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IMPROVEMENTS IN OR RELATING TO FIELD HOWITZERS

This invention relates to field howitzers and is especially, although not exclusively, concerned with providing a lightweight field howitzer which is suitable for use by rapid deployment forces.

As is known with field howitzers, which can fire a heavy projectile over a great range, the recoil presents a particular problem. One method of minimising the effect of recoil is to make the howitzer heavy, however such ordnance are not readily transportable.

In the known field howitzers, which are intended to be air liftable, air droppable and moved around a battle field with comparative ease, a relatively light, though still robust, howitzer is required. To increase the stability of the howitzer and to spread the recoil forces, it is known to provide a pair of trail legs which have 'spades' at their free ends. The purpose of the 'spades' is to dig into the ground and thereby absorb the recoil force. Despite their construction, such field howitzers are far too heavy to be carried by small, or medium, sized lift helicopters which might typically be used near the actual battle zone.

Furthermore NATO is in the process of standardising ordnance and ammunition systems into a single calibre and thus a need exists for an ultra lightweight version of the standard 155 mm field howitzer which can be transported as a single unit by a battlefield helicopter.



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The present invention arose in an endeavour to provide a field howitzer which in part, at least, overcomes the limitations of the known howitzers.

According to a first aspect of the invention there is provided a field howitzer
5 comprising: a cradle; a barrel supported by the cradle such as to be displaceable from
a first position to a second position as a consequence of recoil; on firing a recoil buffer
system to absorb the energy of recoil as the barrel is displaced on firing; and a
recuperator system to return the displaced barrel from the second position to the first
position; wherein the recoil buffer and recuperator system are interconnected such that
10 absorption of energy during recoil is used to compress gas in the recuperator system and
wherein the cradle is constructed from hollow members and the space inside said hollow
members is used wholly, or in part, to provide the volume for compressed gas in the
recuperator system.

15 Preferably the recoil buffer system is a hydraulic system and is interconnected to the
recuperator system by a hydraulic accumulator. The hydraulic accumulator arrangement
of the combined recoil buffer system and recuperator system serves as a 'spring' which
absorbs some of the energy of the recoiling barrel. The energy absorbed is subsequently
released in a controlled manner to run out the barrel to the firing (first) position.
20 Hydraulic accumulators operate against a given volume of compressed gas. The 'spring
constant' is determined by the volume of gas and the amount by which this is reduced
by the compression caused by the volume of hydraulic fluid displaced by the recoil. To
provide a relatively uniform 'spring constant', a large volume of gas is required
compared with the volume of fluid displaced. As it is desirable to allow the barrel to

have as long a recoil as possible, a fairly large volume of hydraulic fluid needs to be displaced and hence as large a volume of gas as possible is required. The weight of thick walled pressure-resistant gas cylinders adds significantly to the overall weight of the howitzer. By utilising the space inside the hollow member of the Cradle Structure this provides the required gas volume and eliminates the need for additional gas cylinders thereby substantially reducing the overall weight of the howitzer.

According to a second aspect of the invention there is provided a field howitzer comprising: a chassis; a cradle; a barrel supported by the cradle, wherein the cradle is pivotally mounted to the chassis by a trunnion bearing so that the barrel is pivotable about a horizontal axis and elevating means for pivoting the barrel about said axis, said elevating means being assisted by compressed gas; wherein the cradle is constructed from hollow members and the space inside said members is used, wholly or in part, to provide the volume for the compressed gas. Advantageously the barrel is pivotally mounted so as to be out-of-balance and the degree of assistance provided by the compressed gas is sufficient to substantially counterbalance the weight of the barrel due to its out-of-balance. In a preferred arrangement the elevating means comprises a lead screw and a roll screw, the roll screw being fixed relative to the cradle but rotatable such that rotation of the roll screw causes translational movement of roll screw along the lead screw causing the cradle to rotate about the trunnion bearing, thereby elevating/depressing the barrel of the howitzer. In this preferred arrangement the actual elevation of the barrel is effected by means of a geared drive via a handwheel, but this involves minimal physical effort because of the counterbalancing action. Preferably the lead screw is pivotally fixed to the chassis by a flexible mounting which comprises: a

spring means aligned with the axis of the lead screw and a damper, wherein the spring constant, pre-load and resistance to motion provided by the damper are adjustable to give a tunable system. Conveniently the spring means comprises a plurality of spring washers and the damper is a hydraulic damper.

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The gas connection between the hollow members and the cylinders of the gas springs may either be via flexible pressure-resistant tubes or via a bore down the axis of the piston rods of the pistons with the other ends of the rods secured to said hollow members.

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According to a third aspect of the invention there is provided a field howitzer comprising: a chassis; a cradle; a barrel supported by the cradle, such as to be displaceable from a first to a second position as a consequence of recoil on firing; a trunnion support structure secured to the chassis and including a trunnion bearing about which the cradle is pivotally mounted, wherein the trunnion bearing is positioned at a point beyond the limit of maximum recoil of the barrel. Locating the trunnion bearing beyond the point of maximum recoil enables the trunnion bearing to be located closer to the ground thereby minimising the height of the trunnion support structure thereby reducing the mass of the howitzer. Minimising the trunnion height greatly facilitates the transfer of the recoil forces to the ground. Moving the barrel forward so that the whole of it, including the whole of the supporting cradle, is always forward of the trunnion bearing leads to a high degree of out-of-balance which acts to oppose the recoil moment, particularly when the gun is fired at low angles of elevation.

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In a much preferred embodiment a field howitzer comprises the features of any of the above inventions or a combination of features of all three. Such a combination offers a considerable saving in weight as compared to the known howitzer.

- 5 In a preferred embodiment of any of the above inventions the field howitzer further comprises spades for engaging with the ground; front stabilisers operable to support the howitzer when not being fired; and rear trail support legs operable to spread the load of the howitzer over an area of ground and to assist with the absorbing of recoil energy while providing overturning and lateral stability. The rear trail support legs also provide
- 10 overturning and lateral stability. Preferably the spades are of the 'self-digging' type so that they will be fully effective as the first round is discharged. The spades are preferably located at the ends of the rear trail support legs provided that the trail legs are relatively short and inflexible. In an alternative arrangement the spades can be secured directly to the chassis. This in conjunction with a low trunnion bearing height provides
- 15 an essentially rigid means of restraining the howitzer during recoil. Whilst the front stabilisers and trail legs generally improve stability and hence the aiming of the gun, they also play a part in the absorption of recoil energy. The term 'trail legs' is a generally accepted term in this type of howitzer. Although it is not intended that the howitzer of the invention be towed by 'trail legs', the term is retained for descriptive
- 20 consistency. To enable the howitzer to be readily towed it advantageously comprises a muzzle brake attached to the barrel and a hinged lunette attached to the barrel adjacent to the muzzle brake to enable the howitzer to be towed.

Preferably the spades are removable to enable detachment for when the howitzer is

being towed/transported.

In a preferred embodiment the rear trail support legs are hinged mounted to the chassis and hydraulic dampers are provided at, or near, the attachment points of the rear trail support legs to the chassis to assist with the absorbing of recoil energy. These dampers automatically compensate for uneven ground and give protection against excessive recoil forces.

To enable the howitzer to be trained onto a target it is preferable for the trunnion support structure is secured on the chassis by means of a training bearing so as to be rotatable about a vertical axis, said training bearing comprising a central locating bearing having a first bearing surface fast with the chassis and a second bearing surface fast with the trunnion support and a larger diameter thrust bearing formed as a concentric arc with the central locating bearing. Advantageously the training rack is formed as an integral part of the thrust bearing arc.

It is particularly preferred, in all aspects of the invention, for the howitzer to be constructed in a manner which enables it to be quickly and easily separated into two or more parts which can readily be re-assembled. The advantage of a howitzer which can be separated into one or more component parts and easily re-assembled is that transport problems are greatly reduced if two light sections have to be moved instead of one heavier one. In this context, transport may be by vehicle or helicopter on or near a battlefield or by aircraft, ship or road vehicle to or from the scene of conflict. Smaller sections of the howitzer may pack better in a ship or aircraft when many have to be

transported. A further advantage is that damaged parts may be repaired by replacement of a whole section.

For a better understanding of the invention and to show how the same may be carried
5 into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:-

Figure 1 shows a side elevation of a conventional 155 mm field howitzer in a ready-to-fire position;

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Figure 2 shows a side elevation of an ultra lightweight 155 mm field howitzer in accordance with the present invention in a ready-to-fire position;

Figure 3 shows a side elevation of the howitzer of Figure 2 in the towed mode;

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Figure 4 shows a plan view of the howitzer of Figure 2 in the ready-to-fire mode.

Figure 5 shows a cross-section through the barrel and cradle of the howitzer of Figures 2 to 4;

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Figure 6 shows schematically the action of the recoil buffer and recuperator of the howitzer of Figures 2 to 5;

Figure 7 shows a side elevation of the elevating mechanism of the howitzer of Figures 2 to 6;

Figure 8 shows a sectional plan view along the line BB (Figure 9) of the training mechanism of the howitzer of Figures 2 to 7;

Figure 9 shows a sectional side elevation along the line AA (Figure 8) of the training mechanism of the howitzer of Figures 2 to 8;

Figure 10 shows a side elevation of a rear trail leg and spade of a further howitzer in accordance with the present invention; and

Figure 11 is a simplified exploded view of the howitzer of Figures 2 to 10.

Referring to Figure 1 there is shown a known 155 mm field howitzer in a ready-to-fire position. The barrel 1 which is shown in horizontal orientation is located in a trunnion carried on a substantial chassis 3. The height of the trunnion is such that the barrel axis 1A is a relatively large distance 2 from the ground to enable elevation of the barrel 1 to a required firing position. Two trail legs 4 and a sole plate 5 are provided to give a stable 3-point support for the howitzer. In the ready-to-fire position the trail legs are splayed to increase stability of the howitzer. A spade 6 is provided near to the end of each trail leg 4 which is designed to 'dig' into the ground as the howitzer is fired and so provide a horizontal reaction 7 to the horizontal component of the recoil force. When firing the howitzer with the barrel 1 at an elevated angle, the vertical components 8A and 8B of the recoil reaction are taken at the sole plate 5 and spades 6 via legs 4, respectively. In order to withstand the horizontal reaction 7, the vertical component 8B and the turning component 8T of the recoil forces, the trail legs 4 are made from substantial box-section members. A further benefit of the trail legs 4 is that their weight acts as a counterbalance to that of barrel 1 to bring the centre of gravity 9 above sole plate 5.

Although the trail legs 4 are made from substantial box-section members, they still act as 'springs' when the gun is fired. If the howitzer were to be fired in the attitude shown in Figure 1, there would be no vertical component in the recoil. Instead the recoil would consist of a horizontal force which is balanced by the horizontal reaction 7 and a turning moment 8T which results since the line of reaction 7 is offset from the barrel axis 1A which is the line of action of the force. As the howitzer is fired, the horizontal component of the recoil forces the main body of the howitzer to move backwards. Since the spades 6 should be firmly extended in the ground the horizontal component of the

recoil causes the two splayed out trail legs 4 to distort and absorb the strain energy as they transfer the recoil energy to the spades 6. Since there is also a turning moment 8T in the recoil, the sole plate 5 may be lifted off the ground. As the energy of the recoil is dissipated by the spades 6, so the strain energy in trail legs 4 will be released causing the main body of the howitzer to return to, and possibly overshoot, its original position. At the same time, the main body of the howitzer falls back onto the ground. Thus the known howitzer tends to exhibit fairly violent motion under recoil.

Referring to Figures 2, 3 and 4 there is shown a side elevation of the ultra lightweight howitzer according to the present invention.

In these Figures, the same reference numerals are used for like components as shown in Figure 1 but preceded by 100, for example barrel 1 is designated 101.

Referring to Figure 2 it will be apparent that the overall height of the howitzer is very much lower than that of the known design. A factor is the distance 102 of the axis 101A of barrel 101 when in the horizontal position, which is about 650 mm above ground level, as compared to over 1500 mm for distance 2 for the gun in Figure 1. This low overall height is achieved by locating the trunnion bearing 113 of the trunnion support structure 124 to the rear of the extreme recoil position of the barrel 101 and lying on the axis 101A. This makes the design a hybrid between that of a conventional field howitzer and a mortar. As shown by the centre of gravity 109, there is positive out-of-balance.

To ensure that the weight of the howitzer is used in the most effective manner in the

most arduous mode of operation, that is during firing, the design is such as to place the centre of gravity 109 as far forward of the trunnion bearing 113 as possible, i.e. to create as much positive out-of-balance as practicable to counteract the overturning effect 108T of the recoil. Though the result of this design philosophy is to require front stabilisers 110 to give stability in non-firing modes, the net advantages are considerable. Detailed studies of a range of options indicate that the embodiment shown offers the best compromise between weight-saving on the whole ordnance (i.e. after allowing for the weight of the front stabiliser 110) and minimising the net recoil overturning moment 108T.

The trunnion support structure 124 is carried by a platform/chassis 117. Both these structures are fabricated from low weight, high strength alloys which comprise titanium, magnesium and aluminium etc. as constituents. Other low weight, high strength, materials, e.g. glass and carbon fibre reinforced plastic, may be used where appropriate. The design of the trunnion support 124 and platform/chassis 117 structures uses techniques not usually associated with artillery weapons to give robust lightweight components.

The underside of the platform/chassis 117 is convex to ensure that it will readily rest on all normal types of terrain to give a stable 3-point support with the front stabilisers 110. At the rear of the platform/chassis 117, rear trail legs 104 are fitted via a hinged joint 104A. Also incorporated in these hinges are self digging spades 106. The method of hinging is such that the rearwards and downwards direction of the recoil forces causes the spades 106 to lock against the rear of platform/chassis 117. In effect therefore the

spades can be considered as being rigidly fixed to the chassis and form an integral part thereof.

Due to

- i) the greatly lowered trunnion bearing height,
- ii) the location of the barrel, including full recoil length, forward of trunnion bearing,
- iii) the single fabricated chassis
- iv) the self-digging spades attached directly to the chassis,
- v) the positive out-of-balance of the barrel,
- vi) the use of lightweight alloys and construction techniques,

a number of advantages result, these being:

- a) greatly reduced mass of metal in the trunnion and chassis structures;
- b) greatly reduced turning moments due to recoil forces;
- c) high out-of-balance which acts to oppose the turning moment 108T due to the recoil.

These factors act synergetically because the reduced recoil moment requires less mechanical strength in the trunnion support structure 124, allowing a greater choice of lightweight materials.

The front stabilisers 110 are used to counteract the out-of-balance 109 of the howitzer. Thus in the normal ready-to-fire mode, there is a stable, three-point support provided by the chassis 117 and the two feet 111 at the ends of the front stabilisers 110. The vertical reactions due to the howitzer's weight on the chassis 117 and on the front stabilisers 110

are indicated by arrows 108B and 108D.

The rear trail legs 104 are secured to the body by the composite hinges 104A, which also secure self-digging spades 106. Built into the trail leg hinges 104A are hydraulic dampers (not shown), which essentially comprise a hydraulic fluid flowing through an orifice. Under a steady load, the fluid flows through at a constant rate; however, if the load is greatly increased, only a minimal increase in fluid flow occurs.

As described above the recoil force may be considered as consisting of three components:

- a horizontal component;
- a vertical component; and
- a turning moment 108T.

Referring to Figure 2, the horizontal component of the recoil is balanced by the horizontal reaction 107 which is provided by the two spades 106 which engage in the ground. Though no vertical component is generated when the howitzer is fired with the barrel 101 in a horizontal orientation, as shown in Figure 2, the vertical component of the recoil force (when the barrel 101 is elevated) is balanced by the vertical reaction 108B from the ground via the convex base into chassis 117. The turning moment 108T is balanced by vertical reactions 108C on the feet 112 at the end of the rear trail legs 104, plus the out-of-balance 109. Since the hydraulic dampers (not shown) are incorporated into the hinges 104A, the howitzer will tend to attempt to rotate clockwise slightly as the turning moment 108T is dissipated. Once the turning moment has been dissipated, the

howitzer will rotate back onto its forward feet 111 under the effect of the out-of-balance 109, possibly lifting rear feet 112 off the ground. The rear trail legs 104 will then slowly swing downwards under the control of the dampers (not shown) until feet 112 rest on the ground.

No dampers are incorporated in the hinges 110A for the front stabilisers 110 but these stabilisers can be locked in either the ready-to-fire (Figure 2) or towing (Figure 3) modes.

Thus, a stable three-point support is provided in both ready-to-fire and recoil modes, i.e. $2 \times 108D + 108B$ and $2 \times 108C + 108B$ respectively. It will also be noted that the spades 106 are hinged in such a way (104A) that the horizontal and vertical components of the recoil act to 'lock' them in their operative position. Any rotation of the howitzer due to turning moment 108T would probably occur about an axis roughly through the pair of hinges 104A. Because dampers are used in hinges 104A, their action will protect the rear trail legs 104 from excessive loading so that the scantlings of legs 104 may be minimised.

The importance of having spades 106 which are attached to the chassis 117 should not be underestimated. The horizontal and vertical components of the recoil force are taken directly via the trunnion support structure 124 and the chassis 117 to the ground as reactions 107 and 108B, respectively. Thus, these recoil components pass through robust structures directly to the ground. In contrast in the known field howitzers (Figure 1) the horizontal component of the recoil passes through long 'resilient' trail legs 4. The

release of the strain energy in these resilient trail legs 4 is like a second recoil and the net result is that the known howitzer moves violently during firing. In contrast, each recoil on the ultra lightweight field howitzer of the present invention provides the spades 106 and chassis 117 with an ever more stable base accompanied by a small degree of rotation due to the effect of the turning moment.

Thus, on the ultra lightweight field howitzer of the present invention, the spades 106 provide the anchor at the structures 124 and 117 where the recoil forces are generated. On the known field howitzers, the anchor is remote and is effectively connected by resilient trail legs which act like a 'spring'.

To a casual observer, it may seem that the need to provide two front stabilisers is an additional weight penalty. However, this does not recognise the considerable advantages conferred by the out-of-balance, for example:-

- a) the out-of-balance acts to oppose the recoil turning moment 108T;
- b) the position of the trunnion bearing enables the vertical and the horizontal recoil components to go straight to ground and this allows:-
 - i) the use of short light rear trail legs 104
 - ii) a small light trunnion support structure 124
 - iii) a small light chassis 117.

The net weight saving due to the above is found to far exceed the weight penalty associated with the front stabilisers 110.

Referring to Figure 5 there is shown a cross-section through a cradle which supports the

barrel 101. The cradle has a rearward end which is pivotally mounted about the trunnion bearing 113 (see Figures 2, 3, and 4). The cradle consists of four hollow tubes 119 and 119A located in relation to each other by cross-members 125 and 126. The barrel 101 is arranged such that it can move axially (101A) within the cradle via lugs 127 which slide in cut outs 128 in members 126. The internal volumes of hollow tubes 119 and 119A are designated 129 and 129A respectively. These volumes are cleaned and tested to the conditions laid down for pressure vessels. Cross-connections (not shown) in cross-members 125 link the pairs of internal volumes 129 and 129A respectively. Similar connections may be provided in cross-members 126 if required.

When the howitzer is fired, there is a massive release of chemical energy which causes the barrel 101 to recoil and move rapidly backwards from a first to a second position. The energy of the recoil is absorbed in several ways, of which the main ones are:-

- i) by a muzzle brake 118 (Figure 4);
- ii) by a recoil buffer and recuperator system which will now be described;
and
- iii) through the spades 106 and trail legs 104.

Muzzle brakes 118 are known on many gun barrels. They consist of a series of angled baffles, attached to the barrel, which deflect the exhaust gas rearward and so exert a braking effect on the rearward motion of the barrel. Depending on the angle of the baffles and other factors, the magnitude and efficiency of the braking action may be varied. In this case the particular muzzle brake is chosen in such a way that, together with the design of the recoil buffer and carriage geometry, the energy of the recoil is

dissipated in the most acceptable manner. In this context, "carriage" covers the synergetic design of saddle (including trunnions), body, trail, legs and spades.

The known recoil systems use a recoil buffer and a recuperator on each side of the barrel to dissipate the recoil energy symmetrically, that is there is a total of four cylinders. In the howitzer of the present invention, the recoil buffer and recuperator (Figure 6) are combined into a single cylinder, so that there is only a total of two cylinders - one on each side of the barrel 101. This further contributes to the overall weight saving on the whole howitzer.

When the howitzer is fired, barrel 101 recoils to the right (Figure 6) and the lugs 127, via piston rods 134, force pistons 136 into cylinders 177. Inside the cylinders 177 are perforated sleeves 174 so that the motion of pistons 136 causes hydraulic fluid in the central volume 173 of the cylinder to be forced, via the perforated sleeves 174, into annuli 175 and thence, via pipes 185, 186 to an accumulator 130. The perforations in the sleeves 174 are not uniform but decrease in number and/or size from left to right. Thus, as the pistons 136 move to the right, the cross-sectional area of the perforations through which hydraulic fluid can flow is reduced and, hence, the resistance to the rearward movement of the barrel 101 increases. By varying the size and/or number of perforations, the recoil characteristics may be tailored to suit particular requirements. The piston rods 134 pass through seals 135.

Inside the accumulator 130 is a floating piston 188 which has hydraulic fluid 187 on the one side and inert gas 131 on the other. A pipe 189 connects the accumulator 130 with

two of the four tubular members 119 (or 119A) so that the total volume of inert gas on the left of piston 188 is that in spaces 131 and 129 (or 129A). During the recoil, the hydraulic fluid, which is essentially incompressible, is forced from the volume 173 via the perforated sleeve 174 to the annulus 175 and thence via the pipes 185, 186 to the space 187 thereby forcing the piston 188 to the left and compressing the inert gas 131, 129 (or 129A). Since the volume of the inert gas 131 plus 129 (or 129A) is large compared with the volume swept by the pistons 136, the pressure in the accumulator 130 remains substantially constant.

When the howitzer is fired, the pistons 136 are forced to the right raising the pressure in volume 173. The flow of an incompressible fluid through an orifice is proportional to the square root of the pressure difference across it; thus if the pressure difference is doubled, the fluid flow will increase by only 41%. Thus the recoil buffer action is to exert a high and increasing braking effect on the rearward motion of the barrel 101 progressively bringing it to a halt.

In contrast, the recuperator action is to advance the barrel back to the firing position at a slow steady rate. This is achieved by using the relatively constant pressure difference between that of the inert gas 131, 129 (or 129A) and that in volume 173. Despite the smaller pressure difference, the fluid flows through the perforated sleeves 174 at an appropriate rate to move the barrel 101 back to the firing position in time for the next shot. Inert gas 131, 129 (or 129A) is precompressed to an appropriate pressure so that, under all conditions except when recoiling, the barrel 101 is fully run out to its extended position irrespective of the angle of elevation.

Although hydraulic accumulators 130 on field howitzers are known the use of the additional gas volumes 129 (or 129A) to supplement volume 131, as in the present invention, is considered novel and results in the overall size of the accumulator 130 being greatly reduced which provides a further weight saving. In addition, due to the larger volume of pressurised inert gas 131, 129 (or 129A), the recuperator characteristics are better.

As described above, the location of the centre of gravity 109 gives the howitzer a large out-of-balance. If a conventional elevating gear only were to be used to raise and lower the barrel 101, the elevating gear comprising a geared arc piston and gearbox, the effort required would either be very large or would require an excessively higher ratio. In either case, the gearing would be heavy and cumbersome in use. In order to minimise this effort, elevating cylinders 114 filled with compressed inert gas are used to provide a 'counterbalancing' effect. Here again the gas-spring principle is used with the volume 129/129A of the other two of members 119/119A, providing an increased gas volume. By approximately pressurising the inert gas, the force exerted by the cylinders 114 may be adjusted to be approximately equal to the out-of-balance of barrel 101 and related equipment, e.g. 119, 119A, 130, etc. (A slight degree of under balance is preferred.) Under these circumstances, the barrel 101 may be elevated via a lightweight geared rack (with an acceptable ratio) using a conventional handwheel as only a minimal effort would be required.

As the angle of elevation of the barrel 101 increases, so the total volume inside the cylinders 114 and members 119 (or 119A) will increase thus lowering the pressure and

degree of counterbalancing. However, this will be largely offset by the fact that the raising of the barrel 101 will tend to move the centre of gravity 109 to the right (Figure 2) so that the net out-of-balance will also decrease.

In the particular example herein described, the volumes 129 of the two upper hollow members 119 are used in conjunction with cylinders 114 and the volumes 129A of the two lower members 119A are used as part of the recoil buffer. This arrangement is chosen to give the best line of action for cylinders 114 on the barrel/cradle assembly. However, this arrangement may be varied in accordance with particular requirements. Similarly the 2-2 division of the internal volumes 129/129A of members 119/119A may be varied, e.g. 3-1 or 4-0, depending on requirements.

Considerable weight savings accrue from the use of internal volumes 129/129A in conjunction with the hydraulic accumulator 130. If these volumes were not used, equivalent volumes of pressure-resistant cylinders would be required instead. Not only would this contribute a weight penalty to the whole howitzer, it would also present some problems as to where, physically, to locate the cylinders. If the cylinders were located on the barrel, this would increase the out-of-balance and hence the elevating problems while location on the chassis/platform 117 would impede access to other components and may require a larger (and hence heavier) chassis to be used.

By using the internal volumes 129/129A of members 119/119A there is little or no extra weight penalty. The scantlings of members 119/119A can be calculated by taking loadings and a suitable stress level for the material (including an appropriate factor of

safety) and evaluating the desired metal thickness of the desired tube diameter. Then, from the range of standard thickness available in that diameter, the next thickness greater than that evaluated should be chosen, giving a further safety margin. In this case, the stress in the metal comes from the sum of the stress due to the loading plus the stress due to the internal pressure. Since the stress due to internal pressure would probably be small compared to the loadings, e.g. bending forces, it is quite probable that no increase in wall thickness would be required.

As mentioned before, the elevation gearing must be designed to accommodate the load due to the net weight of the barrel, cradle, etc. It must also be accurate enough for adjusting the barrel 101 to a precisely determined angle, e.g. to within seconds of arc. Clearly, if there were no gas cylinder counterbalancing action, the load on the gearing would be much greater requiring massive gear elements and/or a high ratio. While a high ratio permits accuracy of angular adjustment, it also involves many turns on the handwheel which can be time-consuming and unacceptable in a battle situation.

The solution to this problem is to provide gas-spring counterbalancing to make the barrel, cradle, etc., effectively "weightless" while providing a light, highly accurate damped elevating means to give an optimised new concept to elevation gearing.

The counterbalancing means has been described hereinbefore. The elevating mechanism is shown in Figure 7. Essentially, it consists of a lead screw 139 pivotally fixed at its right hand end to the trunnion support structure 124 and passing through main elevation gearbox 148 near its lefthand end. The main elevation gearbox 148 is fixed to the cradle

119, 119A (the non-moving part of the support for barrel 101), a resetter box 147 is pivoted at 147A to the trunnion support structure 124 and the arrangement is such that the lead screw 139 is parallel to the axis 101A of the barrel 101 and is, preferably, located vertically below it. The lead screw 139 passes through a planetary roller screw 149 in the gearbox 148 so that, as roller screw 149 rotates, the gearbox 148 moves along lead screw 139 in the direction shown by the arrows 155. However, as both the main elevation gearbox 148 and the resetter gearbox 147 are positively located, the result is to cause the barrel 101 and cradle 119, 119A to be elevated (or depressed), i.e. angular motion occurs about the horizontal axis through the trunnion bearing 113 and about the pivot 147A to maintain the axis of barrel 101A parallel to that of lead screw 139.

The means of elevation is from an elevation handwheel 115, via bevel gears 156, elevation hand/drive 116, bevel gears 152, input shaft 153 and bevel gears 150 to a roller screw 149. Lead screw 139 is located, and shaft 153 rotates, in bearings 154. A reverse locking mechanism 151 operates on the shaft 153 to maintain the elevation angle once preset.

The right hand end of the lead screw 139 is mounted by a flexible tunable arrangement to protect the elevating system from shock loadings after firing. Near the end of the lead screw 139 is a screw threaded portion 140 on which a thrust nut 142 and lock nut 141 are secured. Thrust nut 142 bears on a spring 143, which is located at its other end by fixing thrust member 144. The spring 143 preferably comprises a series of spring washers. The end of the lead screw 139 terminates in a hydraulic damper which comprises a piston (and/or orifice) 145 in the cylinder 146 which is full of hydraulic

fluid 146A; Thus, by adjusting the stiffness of spring 143 and the size of orifice 145 to vary the damping characteristics, the resetter gearbox 147 can be 'tuned' to damp out any movement in the barrel 101 after firing and simultaneously protect the elevating system in general and the lead screw 139 in particular. In an alternative embodiment frictional damping is used in place of hydraulic damper 145, 146, 146A.

Thus to fire the howitzer, the elevation is set via the elevation handwheel 115. After firing, the barrel 101 will recoil and the elevating mass will rock causing the lead screw 139 to move axially 155 with respect to the resetter gearbox 147. This causes the spring 143 to compress/relax until the action of damper 145, 146, 146A stops the movement and the spring 143 resumes its original length and the barrel elevation returns to that prior to firing.

The discharge of a howitzer and its recoil is a violent process but, by carefully directing the recoil and allowing limited damped freedom of movement, these processes can be controlled by relatively lightweight members compared to those required in a rigid mounting. Thus in the howitzer described the combination of a lightweight damped elevation system coupled with the counterbalanced system offers a net weight saving over the known rigid gear arc, pinion and gearbox design. Additionally, the lighter system is found to be more accurate, more responsive and physically easier to operate.

The lowered trunnion height and consequently reduced recoil overturning moment 108T permits a reduction in the size of the trunnion support structure 124 on the chassis 117. Because of the way in which the forces are transmitted from the trunnion bearing 113 to

the ground, the traversing arrangement (Figures 8 and 9) can be simplified to a small training bearing 158, 159 at the front, which acts as a fulcrum, and a thrust bearing fixed arc 160 at the rear. The actual training gear 163 is a small arc of a gear ring. This contrasts sharply with the massive ring bearings and full gear ring which are used in the known howitzer. The new design also provides a considerable saving of weight. Like the elevating gear, the training gear is operated by a handwheel via gearing (not shown). Here again, because of the lightweight of the trainable mass, a smaller, lighter gearbox is used than for the conventional field howitzer.

The principle of the design is shown in Figures 8 (plan) and 9 (elevation). The howitzer is trainable about vertical training axis 157 via a bearing, e.g. with inner race 158 fast with chassis 117 and rotatable outer race 159 fast with the trunnion support structure 124. Upper 161 and lower 162 thrust bearings are pre-loaded onto bearing arc 160. These are shown as rollers, but any suitable type of bearing, or pad can be used. Rollers 162 support the positive out-of-balance and rollers 151 are loaded during recoil. The training gear arc 163 is machined onto the edge of the bearing arc 160 and a training gear pinion 164 driven by shaft 165 provides the training drive. The roller races 161 and 162 and the pinion 164 are all mounted on the trunnion support structure 124 though the actual mounting means are not shown to avoid confusing other detail.

There are various methods by which the ultra lightweight howitzer can be converted into the towing mode. In one method, one or two men would support the end of the barrel 101 while lightweight wheels 123 are lowered hydraulically about pivot 122 by means of hydraulic cylinders 120 (see Figure 3). The men would thus be supporting the

positive out-of-balance. The other men of the team would then hinge up the front stabilisers 110 and the trail legs 104 (104B) and remove the spades 106 (106A) to be stowed on platform/chassis 117. A towing bracket in the form of a lunette 137 is then deployed by swinging it forward about the hinge 138 and hooking it on to the towing vehicle. (In Figure 2, the wheels 123 etc. have been omitted so as not to obscure other detail.)

The positive out-of-balance resulting from the location of the centre of gravity 109 places a downward load, via the lunette 137, onto the towing hook of the vehicle in conformity with safe towing practice.

The reduction of the barrel height 102 somewhat complicates the loading arrangements. However, one of the neatest solutions is to place the loading tray above the barrel 101. The position of a shell 121 is shown (Figure 2), but not that of the loading tray or loading linkages, as these would obscure other detail.

The problem with the known howitzers in which the spades 6 (Figure 1) are attached at the ends of long flexible trail legs 4 is that the legs 4 are elastic and absorb much energy in the recoil mode, to be released as a further subsequent reaction. The net effect is that the whole ordnance "bounces" around violently. An alternative to locating the spades adjacent to chassis 117 as in Figure 2 is to secure them by bolts 106B at the ends of short, inelastic legs 104B (see Figure 10 where the spades are denoted by reference numeral 106A) and to provide a hydraulic damper which comprises a cylinder 166 and a piston (not shown) to allow the ordnance limited angular motion about hinge 104A.

The cylinder 166 is pivotally mounted by a joint 169 on to chassis fixture 168 and a piston rod 167 pivotally mounted by joint 171 on to a leg fixture 170. The reference numeral 172 indicates that the legs 104B are not shown to their full length.

The advantage of using such a system is that, after recoil, the chassis 117 and the spades 106A will gently settle back onto the ground. The horizontal element 107 of the recoil would be spread over a larger area of ground than that of two spades 106 situated relatively close together. After several firings from the same spot, the spades 106 will dig deeply into the ground stopping the chassis 117 from settling down as firmly on the ground as desired. The spades 106A eliminate this possibility.

A further advantage of the spades 106A at the end of trail legs 104B is that they enable minor design changes to be made to the chassis 117 giving a further slight lowering of the trunnion bearing 113. This gives a further level of improvement to many of the features described hereinbefore.

The present invention provides a number of advances over the known field artillery. As will have been apparent, a primary object of the present invention is to save weight and so produce an ultra lightweight field howitzer. Though the present invention has led to the introduction of some additional components, e.g. front stabilisers 110, the net result is an ultra lightweight field howitzer. In addition, a field howitzer in accordance with the present invention is much lower in height and is consequently much easier to conceal on a battlefield.

In the foregoing description, reference has been made to the use of light and strong materials. As one of the foremost amongst this class of metals, titanium and its alloys are extensively used wherever the stress levels permit. Furthermore, aerospace principles can be applied to combine lightness and strength, for example to design a given component to perform two or more functions.

Though the aim has been to produce a howitzer which, together with its crew and ammunition, can be carried by a single battlefield helicopter, and this aim has been achieved, smaller helicopters are also used on battlefields. The howitzer has thus been designed to separate quickly and easily into two or more parts so that, separately, the howitzer, crew and ammunition can also be carried by two smaller helicopters or land vehicles. Howitzers that can be readily separated into components and reassembled on a battlefield are much easier to transport in large numbers as the separate parts will pack better into the hold of a ship or an aircraft than fully assembled items. An added feature of howitzers which can be separated into two or more major components is that a failure in one part can be rectified by replacement of the whole component allowing the faulty one to be returned to a workshop for repair.

There are two main occasions when it may be necessary to separate the howitzer into parts. The first is on the battlefield where speed would be essential. In this case, the howitzer would be separated into the "elevating mass" and "carriage" by the removal of the trunnion caps, etc, as shown in Figure 11. Each part would be light enough to be carried by a lorry or small battlefield helicopter. The second occasion could be when the howitzers are to be transported in large numbers from a base to a scene of possible

conflict. Here, speed would not be as important as the density of packing. In this case, other parts such as the stabilisers 110, the trail legs 104B, the wheels 123, etc, may be removed.

A further feature is a lunette 137 (Figure 4) which may be hinged vertically downwards and locked to form a "leg" to support the muzzle end of barrel 101. This would greatly assist separation and reassembly of the howitzer's two main parts.

It will be appreciated by those skilled in the art that modification can be made to the howitzer described within the scope of the present invention. For example, whilst the howitzer described has a number of features which in combination result in a considerable reduction in weight, these features could be used alone to provide a more lightweight field howitzer.

CLAIMS

1. A field howitzer comprising: a cradle; a barrel supported by the cradle such as to be displaceable from a first position to a second position as a consequence of recoil on firing; a recoil buffer system to absorb the energy of recoil as the barrel is displaced on firing; and a recuperator system to return the displaced barrel from the second position to the first position; wherein the recoil buffer and recuperator system are interconnected such that absorption of energy during recoil is used to compress gas in the recuperator system and wherein the cradle is constructed from hollow members and the space inside said hollow members is used wholly, or in part, to provide the volume for compressed gas in the recuperator system.
2. A field howitzer according to Claim 1 in which the recoil buffer system is a hydraulic system and is interconnected to the recuperator system by a hydraulic accumulator.
3. A field howitzer comprising: a chassis; a cradle; a barrel supported by the cradle, wherein the cradle is pivotally mounted to the chassis by a trunnion bearing so that the barrel is pivotable about a horizontal axis and elevating means for pivoting the barrel about said axis, said elevating means being assisted by compressed gas; wherein the cradle is constructed from hollow members and the space inside said members is used, wholly or in part, to provide the volume for the compressed gas.

4. A field howitzer comprising: a chassis; a cradle; a barrel supported by the cradle such as to be displaceable from a first to a second position as a consequence of recoil on firing; a trunnion support structure secured to the chassis and including a trunnion bearing about which the cradle is pivotally mounted, wherein the trunnion bearing is positioned at a point beyond the limit of maximum recoil of the barrel.
5. A field howitzer having the features of any two of Claims 1, 3 and 4.
6. A field howitzer having the features of Claims 1, 3 and 4.
7. A field howitzer according to Claim 3 or Claim 6 or Claim 5 when dependent on Claim 3 wherein the barrel is pivotally mounted so as to be out-of-balance and the degree of assistance provided by the compressed gas is sufficient to substantially counterbalance the weight of the barrel due to its out-of-balance.
8. A field howitzer according to any one of Claims 3, 6 or 7 when dependent on Claim 3 wherein the elevating means comprises a lead screw and a roll screw, the roll screw being fixed relative to the cradle but rotatable such that rotation of the roll screw causes translational movement of roll screw along the lead screw causing the cradle to rotate about the trunnion bearing, thereby elevating/depressing the barrel of the howitzer.
9. A field howitzer according to Claim 8 wherein the lead screw is pivotally fixed

to the chassis by a flexible mounting.

10. A field howitzer according to Claim 9 wherein the flexible mounting comprises: a spring means aligned with the axis of the lead screw and a damper, wherein the spring constant, pre-load and resistance to motion provided by the damper are adjustable to give a tunable system.
11. A field howitzer according to Claim 10 wherein the spring means comprises a plurality of spring washers and the damper is a hydraulic damper.
12. A field howitzer according to any preceding claim and further comprising spades for engaging with the ground; front stabilisers operable to support the howitzer when not being fired; and rear trail support legs operable to spread the load of the howitzer over an area of ground and to assist with the absorbing of recoil energy while providing overturning and lateral stability.
13. A field howitzer according to Claim 12 wherein the spades are located at the ends of the rear trail support legs.
14. A field howitzer according to Claim 12 wherein the spades are secured directly to the chassis.
15. A field howitzer according to any one of Claims 12 to 14 wherein the rear trail support legs are hingedly mounted to the chassis and hydraulic dampers are

provided at, or near, the attachment points of the rear trail support legs to the chassis to assist with the absorbing of recoil energy.

16. A field howitzer according to any one of Claims 12 to 15 wherein the spades are removable.
17. A field howitzer according to any preceding claim wherein the trunnion support structure is secured on the chassis by means of a training bearing so as to be rotatable about a vertical axis, said training bearing comprising a central locating bearing having a first bearing surface fast with the chassis and a second bearing surface fast with the trunnion support and a larger diameter thrust bearing formed as a concentric arc with the central locating bearing.
18. A field howitzer according to Claim 17 and further comprising a training rack which is integral with a part of the thrust bearing arc.
19. A field howitzer according to any preceding claim and further comprising a muzzle brake attached to the barrel and a hinged lunette attached to the barrel adjacent to the muzzle brake to enable the howitzer to be towed.
20. A field howitzer substantially as described and as illustrated by way of reference to Figures 2, 3, 4 or 5 of the accompanying drawings.
21. A recoil buffer and recuperator system for a field howitzer substantially as

described and as illustrated by way of reference to Figure 6 of the accompanying drawings.

22. A training mechanism for a field howitzer substantially as described and as illustrated by way of reference to Figures 7, 8 or 9 of the accompanying drawings.