices, or alternatively of a sheet of material whose electrical properties are modified by the presence of an optical image.

The boreline direction of a gun is affected by temperature gradients which are present across the diameter of its barrel. After the gun has been fired for some time the barrel will become hot and the effect of a side wind or rain is to cool the barrel unevenly. As a result, the coolest face of the barrel shrinks slightly and the barrel bends into the direction of the cooling effect. Similarly, the effect of solar radiation on the barrel is very similar and a temperature gradient can exist from the top surface of the barrel to the lower surface whether the gun has been fired or not, thereby causing the barrel to droop very slightly. The effects of the distortion can be very marked and can significantly influence the aiming accuracy of a gun. For example, a 5^{o}C difference from one

surface of the barrel to the other can at long range produce an aiming error of a few metres.

It has been previously suggested that aiming errors due to this effect can be minimised by using the conventionally provided optical sight in combination with a reflector mounted on the muzzle of the barrel. The optical sight is used by the gunner and is consequently mounted on a rotatable turret in conventional tanks. Because of this it is off-set from the axis of the barrel and it can be used to view a reflector mounted on the muzzle of the barrel only at magnifications which are less than those which would normally be used in firing the gun. Additionally, it is necessary to bring the elevation of the barrel to a predetermined low angular position and to insert an optical prism into the gunner's sight by means of a mechanical lever mechanism to allow the gunner to view the reflector mounted on the muzzle when using the high-gain optical channel of the sight. Boreline errors measured in this way do not take any account of mechanical backlash which might be present between the barrel and the turret in which it is mounted and these backlash errors can also be significant.

The invention is further described by way of example with reference to the accompanying drawing in which,

Figure 1 shows a side view of a gun in accordance with the present invention mounted on a tank,

Figure 2 is a diagrammatic plan view of the gun barrel and

Figure 3 is an explanatory diagram illustrating part of the optical means of which muzzle boreline errors can be corrected.

Referring to the drawing, a battle tank 1 is provided with a turret 2, which is mounted so as to be rotatable in azimuth about a vertical axis 3. The turret supports a long barrel 4 which is mounted within the turret 2 so as to be rotatable in elevation relative to the turret. A gunner who controls the firing of the gun is located within the turret 2 in a position to one side of the axis of the barrel 4. An optical reflector 5 is mounted at the muzzle 6 of the barrel 4 with the reflector 5 being arranged to co-operate with optical means 7. These optical means 7 comprises an optical source

8 and an optical detector 9, which are mounted side by side and are illustrated diagrammatically in Figure 3. These optical means 7 are mounted on the mantlet 10 of the gun.

It is necessary to allow for the recoil of the barrel when a shell is fired and for this reason the barrel 4 is slidably mounted within a cradle 11. The cradle 11 is illustrated in plan view in Figure 2 and it is arranged to surround the barrel 4 and is mounted within the turret 2 so as to be rotatable in elevation about a horizontal axis 12. The cradle 11 is rotatable by means of suitably shaped trunnions which align with the axis 12 and allow the cradle 11 to be rotatably mounted on members 13, which are rigidly secured to the body of the turret 2.

Thus when the gun is fired and a shell is ejected from the muzzle 6, the barrel 4 recoils and slides backwardly within the cradle 11. The cradle 11 is provided with bearing surfaces so as to permit the barrel 4 to slide with the minimum of sideways movement, but even so a certain amount of lateral movement due to mechanical tolerances and sliding clearances is inevitable.

When the gun is to be fired at a target, an aiming mark 30 in an optical sight 31 is manually aligned with the target by the gunner, as the aiming mark is normally to be superimposed on the target when the gun is correctly aimed. The aiming mark is positioned within the optical sight so as to allow for a number of factors, such as the characteristics of the shell, its initial velcoity, cross wind, range etc. These variable factors can be stored in a gun fire control 32 system into which they are entered via leads 33 and used to modify the position of the aiming mark in the sight as necessary. The invention provides for the positioning of the aiming mark to additionally take into account boreline direction errors, that is to say, the errors which stem from the fact that the boreline direction 15 of the muzzle 6 may not be exactly correctly orientated relative to the aiming sight. As previously described these errors can stem from temperature gradients set up across the barrel. Additionally, errors can stem from mechanical movements of the barrel within cradle 11. In particular, this mechanical movement can be caused by wear in

the cradle as the barrel slides within it. Even a relatively small mechanical movement at this point can produce a relatively large error in the boreline pointing direction 15. For example, if the boreline direction is accurately measured whilst the tank is stationary, the errors may change when the tank is used on an incline which imposes a sideways gravitational thrust upon the cradle and trunnion. Such errors cannot be predicted in advance, since they depend on a large number of variable factors, e.g. the slope of the ground on which the tank is standing, the angle of elevation of the barrel and the angle of azimuth or traverse of the turret. If the tank is to be fired whilst it is on the move, the dynamic flexing of the gun barrel due to its length can cause further errors of an unpredictable nature. The invention provides means for monitoring these errors so as to modify the position of an aiming mark in the optical sight to compensate.

The operation of the gun is as follows. The optical source 8 produces a narrow beam of infra-red light which is directed towards the reflector 5 mounted on the muzzle 6 of the barrel 4. The reflector 5 is mounted very securely so that it is not displaced by the recoil of the gun when it is fired. The position and direction of the reflecting surface are very important and must be maintained constant relative to the muzzle. The beam of light is reflected back to an optical detector 9. The movement of the optical beam across the detecting surface of the detector 9 is twice that of the movement of the reflector 5, due to the double path length. Typically the distance between the mantlet 10 and the reflector 5 is 5 metres or more. Consequently even extremely small movements of the reflector 5 produce significant and measurable movements of the light beam across the surface of the detector 9. To allow for large errors, the surface area of the detector 9 should typically be several centimetres square. Alternatively, if a proprietary detector of small area is employed, an optical arrangement placed in front of the detector can be used to reduce the area swept by the light beam to the available area of the detector surface.

The detector 9 may comprise a two dimensional planar matrix

of photosensitive diodes, with typically the diodes being spaced about 1 millimetre apart to provide the required degree of resolution. Of course the actual size of the detector 9 and its resolution will depend on the characteristics of the gun and the required degree of accuracy. Instead of forming the detector 9 of an array of individual photo diodes, it may instead comprise an area of a light sensitive receiving surface surrounded by a number of electrodes. In this case the signal amplitude provided at each electrode is related to the position of the optical beam on the surface and these signals are fed to the fire control system 32. One device of this kind is an opto electronic analogue sensor type S1200 or S1300 produced by Hamamatsu TV Co. Limited, Japan.

Although the optical beam and detector may be operated continuously, this is not necessary since it need only be energised during the period immediately preceding the firing of the gun. It may be arranged to be automatically engaged at the commencement of a fire control sequence. Since the system is capable of operating continuously, whilst the gun is being layed for firing, the effect of errors can be corrected as they develop and are detected.

CLAIMS:-

1. A gun including a barrel mounted so as to be rotatable in elevation; optical means for monitoring the boreline direction of the barrel in the region of its muzzle, said optical means including an optical detector arranged to receive an image from an optical source via a reflector mounted on the muzzle, and the optical means being mounted so as to be movable in elevation with said barrel.

2. A gun as claimed in claim 1 and wherein the optical means is mounted on a member which moves with and is rigidly coupled to a cradle within which the barrel is slidably mounted.

3. A gun as claimed in claim 2 and wherein the optical means is mounted on a mantlet.

4. A gun as claimed in claim 1, 2 or 3 and wherein the optical source is arranged to generate a narrow beam of infra-red light.

5. A gun as claimed in claim 4 and wherein the optical detector comprises a two dimensional receiving surface which is positioned so as to receive light via said reflector from the optical source.

6. A gun as claimed in claim 5 and wherein the receiving surface comprises a two dimensional matrix of individual photosensitive devices.

7. A gun as claimed in claim 6 and wherein the photosensitive devices are photo diodes.

8. A gun as claimed in claim 5 and wherein the optical detector comprises a two dimensional receiving surface which is constituted by a sheet of material whose electrical properties are modified by the presence of an optical image.

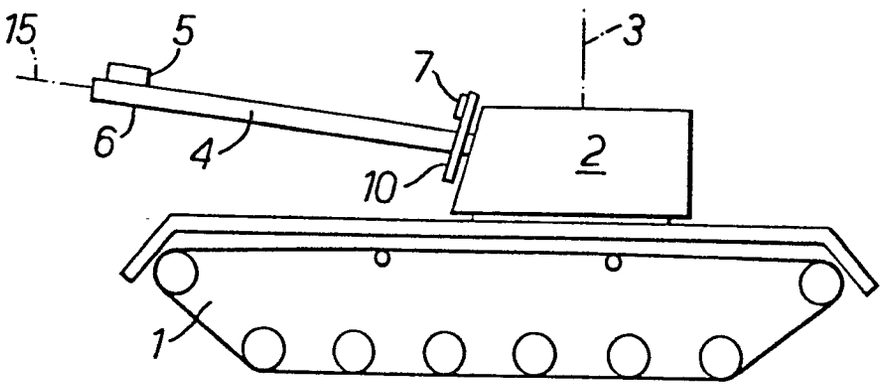

FIG. 1.

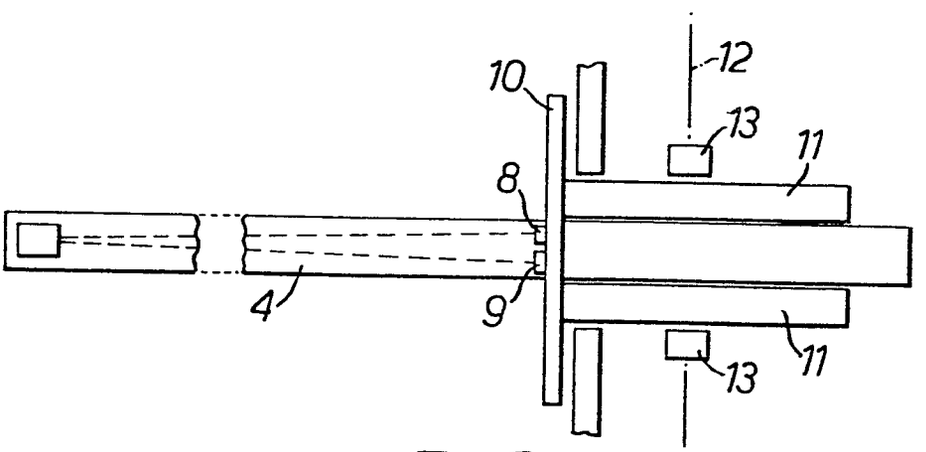

FIG. 2.

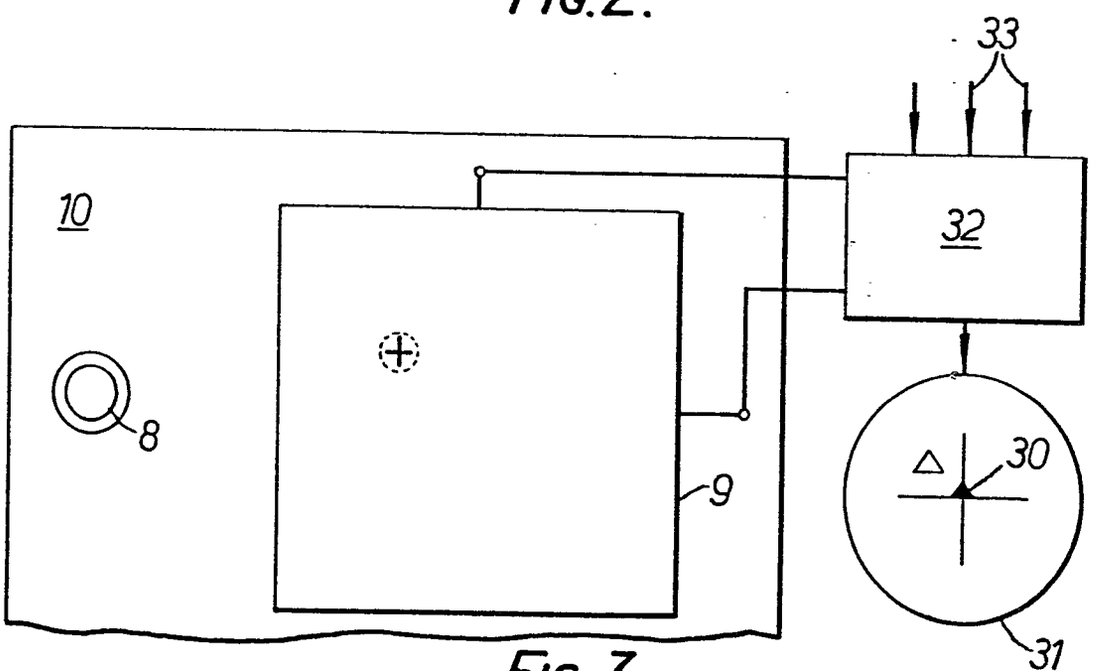

FIG. 3.

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European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 81 30 0462

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	US - A - 3 684 383 (A.J. JOHANSSON) * Whole document * --	1,4-6, 8
	US - A - 4 020 739 (C.F. PIOTROWSKI et al.) * Figure 2; column 1, line 33 - column 4, line 38 * --	1,4-7
A	DE - A - 2 040 225 (RHEINMETALL)	
A	US - A - 2 864 280 (W.E. KELLER et al.) ----	

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

F 41 G 3/32

TECHNICAL FIELDS SEARCHED (Int. Cl.³)

F 41 G
G 01 B

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18-05-1981	CHAIX DE LAVARENE