

Description

The present invention is directed to the field of gun systems, and more specifically directed to a stabilizing system using curvilinear recoil energy management to improve weapon stability for gun systems, especially towed artillery.

Recoil systems currently in use for artillery, and particularly towed artillery, are strictly rectilinear. In other words, the axis of motion during recoil is coaxial with the tube axis. Retardation of the recoiling parts is provided by one or more hydropneumatic cylinders, in which a working fluid is forced through one or more orifices. In these currently used systems, the moment of retarding force tends to tip the gun over backwards. Opposing this is the moment of weapon weight about the trail ends. If the overturning moment exceeds the downward weight moment, the weapon will momentarily lift about its trail ends. This condition is termed "instability", and is undesirable because of (1) possible damage to the weapon and (2) gross weapon movement requiring resighting.

An alternative, non-rectilinear, recoil system is disclosed in U.S. Patent No. 3,114,291 to Ashley. As shown in Ashley's Figure 1, the system makes use of levers and guides. The levers connect a slide and guideway to a barrel. One of the levers extends to a second guideway, which can be curved, so that during recoil the barrel is forced to a rearward and upward position. The barrel is moved so that the recoil force is directed down, rather than only back. However, Ashley does not address the problem of controlled deceleration of upward velocity to maintain stability.

German Patent No.75137 to Olliver describes a curved recoil path which causes increased pressure of adhesion between the gun and the ground, and states that the path may be either a circular arc or some other geometric curve, or even a path formed by curves and straight lines. Olliver does not however teach a two-stage curvilinear path, with the first stage inducing a vertical acceleration component to the recoiling mass and a second stage for controlling vertical deceleration of the mass.

German Patent No. 134007 to Heinrich, which forms the basis for the preamble of claim 1, describes recoiling parts mounted on pairs of guide rails which may be partly curved and partly in the form of straight lines. Although Heinrich refers to two stages of lifting the barrel in recoil, the movement of the centre of mass of the barrel in Heinrich is in a single continuous curved stage and Heinrich does not address controlled vertical acceleration and deceleration, in a first and second stage of the recoil respectively.

Significantly, none of Ashley, Olliver or Heinrich teach that the characteristics of a recoil buffer system and the shape of the guideway or recoil path can be matched to optimise stability.

U.S. Patent No.439,570 to Anderson and U.S. Patent No.463,463 to Spiller disclose "disappearing" guns which, after being fired, rotate vertically so that they descend behind a wall. This motion is caused by recoil. Anderson and Spiller also do not solve the problem of lightweight weapon stability. Also Anderson and Spiller disclose gun mountings which are suitable for use only with heavy ordnance.

In summary, no system exists which addresses the problem of deceleration of upward velocity and which uses recoil means to optimise stability in a way applicable to lightweight towed howitzers. It is the solution of these and other problems to which the present invention is directed.

Summary of Invention

Therefore, it is the primary object of this invention to provide a system for providing improved weapon stability for gun systems.

It is another object of this invention to provide a system for providing improved weapons stability for towed artillery.

It is still another object of this invention to provide a weapon stabilizing system for use with lightweight artillery.

It is still another object of this invention to provide a weapon stabilizing system which imposes a transient stabilizing moment during time of high destabilizing recoil loads.

It is yet another object of this invention to provide a weapon stabilizing system in which the transient stabilizing moment is tailored to overcome the destabilizing recoil loads to assure that the weapon never lifts off the ground.

It is yet another object of this invention to provide a weapon stabilizing system which does not rely solely on the static moment of weapon weight about the trail ends, so that a lighter structure can be employed without fear of instability.

The foregoing and other objects of the invention are achieved by the features of claim 1, i.e. by provision of a gun system having a fixed carriage and which remains relatively fixed during the firing cycle. A recoiling cannon assembly is movably mounted in relation to the cradle so that the cannon assembly can

travel on a defined recoil path. The gun system has recoil braking means for decelerating the cannon assembly and conventional recuperator means for returning the cannon assembly to its original prefiring orientation. In present invention the recoil path is a two-stage curvilinear path, and the means for movably mounting the recoiling cannon assembly includes at least a pair of parallel campaths and associated cam followers, one on each side of the recoiling cannon assembly which constrain travel of the cannon assembly on the recoil path defined by the configuration of each campath. The first stage has a curved configuration portion to produce an upward force and vertical acceleration component to the centre of the mass of the recoiling cannon assembly and the second stage has a configuration different from that of the first stage for causing controlled vertical deceleration of the cannon assembly during recoil. The recoil system generates a retarding force which predictably and controllably decelerates the cannon assembly, and is adapted such that the magnitude of the retarding force is matched in a predetermined relationship to the configuration of the two stage curvilinear recoil path. In this way, in the first stage, the instantaneous destabilizing moment of the recoil forces is overcome by the instantaneous stabilizing moment of the forces resulting from the reaction to the upward force of the recoiling cannon assembly in the curved configuration portion of the first stage of the curvilinear recoil path, and the moment of the static weight of the gun system, and, in the second stage, the instantaneous destabilizing moments of both the recoil forces and the reaction to the downward force of the recoiling cannon assembly during controlled vertical deceleration is overcome by the moment of the static weight of the gun system.

It is therefore possible by dynamic analysis of the forces in operation during recoil to select or design suitable characteristics for the recoil system, and by appropriate design of the exact configuration of the two-stage curvilinear recoil path in relation to such characteristics, to maximise the stabilizing moment of the reaction to the upward force of the recoiling cannon assembly in relation to the destabilizing moment of the recoil system. In this way it will be seen that the moment of the static weight of the gun system required to maintain stability is minimised. This allows the static weight of the gun system to be reduced whilst maintaining stability.

The first stage of the two-stage curvilinear recoil path preferably has a linear portion shaped to maintain the prefiring orientation of the cannon assembly at the beginning of recoil. The curved configuration portion of the first stage preferably has a portion of decreasing radius of curvature in the direction of recoil travel. The second stage of the two-stage curvilinear recoil path may be either linear or curved in either the same or the opposite direction as the first stage, or a combination of these, as necessary. If curved in the same direction as the first stage, the second stage will have a shallower curve than that of the first.

The campath which defines the configuration of the two-stage curvilinear recoil path will have a curved portion corresponding to the first stage of the curvilinear recoil path and a straight or differently curved portion or a combination of both straight and differently curved portions, corresponding to the second stage of the curvilinear recoil path. The campath mechanism can be fixedly mounted on the cannon portion, with the cam follower mechanism fixedly mounted on the carriage portion, or the campath mechanism can be fixedly mounted on the carriage portion with the cam follower mechanism being fixedly mounted on the cannon portion.

A better understanding of the disclosed embodiments of the invention will be achieved when the accompanying detailed description is considered in conjunction with the appended drawings, in which like reference numerals are used for the same parts illustrated in the different figures.

Brief Description of the Drawings

Figure 1 is a right elevational view of a light weight towed Howitzer incorporating a first embodiment of the stabilizing system of the invention;

Figure 2 is a partial, top plan view of Figure 1;

Figure 3 is a partial perspective view of the mounting mechanism of the cannon shown in Figure 1;

Figure 4 is an exploded perspective view of a right side roller set and campath of the mounting mechanism shown in Figure 3;

Figure 5 is a perspective view of a left side roller set and campath of the mounting mechanism shown in Figure 3;

Figure 6 is a cross-sectional view of the stabilizing system, taken along line 6-6 of Figure 1;

Figure 7 is a top plan view of Figure 6;

Figure 8 is a partial, right elevational view of a light weight towed Howitzer incorporating a second embodiment of the stabilizing system of the invention;

Figure 9 is a top plan view of Figure 8;

Figure 10 is a cross-sectional view of the stabilizing system shown in Figure 8, taken along line 10-10 of Figure 8;

Figure 11 is a cross-sectional view of the mounting mechanism of the cannon, taken along line 11-11 of Figure 10;

Figure 12 is a graph plotting the path of the center of mass of the recoiling parts;

Figure 13 is a graph plotting cannon reaction forces versus recoil length;

Figures 14a and 14b are graphs plotting axial and normal force, respectively, versus time;

Figures 15a and 15b are graphs plotting the tube-axial and tube-normal recoil velocities, respectively, versus time;

Figure 15c is a graph plotting maximum tube-normal displacement versus maximum tube-axial displacement;

Figure 16 is a diagrammatic representation of the general gun configuration;

Figure 17 is a diagrammatic representation of the forces acting on the cannon assembly;

Figure 18 is a diagrammatic representation of the forces acting on the carriage and cradle assembly;

Figures 19a - 19c are free body diagrams of the cannon showing the forces acting on the cannon;

Figures 20a and 20b are vector diagrams showing the forces acting on the cannon; and

Figure 21 is a graph plotting orifice areas for long and short recoils;

Figure 22 is a graph plotting moments versus recoil time;

Figure 23 is a graph plotting vertical reaction on the firing platform versus recoil length;

Figure 24 is a graph showing the effect of charge on stability (i.e. vertical ground force);

Figure 25 is a graph plotting cannon velocities versus recoil length;

Figure 26 is a graph plotting cannon accelerations versus recoil length;

Figure 27 is a graph plotting track angle versus recoil length; and

Figure 28 is a graph plotting recoil height versus recoil length.

Description of the Preferred Embodiments

In the present invention, curvilinear recoil is used to provide stability to a lightweight towed Howitzer. As will be described in greater detail below, curvilinear recoil works as follows: the recoiling parts travel rearwardly and upwardly during recoil in curved tracks mounted to the recoil cradle.

Weapon stability requires the balancing of the destabilizing (recoil) moment by an equal and opposite stabilizing moment. In conventional towed weapons, e.g. an M198 Howitzer which weighs 15,000 pounds, this stabilizing moment is derived from gravity acting upon the weapon's mass. In the lightweight towed Howitzer, the weapon weight is 9,000 pounds, just over one-half that of existing large caliber weapons; the available stabilizing moment therefore is substantially reduced compared with that of the conventional weapon.

Our invention involves generating an additional vertical force which produces a supplemental stabilizing moment, counteracting the destabilizing moment of the recoil force. This vertical force acts upon the recoiling parts, resulting in a recoil path which is both rearward and upward. From the shape of this path, we have termed it "curvilinear" in contrast to conventional straight-line or "rectilinear," recoil motion.

The application of a vertical upward force to the recoiling parts causes an equal and opposite downward reaction force on the non-recoiling parts in accordance with Newton's Third Law. This downward reaction supplements the gravitational force, and acts as a stabilizing moment about the trail ends, permitting recoil loads to be higher without an unstable condition resulting. The vertical force on the recoiling parts results in an upward velocity, and this velocity must be returned to zero by the end of the recoil stroke. This results in a two stage recoil cycle, which is described with respect to a lightweight towed 155 millimeter Howitzer incorporating a first embodiment of the invention.

Referring now to Figures 1-7, there is shown a conventional lightweight towed 155 millimeter Howitzer 10 modified to incorporate a first embodiment of the stabilizing system of the invention. Howitzer 10 comprises a conventional stationary carriage 12 supported by conventional left and right wheels 14 and 16 and conventional left and right trails 18 and 20. A cradle 22 having left and right sides 24 and 26 held together at the top by cross members 27 and modified according to the invention as will be described in greater detail hereinafter is pivotally mounted on carriage 12. Cradle 22 is rotated up or down by a conventional balancing/elevating mechanism, shown here as left and right pistons 28 and 30.

As shown in Figure 1, a cannon 32 having a longitudinal tube axis A is mounted in cradle 22 for reciprocating movement between a first, forward and downward position (solid lines) and a second, rearward and upward position (dashed lines). Most of the recoil energy is absorbed and the cannon is returned to battery by a conventional recoil recuperator mechanism, such as left and right recoil/recuperator cylinders

34 and 36 pivotally mounted between cradle 22 and cannon 32.

The mounting mechanism for cannon 32 includes a forward yoke 38 positioned forward of the tube center of mass and a rearward yoke 40 positioned rearward of the tube center of mass. Yokes 38 and 40 comprise cylindrical central collars 42 and 44, respectively, for supporting and housing cannon 32 and forward left and right ears 46a and 46b and rearward left and right ears 48a and 48b, respectively, in the form of tapered structures extending from either side of central collars 42 and 44. Each collar includes a torque key 50 to prevent spinning between the yoke and the cannon tube, and a doubler 52 enveloping torque key 50. Forward left and right twin roller sets 54a and 54b are mounted on forward left and right ears 46a and 46b and rearward left and right twin roller sets 56a and 56b are mounted on rearward left and right ears 48a and 48b, respectively, via stub axes 62. Left twin rollers 54a and 56a preferably are flat, i.e., have rectangular longitudinal cross-sections, while right twin rollers 54b and 56b are trapezoidal, i.e., have trapezoidal longitudinal cross-sections.

The left and right sides 24 and 26 of cradle 22 are provided with forward left and right parallel campaths 64a and 64b, respectively, for movably engaging forward left and right roller sets 54a and 54b, and rearward left and right parallel campaths 66a and 66b, respectively, for movably engaging rearward roller sets 56a and 56b, respectively. Forward and rearward left campaths 64a and 66a have rectangular cross-sections, while forward and rearward right campaths 64b and 66b have cross-sections which are rectangular with a necked in portion at the outer face to better accommodate lateral thrust loads. The precise location of yokes 38 and 40 and their appended roller sets 54a and 54b and 56a and 56b is determined by convenience with respect to the overall weapon design. The locations will affect the division of force between the forward and rearward roller sets.

As shown in Figures 1 and 3, campaths 64a, 64b, 66a, and 66b have identical configurations, consisting of a first, curved stage and a second, straight stage.

Most of the energy of the recoiling parts in a tube-axial direction, i.e. along tube axis A, is absorbed during the first stage of the recoil cycle. During this period, weapon stability is ensured by accelerating the recoiling parts (i.e., cannon 32 and its mounting mechanism) in a direction normal to the tube axis A. The normal force is generated by the action of roller sets 54a and 54b and 56a and 56b attached to the recoiling parts on curved campaths 64a and 64b and 66a and 66b, which are part of non-recoiling cradle 22.

The hydropneumatic recoil system (i.e. recoil cylinders 34 and 36) brakes the recoiling parts along tube axis A. When the recoil velocity has been reduced to an appropriate level by the recoil system, the recoiling parts will have both a small axial and small normal velocity. At this time (stage II), the high initial recoil force is reduced, and simultaneously the tube-normal force is removed by straightening campaths 64a, 64b, 66a, and 66b. Gravitational forces, plus a small component from recoil/recuperator cylinders 34 and 36, and a possible small contribution from the campaths 64a, 64b, 66a, and 66b, slow the recoiling parts to rest in a tube-normal direction by the end of the recoil stroke, as shown in Figure 13.

More specifically, as Figure 12 shows, the interaction of the cam followers (i.e. roller sets 54a, 54b, 56a, and 56b) and curved campaths (64a, 64b, 66a, and 66b, respectively) causes the center of mass of recoiling parts to follow a like curved path. A centrifugal force is generated whose magnitude is

$$F = \frac{M \cdot V_{inst}^2}{R_{inst}}$$

and whose direction is along the local radius vector. V_{inst} is the instantaneous velocity of the center of mass of the recoiling parts. R_{inst} is the corresponding radius of curvature of the campath at the point of contact between roller sets 54a, 54b, 56a, and 56b and campaths 64a, 64b, 66a, and 66b, respectively.

When fired, the specific combination of projectile and propelling charge will produce a predictable firing recoil impulse, determinable by testing of the specific combination of projectile and propelling charge or through tables. This in turn will cause the recoiling parts of the gun to move rearwardly at a predetermined velocity, likewise determinable by testing or from tables. The recoil system causes this velocity to be diminished in a controlled manner by applying a retardation force, determined by choice of the orifice size through which the recoil working fluid is forced. Again, the retardation force is determinable either by testing of the cylinder or through tables. In this manner, the force applied by the recoil system is known and predictable at any point in the recoil stroke. Additionally, the remaining velocity of the recoiling part is also known and predictable. The overturning moment is thus known and predictable at all points in the recoil stroke.

The difference between the overturning and the stabilizing moment gives the minimum additional stabilizing moment required to maintain the gun in contact with the ground. This additional moment (plus any additional safety factor) is provided by the centrifugal force generated by the cam followers/cam path interaction. Since the required instantaneous centrifugal force, together with the mass of the recoiling parts and their instantaneous velocity is now known, the corresponding value for radius of curvature can be predetermined. That is,

$$R_{inst} = \frac{M \cdot v_{inst}^2}{F}$$

In this manner, the "y" coordinates of each of cam paths 64, 66, 68, and 70 can be determined for all corresponding values of "x" (tube-axial) coordinates.

At all points in the recoil stroke, the recoiling parts will have a velocity component in both the "y" direction (normal to tube axis A) and in the "x" direction (along tube axis A). Both of these velocities must be reduced to zero by the end of the recoil stroke. At some point in the recoil stroke, the centrifugal force is reduced to 0 by making the radius of curvature infinite (i.e., each of cam paths 64, 66, 68, and 70 becomes a straight line). Accordingly, the recoiling parts now cease their upward acceleration. The recoil system continues to apply a gentle retardation force, eventually bringing the recoiling parts to rest in both the "x" and "y" axes.

The final retardation force causes a small destabilizing moment, but its magnitude is such that it can be overcome by the stabilizing moment of the static weight of the complete weapon. In effect, the curvilinear recoil motion gives Howitzer 10 an apparent weight greater than the static weight of the weapon during the period of high recoil forces. The curvilinear cam path is designed to assure that the stabilizing moment of the apparent weight of the gun is sufficient to overcome the overturning moment of the recoil retardation forces, maintaining ground contact. During the latter part of recoil travel, when the curvilinear recoil force has been discontinued, the apparent weight of Howitzer 10 is diminished but ground contact is still maintained.

An alternate, equally viable stability solution exists if, as shown in Figures 8-11, the positions of the cam paths and the cam followers are reversed. Thus, referring now to Figures 8-11, there is shown a lightweight towed 155 millimeter Howitzer 10' incorporating a second embodiment of the stabilizing system of the invention. Howitzer 10' also comprises a carriage 12, wheels 14 and 16, and trails 18 and 20. A cradle 22' having left and right sides 24' and 26' and modified according to a second embodiment of the invention as will be described in greater detail hereinafter is pivotally mounted on carriage 12. Cradle 22' is pivoted up and down by left and right pistons 28 and 30.

As shown in Figure 8, cannon 32 is mounted in cradle 22' for reciprocating movement between a first, forward and downward position (solid lines) and a second, rearward and upward position (dashed lines). The mounting mechanism for cannon 32 according to the second embodiment of the invention is the reverse of mounting mechanism for cannon 32 according the first embodiment of the invention, in that the cam paths are positioned on cannon 32, while the cam followers are positioned on cradle 22'. Specifically, the mounting mechanism for cannon 32 comprises forward left and right cam paths 64a' and 64b' and rearward left and right cam paths 66a' and 66b', welded or bolted or otherwise attached to track support collars 72 mounted on cannon 32. Left and right sides 24' and 26' of cradle 22' are provided with forward left and right roller sets 54a' and 54b' of twin rollers and rearward left and right twin roller sets 56a' and 56b', respectively for movable engagement with forward left and right cam paths 64a' and 64b' and rearward left and right cam paths 66a' and 66b', respectively. Each of roller sets 54a', 54b', 56a', and 56b', consists of four rollers, an upper twin roller set and a lower twin roller set, housed in a circular housing 74. Placement of the roller sets in a circular housing is important in that the housing provides the walking beam structure and strength required to make the roller (follower) system work. Circular housings 74 allow the rollers to stay perpendicular to the resultant tangent of the twin rollers to the cam path, as the cam path curves and angles upward or downward.

Choice of the design of either the first embodiment or the second embodiment of the invention does not affect the function of the stabilizing system, and is dictated by overall weapon design. In a further alternate design, the cam path of either the first or the second embodiment can be curved in the opposite direction during the second stage of recoil; that is, towards tube axis A to achieve a greater retardation in the "y" axis (the tube-normal direction). Use of this alternate construction is limited by the requirement to keep ground contact during the second stage of recoil travel.

In a still further alternate design, the campath of either the first or the second embodiment can be curved in the same direction during the second stage of recoil. In this case the curve of the second stage is shallower than that of the first stage.

Stylized tube-axial and tube-normal force-time curves for the first embodiment of the stabilizing system of the invention are shown in Figures 14a and 14b. Superimposing these two force-time curves gives a net force vector and a resultant acceleration. Integration leads to a velocity-time history, resolvable into vertical and horizontal components. Further integration produces the horizontal and vertical displacement of the recoiling parts' center of mass. In stylized form, velocity-time is shown in Figures 15a and 15b and displacements shown in Figure 15c. In the configuration of the invention represented by Figures 15a and 15b, stage I accounts for 60% of the recoil distance and 40% of the recoil time, while stage II accounts for 40% of the recoil distance and 60% of the recoil time.

The preceding description of our curvilinear system and the following dynamic (stability) analysis directly support the campath location on the cradle as described with respect to the first embodiment shown in Figures 1-7, and the stability achieved thereby.

The preceding discussion on stability and the recoil system as well as the development of the governing equations and the dynamic analysis are all based on modeling the gun system as two planar rigid bodies: one recoiling and the other fixed. The recoiling body (mass) will hereafter be referred to as the "carriage." Actually, the carriage is made up of two masses or weights, one that elevates (WE) and one that remains fixed (WF). This is to allow for the movement of the carriage center of gravity associated with elevating and depressing the gun.

The general gun configuration is shown diagrammatically in Figure 16. There are two coordinate systems associated with the cannon model. The first is a ground fixed coordinate system (X-Y) centered at the end of the trail at ground level. The second is a coordinate system (U-Z) which rotates with the gun tube as the cannon elevates and which is centered at the in-battery location of the recoiling mass. This reference frame does not recoil with the cannon. The recoil displacement of the cannon (center of gravity) is measured from the U-Z coordinate system and the horizontal and vertical displacements are U and Z, respectively. The coordinate directions U and Z and the displacements U and Z should not be confused. Similarly the position (X,Y) of the cannon center of gravity can be found relative to the X-Y coordinate system.

The two rigid bodies are shown separately in Figures 17 and 18 to facilitate the illustration of the forces that act between these two bodies and to make clear their equal and opposite effect. The cannon experiences forces from the carriage, parallel to the tube primarily from the recoil mechanism, and normal to the tube from cradle support points. In the case shown in Figures 1-7, the support is provided by rollers 54a and 54b and 56a and 56b constrained in campaths 64a and 64b and 66a and 66b, respectively, both fore and aft. The force from the recoil mechanism is referred to here as the "rod pull" and is the sum of both the recoil (cylinder) force and the recuperator force. To simplify the analysis and discussion, all the forces between the carriage and the cannon are lumped into two force components F_u parallel to the tube and F_z normal to the tube. F_u and F_z are reaction forces that support the cannon. F_x and F_y are equivalent to F_u and F_z yet based on the ground fixed X-Y coordinate system.

At zero quadrant elevation $F_x = F_u$ and $F_y = F_z$.

$$F_x = +F_u(\cos \phi) - F_z(\sin \phi)$$

$$F_y = +F_u(\sin \phi) + F_z(\cos \phi)$$

ϕ = Quadrant Elevation

The criterion for stability can be derived from a consideration of Figure 18. Stability is the condition when the carriage does not rotate about the trail ends. This condition is satisfied if the vertical reaction on the firing platform (R2Y) remains positive. R2Y will remain positive and the gun stable if the stabilizing moment M_{st} remains larger than the overturning moment M_{ov} . At zero quadrant elevation, the overturning moment is the horizontal force F_x times its moment arm:

$$M_{ov} = F_u(h + z + hsp) \quad \text{Eq. 1}$$

The stabilizing moment is the vertical force F_z and the fixed weights WF and WE times their respective moment arms:

$$M_{st} = F_z(A + B + U) + WF(A + AF) + WE(A + AE) \quad \text{Eq. 2}$$

For stability

$$M_{st} > M_{ov} \quad \text{Eq. 3}$$

- 5 The degree of stability can be found by defining the excess stability moment M_{ex} as

$$M_{ex} = M_{st} - M_{ov} \quad \text{Eq. 4}$$

also

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$$R2Y = M_{ex}/C \quad \text{Eq. 5}$$

The larger M_{ex} and $R2Y$ are, the more stable the gun system is.

- 15 For a conventional recoil system, F_u would be equal to the rod pull (RP), and the force F_z would support the portion (WRZ) of the recoiling weight WR that was acting normal to the tube and cradle. At zero quadrant elevation, F_z would be equal to the entire recoiling weight, i.e., $F_z = WRZ = WR$.

Because the sum of WF, WE and WR is limited to 9000 pounds, the stabilizing moment is greatly reduced.

$$M_{st} = F_z(A + B + U) + WF(A + AF) + WE(A + AE)$$

(For a conventional gun) $F_z = WR$

$$M_{st} = WR(A + B + U) + WF(A + AF) + WE(A + AE)$$

- 25 Curvilinear recoil increases the stabilizing moment by increasing F_z . With curvilinear recoil F_z does not simply support the weight of the cannon but acts also to accelerate the cannon upward (normal to the tube) when greater stability is needed. Accelerating the tube upward (Z direction) increases F_z by the inertial force associated with this acceleration:

$$F_z = M(A_z) + WRZ \quad \text{Eq. 6}$$

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- The application of this increased F_z and resulting acceleration of the cannon in the z-direction gives the cannon a displacement (z) and velocity (V_z) in the z-direction. At some point in the latter part of the stroke, this velocity (V_z) must be returned to zero. To accomplish this, F_z must be reduced sufficiently to switch the sign of A_z , in effect to pull down on the cannon. If F_z is reduced in the latter portion of the recoil stroke as required, then the overturning moment must also be reduced to prevent instability during this portion of the recoil. This gives rise to two distinct stages during curvilinear recoil: stage one, defined as the portion of recoil when the tube normal acceleration A_z is positive ("upward"), and characterized by a large tube axial force F_u (rod pull large) and a commensurate tube normal force F_z for stability; and stage two, defined as the portion of recoil when the tube normal acceleration A_z is negative ("downward"), characterized by a reduced or even negative tube normal force F_z and a necessarily greatly reduced tube axial force F_u (rod pull small).

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In the transition from stage one to stage two, the recoil force is greatly reduced so that during stage two, the rod pull is primarily provided by the recuperator force.

- 45 The dynamic analysis models the gun system as two planar rigid bodies; one recoiling, the other fixed. Both rigid bodies are initially at rest; at time equals zero, the time varying forces from firing impulse is applied. This accelerates the cannon in the negative U-direction while it is being acted upon by retarding forces from the recoil mechanism as modeled. Any of several firing impulse functions can be applied to the gun including (but not limited to) M203 PIMP, M203 nominal, and M119, all matched to the cannon tube with 0.7 index muzzle brake and M483 projectile. The recoil force acts to prevent the cannon from attaining free recoil velocity and continues to act to return the recoiling mass to rest.

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The cannon is constrained in the cradle to follow a pre-defined curvilinear cam path. The path is curved upward, which forces the cannon to be displaced and accelerated normally to the tube center-line as it recoils axially. This acceleration "generates" the force that contributes the stability during stage one recoil.

- 55 The magnitudes of F_u and F_z at all time steps are found by solving the differential equations of motion set forth below for the recoiling mass. Once the dynamic forces are found, the firing loads on all major components are statically determined at each time step using the known system geometry.

Figure 19a is the free body diagram of the cannon (recoiling mass). From this diagram comes the two differential equations that describe the motion of the gun system. The carriage is assumed stationary, a

condition satisfied if the vertical firing platform reaction R2Y remains positive. Summing forces in the u direction yields the first differential equation.

Tube axial: $\Sigma F(u) = M(A_u) = F_u - (-)FIMPU - WRU$

$$M(A_u) = F_u + FIMPU - WRU$$

$$A_u = (F_u + FIMPU - WRU)/M \quad \text{Eq. 7}$$

Summing forces in the z direction yields the second differential equation

$$10 \quad \text{Tube normal: } \Sigma F(z) = M(A_z) = F_z - WRZ$$

$$A_z = (F_z - WRZ)/M \quad \text{Eq. 8}$$

As shown in Figure 19a the center of gravity may be displaced from the center line of the tube. This introduces a moment from the firing impulse force (FIMPU) which is balanced by moving the point of application of the reaction forces F_u and F_z axially, providing a countering moment.

Sum of the moments about the center of gravity yields

$$\Sigma MOM = 0 = (-) FIMPU(ZEIMP) - F_z(-UEFZ)$$

$$UEFZ = FIMPU(ZEIMP)/F_z$$

When the firing force has gone to zero, the "eccentricity" UEFZ will be zero and the reaction forces F_u and F_z will act through the center of gravity.

F_u and F_z are the reactions on the cannon from the carriage of the gun; specifically, these forces are supplied by the cradle. The cradle applies these forces by two means, the recoil mechanism and the cam tracks. The recoil mechanism pulls on the cannon via the breech band (see Figures 19b and 19c), and has two components that are related by the geometry of the recoil mechanism. Although as shown in Figure 3 there are two pairs of tracks, a front pair and a rear pair, a single equivalent track force (TR) will be used (a single force on a rigid body can be replaced by two different forces located at any two locations, here the fore and aft roller contact points).

The point of action of the track force (TR) is not fixed; rather it moves such that the sum of the moments about the center of gravity remains equal to zero. This ensures that the cannon translates only.

Figures 19a, 19b, and 19c are all equivalent. So,

$$F_u = TRU + RPU \quad \text{Eq. 9}$$

and

$$F_z = TRZ - RPZ \quad \text{Eq. 10}$$

The total recoil force (RP) is found from the mathematical recoil model and components are found from using the recoil mechanism inclination angle α .

$$RP = (C) (VS VS)/(A_o A_o) = (\text{Recup. Force}),$$

where C is a constant that includes effective piston area, orifice discharge coefficient, and oil density.

$$RPU = RP \cos \alpha$$

$$RPZ = RP \sin \alpha$$

The track force TR is not known, but the relationship between the components can be determined. The track force results from constraining the cannon to follow a predetermined path. The path can be represented by a function of u, pf(u), such that:

$$Z' = pf(u) \text{ or } Z = pf$$

$$\text{The track slope} = dz/du = \frac{d(pf)}{du} = pf'$$

The track angle (β) is defined as positive CW so:

$$\tan \beta = -\text{slope} = -dz/du = -pf'$$

5 Referring to Figures 20(a) and 20(b):

$$\begin{aligned} \tan \beta - \text{TRU/TRZ} &= -pf' \\ \text{TRU} &= -(\text{TRZ})pf' \quad \text{Eq. 11} \end{aligned}$$

10 Two differential equations were developed, Equations 7 and 8. The constraint of the recoil track couples these two equations, resulting in the first equation 7 being the only independent equation. The displacement Z is strictly a function of U (i.e. $Z = pf$) so the following relationship can be developed:

$$Z = pf \quad \text{Eq. 12}$$

$$\begin{aligned} dz/du &= pf' \\ \frac{dz}{dt} &= \frac{dz}{du} \cdot \frac{du}{dt} = pf' \cdot VU \\ V_z &= pf' \cdot VU \quad \text{Eq. 13} \end{aligned}$$

and

$$\frac{d^2z}{dt^2} = \frac{d}{dt} \frac{dz}{dt} = \frac{d}{dt} \frac{dz}{du} \cdot \frac{du}{dt} = \frac{du}{dt} \cdot \frac{d}{dt} \frac{dz}{du} + \frac{dz}{du} \cdot \frac{d}{dt} \frac{du}{dt}$$

$$\frac{d^2z}{dt^2} = \frac{du}{dt} \cdot \frac{du}{dt} \cdot \frac{d}{du} \frac{dz}{du} + \frac{dz}{du} \frac{d^2u}{dt^2}$$

$$\frac{d^2z}{dt^2} = \frac{du^2}{dt} \frac{d^2z}{du^2} + \frac{dz}{du} \frac{d^2u}{dt^2}$$

$$A_z = pf''(V_u)^2 + pf' \cdot (A_u) \quad \text{Eq. 14}$$

35 Now defined are position, velocity, and acceleration in the z-direction, all as functions of position, velocity, and acceleration in the u-direction.

From Eq. 7 $A_u = (F_u + FIMPU - WRU)/M$

8 $A_z = (F_z - WRZ)/M$

9 $F_u = TRU + RPU$

10 $F_z = TRZ - RPZ$

11 $TRU = -(TRZ) pf'$

From Eq. 9

and 11 $F_u = -TRZ(pf') + RPU$

From Eq. 10 $TRZ = F_z + RPZ$

Combine $F_u = -pf'(F_z + RPZ) + RPU$

From Eq. 8 $F_z = MA_z + WRZ$

Combine $F_u = -pf'(MA_z + WRZ + RPZ) + RPU$

From Eq. 14 $A_z = pf'.A_u + pf''.V_u^2$

$$F_u = -pf'(M[pf'.A_u + pf''.V_u^2] + WRZ + RPZ) + RPU$$

Add Eq. 7 for A_u

$$F_u = -pf'(M[pf'(F_u + FIMPU - WRU)/M + pf''.V_u^2] + WRZ + RPZ) + RPU$$

Solve for F_u :

$$F_u = \frac{-pf'(M pf'' V_u \cdot V_u + pf' (FIMPU - WRU) + WRZ + RPZ) + RPU}{(1 + pf'' \cdot pf')} \quad \text{Eq. 15}$$

Also from Eq. 8 $F_z = M.A_z + WRZ$

Combining with Eq. 14

$$F_z = Mpf'.A_u + Mpf'' V_u \cdot V_u + WRZ$$

Combining with Eq. 7

$$F_z = pf' (F_u + FIMPU - WRU) + Mpf'' V_u \cdot V_u + WRZ \quad \text{Eq. 16}$$

The track campath used for the dynamic analysis was matched to the current configuration and recoil mechanism model to ensure weapon stability at zero quadrant elevation. In the present example, a positive ground force on the firing platform was specified to decay from 2000 to a minimum of 1000 lbf. An additional factor of safety for stability was included by designing the campath in the present example for the M203 PIMP charge. This results in even greater stability when a nominal M203 is fired. The path description consists of pairs of points U and Z (Table 1). One can see that the point pairs do not extend the full length of recoil. The path beyond the data is defined as a straight line tangent to the last portion of the track, and as such does not need to be explicitly tabulated.

The driving function for the dynamic analysis is the force applied to the cannon by the firing of the projectile. This time dependent force is calculated from the tables of total impulse supplied to the recoiling mass versus time. the force is calculated by:

$$FIMPU = (\text{change in IMPULSE})/(\text{change in TIME})$$

The effects of different charges on the curvilinear system are determined by using a different firing impulse table as input. The tables are produced from internal ballistics calculations and include the gas action on a muzzle brake with a momentum index of 0.7. Three different tables were used:

Table 2: M203 PIMP - M483 projectile

Table 3: M203 nominal - M483 projectile

Table 4: M119 nominal - M483 projectile

The recoil force is provided by a recoil cylinder model where the recoil force (F-recoil) is given by:

$$F\text{-recoil} = C (V_s \cdot V_s) / (A_o \cdot A_o)$$

The transition between stage one recoil and stage two is accompanied by a rapid drop in F-recoil. This is accomplished by rapidly enlarging the orifice areas. The enlarging of the orifice areas is modeled as a smooth, albeit rapid, transition rather than as an abrupt change. This should more closely represent the response of a real system. This more protracted transition provides for a more forgiving match between the recoil mechanism and the cam path profile. Additionally, the recoil force is not removed entirely during stage two but rather is designed to a nominal value of 1000 lbf. This has several advantages over letting the recuperator alone control stage two: (1) the orifice areas are now defined in stage two rather than being infinity; (2) the active recoil cylinder can now be used to fine tune the stage two recoil; and (3) a velocity dependent retarding force is now present in stage two to help dissipate the energy from an overpressure.

Two orifice profiles are developed for the recoil model; one for long recoil, and one for short recoil. These orifice areas are plotted in Figure 21 and tabulated in Tables 5 and 6. These orifice areas are equivalent areas, and do not correspond directly to the orifice areas for the actual recoil cylinder.

The total recoil mechanism force RP includes a linear spring representation of the recuperator function. So,

$$RP = F\text{-recoil} + FRCP + DFRCP(S),$$

where S is the magnitude of extension of the recoil mechanism in feet.

The exact gun configuration and all remaining data are contained in the input data file shown in Table 7, and tabulated in Table 8.

The primary objective of the preceding dynamic analysis was to demonstrate the stability of the gun system using curvilinear recoil. Stability is ensured if the stabilizing moment about the trail ends M_{st} is greater than the overturning moment M_{ov} . $M_{ex} = M_{st} - M_{ov}$. If M_{st} is greater than M_{ov} then M_{ex} is positive and the forward vertical ground reaction (R2Y) will remain positive and the gun will not "hop." For the condition of zero quadrant elevation and the M203 (nominal) charge, Figure 22 illustrates that M_{st} is greater than M_{ov} and Figure 23 illustrates that R2Y remains positive. The gun system was designed to be stable, even with a M203 PIMP charge. Figure 24 shows that indeed, the gun is stable with the PIMP charge. Figure 24 also shows that the gun system gets progressively more stable as the charge is reduced, the M119 charge being the most stable of the three shown.

For each dynamic analysis run, there are provided up to four files or tables of output with suffixes ".CP1," ".CP2," ".CP3," and ".CP4." Each run has a file name associated with it, beginning first with the prefix "X1" which identifies all files used by, and generated for, this analysis. The remainder of the file name identifies the charge and the quadrant elevation of the gun in degrees. All plots are generated from the tables provided, and the file name of the source is printed in the right-most portion of the title.

Additional data is plotted in Figures 13 and 25-28 for the case of the M203 (nominal charge) and a quadrant elevation equal to zero, because this is the worst condition at which the gun must remain stable.

Table 9 describes all of the headings for Tables 10-16. In addition to the plotted results are tables containing all the data for a variety of quadrant elevations and charges. The tabulated results include:

Table 10.1	X1M203QE00.CP1	long recoil/M203
Table 10.2	X1M203QE00.CP2	long recoil/M203
Table 10.3	X1M203QE00.CP3	long recoil/M203
Table 10.4	X1M203QE00.CP4	long recoil/M203
Table 11.1	X1SRQE45.CP1	short recoil/M203
Table 11.2	X1SRQE45.CP2	short recoil/M203
Table 11.3	X1SRQE45.CP3	short recoil/M203
Table 11.4	X1SRQE45.CP4	short recoil/M203
Table 12.1	X1SRQE70.CP1	short recoil/M203
Table 12.2	X1SRQE70.CP2	short recoil/M203
Table 12.3	X1SRQE70.CP3	short recoil/M203
Table 12.4	X1SRQE70.CP4	short recoil/M203
Table 13	X1M203QE05.CP1	long recoil/M203
Table 14	X1M203QE20.CP1	long recoil/M203
Table 15	X1PIMPQE00.CP1	long recoil/MPIMP
Table 16	X1M119QE00.CP1	long recoil/M119

Thus, it can be seen that curvilinear recoil will ensure stability for a 9000 pound, 155 mm towed Howitzer Demonstrator under all firing conditions.

1.0	0.0	
0.0	0.0	
-1.3943355E-02	1.3027527E-05	0.1064280
-3.3580475E-02	5.6624860E-05	0.1409592
-6.3684531E-02	1.3510455E-04	0.1563128
-0.1042869	2.5162366E-04	0.1717640
-0.1540052	4.1052324E-04	0.1937785
-0.2104911	6.1716477E-04	0.2249140
-0.2717772	8.7735784E-04	0.2614119
-0.3362349	1.1975885E-03	0.3080340
-0.4028695	1.5843266E-03	0.3572629
-0.4708933	2.0439695E-03	0.4173858
-0.5391440	2.5809486E-03	0.4845083
-0.6071967	3.1974320E-03	0.5538852
-0.6750160	3.8950406E-03	0.6251525
-0.7425436	4.6753157E-03	0.6992530
-0.8097011	5.5395346E-03	0.7756743
-0.8764620	6.4888075E-03	0.8539873
-0.9428217	7.5242161E-03	0.9342385
-1.008725	8.6467713E-03	1.017888
-1.074094	9.8571833E-03	1.104130
-1.138907	1.1155967E-02	1.192294
-1.203163	1.2543593E-02	1.282417
-1.266861	1.4020517E-02	1.374535
-1.330001	1.5587180E-02	1.468686
-1.392581	1.7244002E-02	1.564907
-1.454558	1.8991329E-02	1.665446
-1.515883	2.0829225E-02	1.768319
-1.576554	2.2757646E-02	1.873283
-1.636573	2.4776516E-02	1.980368
-1.695942	2.6885740E-02	2.089606
-1.754664	2.9085198E-02	2.201026
-1.812731	3.1374734E-02	2.315465
-1.870110	3.3754066E-02	2.434139
-1.926781	3.6222722E-02	2.555043
-1.982749	3.8780171E-02	2.678199
-2.038018	4.1425858E-02	2.803630
-2.092594	4.4159204E-02	2.931360
-2.146482	4.6979610E-02	3.061410
-2.199686	4.9886454E-02	3.193803
-2.252212	5.2879095E-02	3.328559
-2.304066	5.5956870E-02	3.465699
-2.355253	5.9119098E-02	3.605246
-2.405778	6.2365074E-02	3.747216
-2.455648	6.5694079E-02	3.891629
-2.504867	6.9105372E-02	4.038505
-2.553442	7.2598197E-02	4.187860
-2.601379	7.6171771E-02	4.339711
-2.648682	7.9825304E-02	4.494075
-2.695359	8.3557993E-02	4.650968
-2.741403	8.7368988E-02	4.812841
-2.786800	9.1257334E-02	4.978995

 $\bar{U}$ $\bar{Z}$ $\bar{\theta}$

TABLE I

	-2.831550	9.5221981E-02	5.147982
	-2.875655	9.9262640E-02	5.322362
5	-2.919115	0.1033798	5.502657
	-2.961929	0.1075741	5.689036
	-3.004096	0.1118458	5.881670
	-3.045615	0.1161953	6.080730
	-3.086488	0.1206231	6.286392
10	-3.126714	0.1251293	6.498833
	-3.166293	0.1297142	6.718233
	-3.205228	0.1343779	6.944769
	-3.243518	0.1391206	7.178625
	-3.281166	0.1439423	7.419980
	-3.318173	0.1488429	7.669021
15	-3.354541	0.1538224	7.925926
	-3.390272	0.1588807	8.190881
	-3.425370	0.1640174	8.464065
	-3.459837	0.1692324	8.745662
	-3.493676	0.1745252	9.035846
20	-3.526892	0.1798956	9.334798
	-3.559488	0.1853429	9.643009
	-3.591464	0.1908675	9.965417
	-3.622815	0.1964707	10.30448
	-3.653537	0.2021539	10.66101
25	-3.683624	0.2079185	11.03582
	-3.713072	0.2137657	11.42976
	-3.741877	0.2196966	11.84371
	-3.770037	0.2257122	12.27855
	-3.797549	0.2318135	12.73519
	-3.824410	0.2380012	13.21455
30	-3.850620	0.2442758	13.71754
	-3.876178	0.2506378	14.24510
	-3.901085	0.2570876	14.79814
	-3.925340	0.2636252	15.37757
	-3.948947	0.2702507	15.98427
35	-3.971907	0.2769639	16.61910
	-3.994224	0.2837644	17.28289
	-4.015902	0.2906516	17.97638
	-4.036945	0.2976250	18.70029
	-4.057360	0.3046835	19.45525
40	-4.077151	0.3118262	20.24179
	-4.096327	0.3190518	21.06035
	-4.114895	0.3263590	21.91125
	-4.132864	0.3337463	22.79468
	-4.150242	0.3412120	23.71479
45	-4.167034	0.3487554	24.66697
	-4.183279	0.3563679	25.52153
	-4.199083	0.3640265	26.12380

50

 $\bar{U}$ $\bar{Z}$ $\bar{B}$

TABLE 1 (Continued)

55

20
 .0000 000.
 .0023 - 502.
 .0031 -1073.
 .0040 -2051.
 .0047 -3016.
 .0054 -4075.
 .0060 -4994.
 .0067 -6025.
 .0075 -7096.
 .0085 -8076.
 .0100 -9035.
 .0123 -9913.
 .0133 -10006.
 .0163 -10211.
 .0203 -10406.
 .0271 -10602.
 .0337 -10704.
 .0514 -10806.
 .1711 -10843.
 10.00 -10843.

M203 SHOT IMPULSE DATA
 (PIMP) M483 0.7 M.B.

TABLE 2

14
 .0000 000.
 .0030 -763.
 .0042 -1797.
 .0048 -2473.
 .0069 -5079.
 .0090 -7291.
 .0108 -8550.
 .0129 -9434.
 .0150 -9677.
 .0195 -9955.
 .0315 -10286.
 .0665 -10443.
 .1365 -10455.
 10.00 -10455.

M203 SHOT IMPULSE DATA
 (NOMINAL) M483 0.7 M.B.

TABLE 3

	16	
	.0000	000.
	.0040	-949.
5	.0050	-1601.
	.0060	-2396.
	.0070	-3261.
	.0080	-4123.
	.0100	-5675.
10	.0120	-6709.
	.0140	-7361.
	.0155	-7712.
	.0203	-7952.
	.0253	-8104.
15	.0453	-8322.
	.0803	-8373.
	.2803	-8379.
	10.00	-8379.

M119 SHOT IMPULSE DATA
(NOMINAL) M483 0.7 M.B.

TABLE 4

	43				
	-1.0	0.1000000			
	0.0	0.1000000			
5	1.0980606E-02	0.2136773	-1.0980375E-02	7.615981	
	2.9442310E-02	0.3697216	-2.9442154E-02	7.634443	
	5.8368206E-02	0.5307279	-5.8368392E-02	7.663369	
	9.7794533E-02	0.6714978	-9.7794317E-02	7.702795	
	0.1463418	0.7719964	-0.1463419	7.751342	
10	0.2016678	0.8272313	-0.2016679	7.806668	
	0.2618084	0.8600011	-0.2618082	7.866809	
	0.3251381	0.8641519	-0.3251382	7.930139	
	0.3906655	0.8674879	-0.3906651	7.995666	
	2.811534	0.6066884	-2.811117	10.41653	
15	3.551729	0.4550896	-3.550291	11.15673	
	4.144249	0.2584715	-4.139843	11.74925	
	4.162491	0.2494449	-4.157892	11.76749	
	4.18	0.260			
	4.20	0.310			
	4.21	0.500			
	4.23	1.500			
	4.24	1.800			
	4.245087	1.838936			
	4.260842	1.830884			
25	4.276539	1.822829	-4.270426	11.88154	
	4.445129	1.734067	-4.436337	12.05013	
	4.620374	1.636875	-4.608381	12.22537	
	4.772849	1.547431	-4.757758	12.37785	
	4.930054	1.449455	-4.911491	12.53505	
30	5.065610	1.359271	-5.043849	12.67061	
	5.203977	1.259954	-5.178774	12.80898	
	5.332038	1.157433	-5.303502	12.93704	
	5.440137	1.063096	-5.408682	13.04514	
	5.539235	0.9684290	-5.505030	13.14424	
35	5.629237	0.8734521	-5.592476	13.23424	
	5.710056	0.7781891	-5.670962	13.31506	
	5.781618	0.6826680	-5.740430	13.38662	
	5.843856	0.5869220	-5.800835	13.44886	
	5.896716	0.4909886	-5.852135	13.50172	
40	5.940156	0.3949136	-5.894298	13.54516	
	5.974138	0.2987556	-5.927299	13.57914	
	5.998644	0.2026038	-5.951124	13.60364	
	6.013669	0.1066578	-5.965774	13.61867	
	6.05	0.060			
45	7.05	0.060			

 $\bar{S}$ $\overline{A_0}$ $\bar{U}$ $\bar{\alpha}$

TABLE 5

	29			
	-1.0	0.1000000		
	0.0	0.1000000		
5	1.1038303E-02	0.2141681	-1.1038204E-02	7.616039
	2.9524803E-02	0.3651744	-2.9524621E-02	7.634525
	5.8463097E-02	0.5136756	-5.8463290E-02	7.663464
	9.7870827E-02	0.6343604	-9.7870767E-02	7.702871
	0.1463437	0.7107175	-0.1463436	7.751344
	0.2015076	0.7425037	-0.2015076	7.806508
10	0.2613635	0.7537519	-0.2613631	7.866364
	0.3242474	0.7553425	-0.3242471	7.929248
	0.3891602	0.7807769	-0.3891598	7.994161
	0.4553499	0.7885355	-0.4553490	8.060350
	0.5216808	0.7871751	-0.5216795	8.126681
15	0.9126625	0.7689710	-0.9126559	8.517663
	1.286214	0.7367233	-1.286190	8.891214
	1.638360	0.6977797	-1.638298	9.243361
	1.966563	0.6532170	-1.966431	9.571564
	2.269381	0.6065208	-2.269134	9.874381
20	2.547086	0.5591587	-2.546663	10.15209
	2.799577	0.5086938	-2.798896	10.40458
	3.026139	0.4566602	-3.025103	10.63114
	3.226931	0.4036990	-3.225414	10.83193
	3.402062	0.3496875	-3.399911	11.00706
25	3.551527	0.2944165	-3.548557	11.15653
	3.675147	0.2374927	-3.671132	11.28015
	3.772432	0.1780574	-3.767100	11.37743
	3.850954	0.1018210	-3.843654	11.45595
	3.90	0.060		
30	7.00	0.060		
	$\bar{S}$	$\bar{A}_0$	$\bar{U}$	$\bar{\alpha}$

TABLE 6

3240. 1430. 4330. 2000. 16.08 8.00 19.33 3.833 -1.43 4.00 .001 5 1
 0.854 6.813 0.854 8.792 700. 0.2 0.0 1000.
 0.0 0.0 2.646 -1.688 6000. 500. 1
 2.0 0.8333 2.25 -0.250 0.0 0.0 0.0 0.0 0.0
 2.417 -1.625 4.833 1.017 4.0 4.0

***** MAY 14, 1986 CONFIGURATION WITH SPADE REACTION OFFSET.

WF	WE	WR	-	A	B	C	H	AF	AE	TIME PRINT - STEP FREQ.
R01	RD1	R02	RD2	-	-	-	STAGE_2	F-RECOIL		
ETR1	ETR1	DTR1	DTR2	FRCP	DFRCP	-				
T1	T2	T3	HSP	AEY	FX_2	A3	BY	HTB		
T4	T5	T6	T7	-	-	-				

***** VARIABLE NAMES ARE LISTED AS THEIR VALUES APPEAR IN THE DATA FILE.

TABLE 7

LWTH SYSTEM DIMENSIONS

DATE OF DISTRIBUTION
OF THIS INFORMATION - May 20, 1986

DATE OF ASSOCIATED
COMPUTER RUNS - May 17, 18, 1986

	<u>lbf</u>
WR	4330.0
WF	3240.0
WE	1430.0
FRCF	6000.0
DFRCF	500.0 (lbf/foot)

	<u>Inches</u>
A	193.0
B	96.0
BY	0.0
C	232.0
H	46.0
HTB	0.0
HSP	3.0
A3	0.0
AF	-17.2
AE	48.0
AEY	0.0
RO1	10.25
RD1	81.75

TABLE 8

R02	10.25
RD2	105.5
ETR1	0.0
DTR1	31.75
ETR2	0.0
DTR2	-20.25
T1	24.0
T2	10.0
T3	29.0
T4	27.0
T5	-19.5
T6	58.0
T7	12.2

TABLE 8 (Continued)

FORCES DESCRIPTIONS FOR COMPUTER PRINT-OUTS

All forces are in lbf. And forces printed-out are the sum for both sides of the gun.

All forces and dimensions are drawn on diagrams in the direction that was assumed positive for the dynamic analysis and resulting computer print-outs except where noted by a "(-)" which means that direction shown is negative.

Displacements, Velocities and Accelerations

	<u>NAME</u>	<u>DESCRIPTION</u>	<u>UNITS</u>
5	U	recoil displacement of cannon parallel to cradle (and tube)	ft
10	Z	recoil displacement of cannon perpendicular to cradle (and tube)	ft
15	VU	recoil velocity of cannon parallel to cradle (and tube)	ft/s
20	VZ	recoil velocity of cannon perpendicular to cradle (and tube)	ft/s
25	AU	recoil acceleration of cannon parallel to cradle (and tube)	ft/s/s
30	AZ	recoil acceleration of cannon perpendicular to cradle (and tube)	ft/s/s

TABLE 9

5	WR	Weight of recoiling mass	centered at
	WF	Weight of non-recoiling non-elevating mass	centered at
10			
	WE	Weight of non-recoiling elevating mass	centered at

15

	<u>NAME</u>	<u>DESCRIPTION</u>	<u>COMPONENT DIRECTION</u>
	RRU	Rod pull force	U
25	RPZ	Rod pull force	Z
	TRU1	Breech end track force	U
30	TRZ1	Breech end track force	Z
	TRU2	Muzzle end track force	U
35	TRZ2	Muzzle end track force	Z
	F14_U	Trunnion force on cradle	U
40	F14_Z	Trunnion force on cradle	Z

TABLE 9 (Continued)

45

50

55

	F13_U	Elevating/equilibrators mech force	U
5	F13_Z	Elevating/equilibrators mech force	Z
	F12_X	Trunnion force on upper carriage	X
10	F12_Y	Trunnion force on upper carriage	Y
	F11_X	Elevator/equilibrators force on upper carriage	X
15	F11_Y	Elevator/equilibrators force on upper carriage	Y
20	F9_Y	Support force on upper carriage from lower carriage	Y
25	F3_Y	Recoil pad support force on upper carriage	Y
30	*F2_X	Lower pintle shear force from spade assembly	X

* The presence of this second pintle shear (F2_X) force makes the upper carriage statically indeterminate. So (F2_X) must be chosen prior to running the computer solution. The value for (F2_X) is dependent upon the design of the pintle-spade assembly interface and upon the deflections of all associated parts.

TABLE 9 (Continued)

<u>NAME</u>	<u>DESCRIPTION</u>	<u>COMPONENT DIRECTION</u>
5 F2_Y	Pintle column load from spade assembly	Y
10 F1_X	Upper pintle shear force from spade assembly	X
15 F10_Y=-F9_Y	Force on trail/lower carriage from upper carriage	Y
20 F8_Y=-F3_Y	Force on recoil pads from upper carriage	Y
25 F7_Y	Force from spade assembly	Y
30 M2	Moment (force couple(s)) from spade assembly	lbf-ft
35 F-FLOAT_Y (=R2Y)	Vertical ground force on float (vertical reaction number 2)	Y
40 R2X	Horizontal ground force on spade/float (horizontal reaction number 2)	X
45 R1Y	Vertical ground forces on trail end (vertical reaction number 1)	Y
50 FTRACK	Total (Net) track force	
55 RP	Total rod pull (recoil + recup.)	

TABLE 9 (Continued)

ORCOEF = 14.40 Q.E. = 0.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	0.	4330.	9335.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	42736.	8587.	5592.	-0.032	0.000	-19.44	0.05	-7829.01	31.63
0.010	70652.	11431.	3100.	-0.232	0.001	-56.47	0.23	-4671.30	52.71
0.015	92648.	14813.	2328.	-0.548	0.003	-65.87	0.57	-170.42	77.66
0.020	96579.	15270.	1703.	-0.874	0.006	-64.51	0.96	387.27	80.72
0.025	97058.	15690.	1720.	-1.190	0.012	-61.93	1.37	518.74	83.37
0.030	97169.	16363.	2070.	-1.494	0.020	-59.33	1.79	520.66	87.75
0.035	95061.	15715.	1342.	-1.783	0.030	-56.15	2.21	677.53	82.22
0.040	91826.	15652.	1533.	-2.055	0.042	-52.82	2.62	654.66	80.99
0.045	88312.	15360.	1530.	-2.311	0.056	-49.61	3.02	629.72	78.00
0.050	84575.	15001.	1516.	-2.551	0.072	-46.53	3.40	603.14	74.50
0.055	80672.	14979.	1919.	-2.777	0.090	-43.58	3.77	575.59	73.49
0.060	80631.	15342.	1855.	-2.987	0.110	-40.71	4.14	577.23	75.00
0.065	80583.	15921.	1986.	-3.184	0.132	-37.81	4.52	579.36	77.97
0.070	79205.	15521.	1371.	-3.365	0.155	-34.82	4.90	603.18	73.69
0.075	76722.	15402.	1297.	-3.532	0.181	-31.84	5.26	587.31	71.48
0.080	78470.	16458.	1345.	-3.684	0.208	-28.87	5.63	605.04	77.11
0.085	79147.	17303.	1316.	-3.820	0.237	-25.81	6.03	615.86	80.82
0.090	77645.	17667.	1217.	-3.942	0.268	-22.74	6.43	611.17	80.73
0.095	73804.	17643.	1197.	-4.048	0.301	-19.73	6.83	589.77	77.52
0.100	67804.	17600.	1559.	-4.139	0.336	-16.86	7.20	553.63	73.66
0.105	10363.	-315.	959.	-4.218	0.373	-14.94	7.35	74.65	-36.70
0.110	9053.	249.	1723.	-4.292	0.409	-14.61	7.18	66.77	-32.82
0.115	9085.	260.	1681.	-4.364	0.445	-14.27	7.02	67.02	-32.95
0.120	9114.	270.	1641.	-4.434	0.480	-13.94	6.85	67.27	-33.07
0.125	9143.	279.	1601.	-4.503	0.513	-13.60	6.69	67.51	-33.19
0.130	9171.	289.	1563.	-4.570	0.546	-13.26	6.52	67.74	-33.30
0.135	9197.	299.	1526.	-4.636	0.579	-12.92	6.35	67.96	-33.41
0.140	9222.	232.	1431.	-4.699	0.610	-12.58	6.18	69.19	-34.01
0.145	9245.	242.	1398.	-4.762	0.641	-12.23	6.01	69.39	-34.11
0.150	9268.	251.	1365.	-4.822	0.670	-11.89	5.84	69.58	-34.20
0.155	9288.	261.	1335.	-4.880	0.699	-11.54	5.67	69.75	-34.29

TABLE 10.1

0.160	9307.	270.	1306.	-4.937	0.727	-11.19	5.50	69.92	-34.37	0.
0.165	9326.	279.	1278.	-4.992	0.754	-10.84	5.33	70.08	-34.45	0.
0.170	9341.	289.	1252.	-5.046	0.780	-10.49	5.16	70.22	-34.52	0.
0.175	9357.	298.	1227.	-5.097	0.805	-10.14	4.98	70.36	-34.59	0.
0.180	9370.	307.	1204.	-5.147	0.830	-9.78	4.81	70.47	-34.64	0.
0.185	9382.	316.	1182.	-5.195	0.854	-9.43	4.64	70.59	-34.70	0.
0.190	9394.	325.	1161.	-5.241	0.876	-9.08	4.46	70.70	-34.75	0.
0.195	9402.	335.	1143.	-5.286	0.898	-8.72	4.29	70.78	-34.79	0.
0.200	9410.	344.	1125.	-5.328	0.919	-8.37	4.11	70.86	-34.84	0.
0.205	9415.	353.	1109.	-5.369	0.939	-8.02	3.94	70.93	-34.87	0.
0.210	9418.	364.	1097.	-5.409	0.959	-7.66	3.77	70.96	-34.88	0.
0.215	9419.	373.	1084.	-5.446	0.977	-7.31	3.59	71.01	-34.91	0.
0.220	9417.	384.	1075.	-5.482	0.995	-6.95	3.42	71.02	-34.91	0.
0.225	9413.	395.	1068.	-5.516	1.011	-6.60	3.24	71.01	-34.91	0.
0.230	9406.	405.	1061.	-5.548	1.027	-6.24	3.07	71.01	-34.91	0.
0.235	9395.	418.	1060.	-5.578	1.042	-5.89	2.89	70.96	-34.88	0.
0.240	9383.	431.	1059.	-5.607	1.056	-5.53	2.72	70.90	-34.85	0.
0.245	9367.	444.	1061.	-5.633	1.069	-5.18	2.54	70.82	-34.81	0.
0.250	9346.	458.	1066.	-5.658	1.081	-4.82	2.37	70.71	-34.76	0.
0.255	9323.	473.	1074.	-5.682	1.093	-4.47	2.20	70.58	-34.70	0.
0.260	9297.	487.	1083.	-5.703	1.103	-4.12	2.02	70.44	-34.63	0.
0.265	9266.	504.	1097.	-5.723	1.113	-3.77	1.85	70.25	-34.54	0.
0.270	9232.	521.	1112.	-5.741	1.122	-3.41	1.68	70.06	-34.44	0.
0.275	9197.	538.	1129.	-5.757	1.130	-3.07	1.51	69.85	-34.34	0.
0.280	9158.	556.	1149.	-5.771	1.137	-2.72	1.34	69.62	-34.22	0.
0.285	9118.	574.	1169.	-5.784	1.143	-2.37	1.16	69.39	-34.11	0.
0.290	9078.	591.	1191.	-5.795	1.149	-2.02	0.99	69.14	-33.99	0.
0.295	9041.	608.	1212.	-5.804	1.153	-1.68	0.82	68.91	-33.87	0.
0.300	9006.	622.	1230.	-5.812	1.157	-1.33	0.66	68.70	-33.77	0.
0.305	8977.	634.	1247.	-5.818	1.160	-0.99	0.49	68.52	-33.68	0.
0.310	8955.	643.	1259.	-5.822	1.162	-0.65	0.32	68.39	-33.62	0.
0.315	8942.	648.	1267.	-5.824	1.163	-0.31	0.15	68.31	-33.58	0.
0.320	8938.	650.	1269.	-5.825	1.163	0.04	-0.02	68.28	-33.56	0.

TABLE 10.1 (Continued)

ORCOEF = 14.40 Q.E. = 0.00 (DEGREES)

TIME	U	Z	RPU	RPZ	TRU1	TRZ1	TRU2	TRZ2	FU	FZ
0.000	0.000	0.000	0.	0.	0.	1686.	0.	2644.	0.	4330.
0.005	-0.032	0.000	42736.	0.	31.	11766.	-8.	-3179.	42758.	8587.
0.010	-0.232	0.001	70652.	6.	76.	18384.	-29.	-6953.	70699.	11425.
0.015	-0.548	0.003	92648.	30.	207.	24073.	-80.	-9260.	92775.	14783.
0.020	-0.874	0.006	96579.	74.	373.	25093.	-146.	-9824.	96806.	15195.
0.025	-1.190	0.012	97057.	135.	562.	25447.	-215.	-9761.	97404.	15551.
0.030	-1.494	0.020	97169.	215.	781.	25855.	-287.	-9500.	97663.	16140.
0.035	-1.783	0.030	95060.	306.	998.	25327.	-379.	-9625.	95679.	15397.
0.040	-2.055	0.042	91825.	402.	1232.	24814.	-456.	-9181.	92601.	15231.
0.045	-2.311	0.056	88310.	502.	1471.	24162.	-538.	-8830.	89244.	14829.
0.050	-2.551	0.072	84573.	603.	1714.	23440.	-620.	-8479.	85667.	14358.
0.055	-2.777	0.090	80668.	702.	1972.	22812.	-682.	-7888.	81959.	14221.
0.060	-2.987	0.110	80627.	838.	2353.	23150.	-802.	-7886.	82178.	14425.
0.065	-3.184	0.132	80577.	984.	2819.	23582.	-929.	-7773.	82467.	14825.
0.070	-3.365	0.155	79197.	1121.	3284.	23354.	-1123.	-7985.	81358.	14248.
0.075	-3.532	0.181	76712.	1245.	3798.	22991.	-1288.	-7795.	79223.	13951.
0.080	-3.684	0.208	78457.	1445.	4686.	24023.	-1535.	-7869.	81608.	14708.
0.085	-3.820	0.237	79130.	1642.	5775.	24736.	-1841.	-7886.	83064.	15208.
0.090	-3.942	0.268	77624.	1803.	7002.	24751.	-2193.	-7751.	82433.	15197.
0.095	-4.048	0.301	73779.	1908.	8320.	24031.	-2548.	-7359.	79552.	14764.
0.100	-4.139	0.336	67777.	1942.	9700.	22712.	-2787.	-6526.	74689.	14244.
0.105	-4.218	0.373	10358.	327.	1202.	2445.	-1341.	-2727.	10219.	-609.
0.110	-4.292	0.409	9048.	311.	1160.	2360.	-1050.	-2136.	9158.	-88.
0.115	-4.364	0.445	9078.	338.	1185.	2410.	-1070.	-2177.	9193.	-105.
0.120	-4.434	0.480	9107.	363.	1209.	2459.	-1090.	-2217.	9226.	-121.
0.125	-4.503	0.513	9135.	387.	1232.	2507.	-1109.	-2256.	9258.	-137.
0.130	-4.570	0.546	9162.	411.	1255.	2553.	-1128.	-2294.	9289.	-152.
0.135	-4.636	0.579	9187.	434.	1277.	2597.	-1145.	-2329.	9319.	-166.
0.140	-4.699	0.610	9211.	457.	1285.	2614.	-1183.	-2406.	9313.	-248.
0.145	-4.762	0.641	9233.	478.	1305.	2656.	-1199.	-2438.	9339.	-261.
0.150	-4.822	0.670	9254.	499.	1325.	2696.	-1214.	-2471.	9365.	-274.
0.155	-4.880	0.699	9274.	519.	1344.	2735.	-1229.	-2501.	9389.	-285.

TABLE 10.2

0.160	-4.937	0.727	9292.	538.	1363.	2772.	-1243.	-2530.	9411.	-296.
0.165	-4.992	0.754	9309.	557.	1380.	2808.	-1257.	-2557.	9432.	-307.
0.170	-5.046	0.780	9323.	575.	1397.	2842.	-1270.	-2583.	9451.	-316.
0.175	-5.097	0.805	9338.	592.	1413.	2875.	-1282.	-2608.	9470.	-325.
0.180	-5.147	0.830	9350.	609.	1429.	2906.	-1293.	-2631.	9486.	-333.
0.185	-5.195	0.854	9361.	624.	1443.	2936.	-1304.	-2653.	9501.	-341.
0.190	-5.241	0.876	9372.	639.	1458.	2965.	-1314.	-2674.	9515.	-348.
0.195	-5.286	0.898	9380.	654.	1471.	2993.	-1323.	-2692.	9527.	-353.
0.200	-5.328	0.919	9386.	667.	1484.	3018.	-1332.	-2710.	9538.	-359.
0.205	-5.369	0.939	9391.	680.	1496.	3043.	-1340.	-2726.	9547.	-363.
0.210	-5.409	0.959	9392.	692.	1507.	3066.	-1346.	-2739.	9553.	-365.
0.215	-5.446	0.977	9393.	703.	1517.	3087.	-1353.	-2752.	9558.	-368.
0.220	-5.482	0.995	9390.	714.	1527.	3106.	-1358.	-2762.	9559.	-369.
0.225	-5.516	1.011	9385.	723.	1536.	3124.	-1362.	-2770.	9559.	-369.
0.230	-5.548	1.027	9378.	732.	1544.	3141.	-1365.	-2777.	9557.	-368.
0.235	-5.578	1.042	9366.	740.	1551.	3155.	-1367.	-2780.	9551.	-365.
0.240	-5.607	1.056	9353.	748.	1558.	3169.	-1368.	-2782.	9543.	-361.
0.245	-5.633	1.069	9336.	754.	1563.	3180.	-1368.	-2782.	9532.	-356.
0.250	-5.658	1.081	9315.	759.	1568.	3189.	-1366.	-2778.	9517.	-348.
0.255	-5.682	1.093	9292.	764.	1572.	3197.	-1363.	-2773.	9500.	-340.
0.260	-5.703	1.103	9265.	768.	1575.	3203.	-1360.	-2766.	9480.	-331.
0.265	-5.723	1.113	9234.	771.	1577.	3208.	-1354.	-2755.	9456.	-318.
0.270	-5.741	1.122	9199.	773.	1578.	3211.	-1348.	-2743.	9429.	-305.
0.275	-5.757	1.130	9164.	775.	1579.	3212.	-1342.	-2729.	9401.	-292.
0.280	-5.771	1.137	9125.	776.	1579.	3212.	-1333.	-2713.	9371.	-276.
0.285	-5.784	1.143	9085.	776.	1578.	3210.	-1325.	-2695.	9338.	-261.
0.290	-5.795	1.149	9045.	775.	1577.	3208.	-1316.	-2677.	9306.	-245.
0.295	-5.804	1.153	9008.	775.	1575.	3205.	-1307.	-2660.	9276.	-229.
0.300	-5.812	1.157	8973.	774.	1574.	3202.	-1300.	-2644.	9247.	-216.
0.305	-5.818	1.160	8944.	773.	1572.	3199.	-1293.	-2630.	9224.	-204.
0.310	-5.822	1.162	8922.	772.	1571.	3196.	-1288.	-2619.	9205.	-195.
0.315	-5.824	1.163	8908.	771.	1570.	3194.	-1284.	-2613.	9194.	-190.
0.320	-5.825	1.163	8904.	771.	1570.	3194.	-1283.	-2611.	9191.	-188.

TABLE 10.2 (Continued)

FORCES ON CRADLE AND TRAIL/LOWER CARRIAGE *****
 ORCOEF = 14.40 Q.E. = 0.00 (DEGREES)

TIME	F14_U	F14_Z	F13_U	F13_Z	F7_Y	R2_X	R2_Y	R1_Y	M2
0.000	-9456.	-4581.	9456.	10341.	4607.	0.	9335.	-335.	0.
0.005	25388.	-8978.	17370.	18995.	21023.	42758.	5592.	7665.	96206.
0.010	48576.	-11338.	22123.	24193.	31913.	70699.	3100.	12994.	159073.
0.015	65683.	-13414.	27093.	29627.	41107.	92775.	2328.	17125.	208745.
0.020	70243.	-12422.	26563.	29048.	43020.	96806.	1703.	18163.	217814.
0.025	71532.	-11311.	25872.	28292.	43720.	97404.	1720.	18501.	219158.
0.030	72179.	-10298.	25484.	27868.	44410.	97663.	2070.	18741.	219743.
0.035	72586.	-8426.	23093.	25253.	43759.	95679.	1342.	18725.	215278.
0.040	70963.	-7001.	21638.	23662.	42941.	92601.	1533.	18368.	208353.
0.045	69317.	-5532.	19927.	21791.	41900.	89244.	1530.	17969.	200798.
0.050	67451.	-4131.	18215.	19919.	40724.	85667.	1516.	17512.	192750.
0.055	64950.	-2949.	17009.	18600.	39639.	81959.	1919.	16972.	184407.
0.060	66017.	-1818.	16162.	17673.	40123.	82178.	1855.	17240.	184902.
0.065	66943.	-721.	15523.	16975.	40735.	82467.	1986.	17509.	185550.
0.070	67507.	531.	13851.	15147.	40331.	81358.	1371.	17547.	183056.
0.075	66632.	1613.	12591.	13769.	39683.	79223.	1297.	17324.	178251.
0.080	69369.	2755.	12239.	13384.	41253.	81608.	1345.	18033.	183618.
0.085	71446.	3932.	11619.	12706.	42355.	83064.	1316.	18562.	186895.
0.090	71824.	5025.	10609.	11602.	42405.	82433.	1217.	18649.	185474.
0.095	70158.	5921.	9394.	10273.	41368.	79552.	1197.	18236.	178992.
0.100	66353.	6557.	8337.	9116.	39515.	74689.	1559.	17355.	168051.
0.105	10312.	923.	-93.	-102.	6845.	10219.	959.	3101.	22992.
0.110	8773.	921.	385.	421.	6695.	9158.	1723.	2859.	20605.
0.115	8900.	1005.	293.	320.	6719.	9193.	1681.	2884.	20684.
0.120	9023.	1088.	203.	221.	6743.	9226.	1641.	2909.	20758.
0.125	9144.	1168.	114.	125.	6766.	9258.	1601.	2932.	20831.
0.130	9260.	1247.	28.	31.	6787.	9289.	1563.	2955.	20900.
0.135	9373.	1323.	-54.	-60.	6854.	9319.	1526.	2977.	20967.
0.140	9496.	1382.	-183.	-200.	6924.	9313.	1431.	2991.	20955.
0.145	9599.	1453.	-260.	-284.	7006.	9339.	1398.	3011.	21014.
0.150	9699.	1522.	-334.	-365.	7086.	9365.	1365.	3031.	21072.

TABLE 10.3

0.155	9794.	1588.	-406.	-444.	7163.	9389.	1335.	3050.	21124.
0.160	9886.	1653.	-475.	-520.	7238.	9411.	1306.	3068.	21175.
0.165	9974.	1716.	-542.	-593.	7310.	9432.	1278.	3085.	21222.
0.170	10057.	1777.	-606.	-663.	7378.	9451.	1252.	3102.	21264.
0.175	10138.	1835.	-668.	-731.	7445.	9470.	1227.	3118.	21307.
0.180	10213.	1892.	-727.	-795.	7509.	9486.	1204.	3133.	21343.
0.185	10284.	1946.	-784.	-857.	7570.	9501.	1182.	3147.	21376.
0.190	10354.	1999.	-838.	-917.	7629.	9515.	1161.	3161.	21410.
0.195	10417.	2050.	-889.	-973.	7684.	9527.	1143.	3174.	21436.
0.200	10477.	2098.	-939.	-1026.	7737.	9538.	1125.	3186.	21460.
0.205	10531.	2144.	-985.	-1077.	7787.	9547.	1109.	3198.	21480.
0.210	10580.	2188.	-1027.	-1123.	7833.	9553.	1097.	3208.	21494.
0.215	10626.	2230.	-1068.	-1168.	7877.	9558.	1084.	3218.	21505.
0.220	10665.	2269.	-1105.	-1209.	7918.	9559.	1075.	3226.	21509.
0.225	10699.	2307.	-1139.	-1246.	7955.	9559.	1068.	3234.	21508.
0.230	10728.	2342.	-1171.	-1281.	7989.	9557.	1061.	3240.	21503.
0.235	10749.	2375.	-1198.	-1310.	8020.	9551.	1060.	3245.	21489.
0.240	10766.	2406.	-1223.	-1338.	8047.	9543.	1059.	3250.	21472.
0.245	10777.	2435.	-1245.	-1361.	8072.	9532.	1061.	3253.	21447.
0.250	10779.	2462.	-1262.	-1380.	8091.	9517.	1066.	3255.	21413.
0.255	10777.	2486.	-1277.	-1396.	8109.	9500.	1074.	3256.	21375.
0.260	10768.	2508.	-1288.	-1409.	8122.	9480.	1083.	3256.	21330.
0.265	10752.	2528.	-1296.	-1417.	8132.	9456.	1097.	3255.	21276.
0.270	10729.	2546.	-1300.	-1422.	8138.	9429.	1112.	3252.	21216.
0.275	10703.	2562.	-1302.	-1424.	8141.	9401.	1129.	3249.	21153.
0.280	10671.	2575.	-1300.	-1422.	8141.	9371.	1149.	3245.	21084.
0.285	10635.	2587.	-1296.	-1418.	8139.	9338.	1169.	3240.	21011.
0.290	10596.	2596.	-1290.	-1411.	8134.	9306.	1191.	3234.	20938.
0.295	10559.	2605.	-1284.	-1404.	8129.	9276.	1212.	3229.	20870.
0.300	10524.	2610.	-1277.	-1396.	8123.	9247.	1230.	3224.	20807.
0.305	10494.	2615.	-1270.	-1389.	8117.	9224.	1247.	3219.	20753.
0.310	10470.	2618.	-1265.	-1383.	8112.	9205.	1259.	3216.	20712.
0.315	10456.	2620.	-1261.	-1379.	8109.	9194.	1267.	3214.	20687.
0.320	10451.	2620.	-1260.	-1378.	8108.	9191.	1269.	3213.	20680.

TABLE 10.3 (Continued)

FORCES ON UPPER CARRIAGE *****
 ORCOEF = 14.40 Q.E. = 0.00 (DEGREES) F2_X CHOSEN= 0.

TIME	F12_X	F12_Y	F11_X	F11_Y	F9_Y	F1_X	F2_Y	F3_Y
0.000	9456.	4581.	-9456.	-10341.	10341.	0.	4728.	-9309.
0.005	-25388.	8978.	-17370.	-18995.	18995.	42758.	-15431.	6452.
0.010	-48576.	11338.	-22123.	-24193.	24193.	70699.	-28813.	17475.
0.015	-65683.	13414.	-27093.	-29627.	29627.	92775.	-38779.	25365.
0.020	-70243.	12422.	-26563.	-29048.	29048.	96806.	-41317.	28895.
0.025	-71532.	11311.	-25872.	-28292.	28292.	97404.	-42000.	30689.
0.030	-72179.	10298.	-25484.	-27868.	27868.	97663.	-42340.	32042.
0.035	-72586.	8426.	-23093.	-25253.	25253.	95679.	-42417.	33991.
0.040	-70963.	7001.	-21638.	-23662.	23662.	92601.	-41408.	34407.
0.045	-69317.	5532.	-19927.	-21791.	21791.	89244.	-40370.	34838.
0.050	-67451.	4131.	-18215.	-19919.	19919.	85667.	-39208.	35077.
0.055	-64950.	2949.	-17009.	-18600.	18600.	81959.	-37720.	34771.
0.060	-66017.	1818.	-16162.	-17673.	17673.	82178.	-38268.	36450.
0.065	-66943.	721.	-15523.	-16975.	16975.	82467.	-38749.	38029.
0.070	-67507.	-531.	-13851.	-15147.	15147.	81358.	-38960.	39491.
0.075	-66632.	-1613.	-12591.	-13769.	13769.	79223.	-38386.	39999.
0.080	-69369.	-2755.	-12239.	-13384.	13384.	81608.	-39907.	42662.
0.085	-71446.	-3932.	-11619.	-12706.	12706.	83064.	-41039.	44971.
0.090	-71824.	-5025.	-10609.	-11602.	11602.	82433.	-41187.	46212.
0.095	-70158.	-5921.	-9394.	-10273.	10273.	79552.	-40170.	46092.
0.100	-66353.	-6557.	-8337.	-9116.	9116.	74689.	-37956.	44514.
0.105	-10312.	-923.	93.	102.	0.	10219.	-5886.	6706.
0.110	-8773.	-921.	-385.	-421.	421.	9158.	-4972.	5893.
0.115	-8900.	-1005.	-293.	-320.	320.	9193.	-5038.	6044.
0.120	-9023.	-1088.	-203.	-221.	221.	9226.	-5102.	6190.
0.125	-9144.	-1168.	-114.	-125.	125.	9258.	-5165.	6333.
0.130	-9260.	-1247.	-28.	-31.	31.	9289.	-5225.	6471.
0.135	-9373.	-1323.	54.	60.	0.	9319.	-5327.	6591.
0.140	-9496.	-1382.	183.	200.	0.	9313.	-5493.	6675.
0.145	-9599.	-1453.	260.	284.	0.	9339.	-5608.	6777.

TABLE 10.4

0.150	-9699.	-1522.	334.	365.	0.	9365.	-5721.	6877.
0.155	-9794.	-1588.	406.	444.	0.	9389.	-5828.	6973.
0.160	-9886.	-1653.	475.	520.	0.	9411.	-5932.	7065.
0.165	-9974.	-1716.	542.	593.	0.	9432.	-6031.	7155.
0.170	-10057.	-1777.	606.	663.	0.	9451.	-6126.	7240.
0.175	-10138.	-1835.	668.	731.	0.	9470.	-6218.	7323.
0.180	-10213.	-1892.	727.	795.	0.	9486.	-6305.	7402.
0.185	-10284.	-1946.	784.	857.	0.	9501.	-6388.	7477.
0.190	-10354.	-1999.	838.	917.	0.	9515.	-6468.	7550.
0.195	-10417.	-2050.	889.	973.	0.	9527.	-6541.	7618.
0.200	-10477.	-2098.	939.	1026.	0.	9538.	-6612.	7683.
0.205	-10531.	-2144.	985.	1077.	0.	9547.	-6677.	7744.
0.210	-10580.	-2188.	1027.	1123.	0.	9553.	-6736.	7801.
0.215	-10626.	-2230.	1068.	1168.	0.	9558.	-6793.	7855.
0.220	-10665.	-2269.	1105.	1209.	0.	9559.	-6843.	7904.
0.225	-10699.	-2307.	1139.	1246.	0.	9559.	-6888.	7949.
0.230	-10728.	-2342.	1171.	1281.	0.	9557.	-6928.	7989.
0.235	-10749.	-2375.	1198.	1310.	0.	9551.	-6960.	8025.
0.240	-10766.	-2406.	1223.	1338.	0.	9543.	-6989.	8057.
0.245	-10777.	-2435.	1245.	1361.	0.	9532.	-7011.	8085.
0.250	-10779.	-2462.	1262.	1380.	0.	9517.	-7025.	8107.
0.255	-10777.	-2486.	1277.	1396.	0.	9500.	-7035.	8125.
0.260	-10768.	-2508.	1288.	1409.	0.	9480.	-7039.	8138.
0.265	-10752.	-2528.	1296.	1417.	0.	9456.	-7035.	8146.
0.270	-10729.	-2546.	1300.	1422.	0.	9429.	-7025.	8150.
0.275	-10703.	-2562.	1302.	1424.	0.	9401.	-7012.	8150.
0.280	-10671.	-2575.	1300.	1422.	0.	9371.	-6993.	8146.
0.285	-10635.	-2587.	1296.	1418.	0.	9338.	-6969.	8138.
0.290	-10596.	-2596.	1290.	1411.	0.	9306.	-6943.	8129.
0.295	-10559.	-2605.	1284.	1404.	0.	9276.	-6917.	8118.
0.300	-10524.	-2610.	1277.	1396.	0.	9247.	-6892.	8106.
0.305	-10494.	-2615.	1270.	1389.	0.	9224.	-6870.	8096.
0.310	-10470.	-2618.	1265.	1383.	0.	9205.	-6853.	8088.
0.315	-10456.	-2620.	1261.	1379.	0.	9194.	-6842.	8082.
0.320	-10451.	-2620.	1260.	1378.	0.	9191.	-6839.	8081.

TABLE 10.4 (Continued)

ORCOEF = 14.40 Q.E. = 45.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	3062.	3062.	8724.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	44063.	7308.	31602.	-0.032	0.000	-19.54	0.05	-7841.92	31.55
0.010	87934.	10105.	53965.	-0.232	0.001	-56.40	0.23	-4565.70	52.27
0.015	105563.	13268.	65080.	-0.547	0.003	-65.27	0.56	-97.32	75.57
0.020	104530.	13596.	64737.	-0.869	0.006	-63.64	0.94	423.40	77.67
0.025	102663.	13924.	64003.	-1.181	0.012	-60.92	1.33	537.32	79.63
0.030	102178.	14470.	64090.	-1.479	0.020	-58.25	1.73	534.65	83.06
0.035	100779.	13603.	62236.	-1.762	0.029	-55.00	2.13	696.58	75.89
0.040	99304.	13367.	61038.	-2.028	0.041	-51.54	2.50	686.53	73.31
0.045	98165.	12608.	59435.	-2.278	0.054	-48.13	2.86	678.78	66.75
0.050	97313.	11698.	57809.	-2.510	0.069	-44.74	3.17	673.05	58.98
0.055	97201.	10714.	56435.	-2.725	0.086	-41.38	3.44	672.66	50.57
0.060	97560.	9942.	55495.	-2.924	0.104	-38.01	3.67	675.83	43.63
0.065	98288.	9047.	54590.	-3.105	0.123	-34.63	3.87	681.58	35.68
0.070	98770.	6941.	52344.	-3.270	0.142	-31.10	4.01	716.32	18.79
0.075	99371.	4627.	49947.	-3.416	0.163	-27.51	4.06	719.19	0.37
0.080	100752.	1543.	47096.	-3.545	0.183	-23.89	4.00	726.32	-23.71
0.085	98736.	-1065.	43345.	-3.655	0.202	-20.29	3.83	707.95	-43.71
0.090	103914.	-5717.	40466.	-3.748	0.221	-16.69	3.53	739.09	-79.32
0.095	103908.	-10366.	35478.	-3.822	0.237	-12.99	3.04	730.27	-113.77
0.100	101118.	-14393.	30032.	-3.878	0.251	-9.44	2.40	700.69	-142.80
0.105	84250.	-14147.	23339.	-3.917	0.261	-6.18	1.68	574.27	-138.38
0.110	57031.	-9483.	17089.	-3.941	0.268	-3.80	1.07	380.43	-100.38
0.115	35237.	-4820.	13079.	-3.956	0.272	-2.31	0.67	227.72	-63.31
0.120	21947.	-1714.	10916.	-3.965	0.275	-1.42	0.42	135.38	-38.84
0.125	14649.	67.	9809.	-3.971	0.277	-0.88	0.26	84.92	-24.87
0.130	10778.	1035.	9248.	-3.974	0.278	-0.53	0.16	58.24	-17.30
0.135	8823.	1531.	8971.	-3.976	0.278	-0.28	0.08	44.78	-13.43
0.140	8040.	1681.	8811.	-3.977	0.279	-0.07	0.02	40.57	-12.22

TABLE 11.1

ORCOEF = 14.40 Q.E. = 45.00 (DEGREES)

TIME	U	Z	RPU	RPZ	TRU1	TRZ1	TRU2	TRZ2	FU	FZ
0.000	0.000	0.000	3062.	0.	0.	1796.	0.	1266.	3062.	3062.
0.005	-0.032	0.000	44063.	0.	30.	11529.	-11.	-4221.	44082.	7308.
0.010	-0.232	0.001	87934.	8.	88.	21275.	-46.	-11170.	87976.	10097.
0.015	-0.547	0.003	105563.	34.	224.	26022.	-110.	-12755.	105677.	13233.
0.020	-0.869	0.006	104530.	79.	384.	26016.	-183.	-12421.	104731.	13516.
0.025	-1.181	0.012	102663.	141.	565.	25872.	-261.	-11952.	102967.	13780.
0.030	-1.479	0.020	102178.	222.	778.	26115.	-347.	-11652.	102609.	14242.
0.035	-1.762	0.029	100779.	316.	992.	25649.	-466.	-12056.	101304.	13277.
0.040	-2.028	0.041	99303.	422.	1236.	25431.	-587.	-12080.	99952.	12929.
0.045	-2.278	0.054	98163.	540.	1489.	25094.	-742.	-12508.	98910.	12046.
0.050	-2.510	0.069	97311.	668.	1755.	24770.	-928.	-13101.	98138.	11001.
0.055	-2.725	0.086	97198.	809.	2045.	24583.	-1157.	-13906.	98086.	9868.
0.060	-2.924	0.104	97555.	962.	2377.	24589.	-1420.	-14693.	98512.	8934.
0.065	-3.105	0.123	98282.	1126.	2756.	24638.	-1751.	-15647.	99287.	7865.
0.070	-3.270	0.142	98762.	1294.	3116.	24175.	-2229.	-17291.	99649.	5590.
0.075	-3.416	0.163	99360.	1466.	3491.	23666.	-2815.	-19089.	100035.	3112.
0.080	-3.545	0.183	100739.	1652.	3856.	23040.	-3601.	-21518.	100994.	-130.
0.085	-3.655	0.202	98720.	1775.	4117.	21835.	-4315.	-22881.	98522.	-2822.
0.090	-3.748	0.221	103895.	2021.	4536.	21471.	-5717.	-27065.	102713.	-7615.
0.095	-3.822	0.237	103886.	2158.	4662.	19931.	-7024.	-30025.	101525.	-12252.
0.100	-3.878	0.251	101094.	2210.	4571.	17962.	-8121.	-31910.	97544.	-16158.
0.105	-3.917	0.261	84228.	1910.	3870.	14281.	-7570.	-27935.	80528.	-15564.
0.110	-3.941	0.268	57016.	1323.	2758.	9761.	-5336.	-18887.	54438.	-10450.
0.115	-3.956	0.272	35227.	830.	1869.	6443.	-3211.	-11072.	33884.	-5459.
0.120	-3.965	0.275	21940.	521.	1328.	4502.	-1812.	-6147.	21456.	-2166.
0.125	-3.971	0.277	14645.	350.	1031.	3461.	-1012.	-3397.	14664.	-286.
0.130	-3.974	0.278	10775.	258.	874.	2915.	-577.	-1924.	11072.	733.
0.135	-3.976	0.278	8821.	212.	795.	2642.	-354.	-1176.	9262.	1254.
0.140	-3.977	0.279	8037.	193.	758.	2515.	-273.	-905.	8523.	1417.

TABLE 11.2

FORCES ON CRADLE AND TRAIL/LOWER CARRIAGE *****
ORCOEF = 14.40 Q.E. = 45.00 (DEGREES)

TIME	F14_U	F14_Z	F13_U	F13_Z	F7_Y	R2_X	R2_Y	R1_Y	M2
0.000	-4406.	-3616.	8479.	7689.	8444.	0.	8724.	276.	0.
0.005	26595.	-8457.	18499.	16776.	45659.	26003.	31602.	9406.	58508.
0.010	64503.	-11096.	24484.	22204.	84218.	55068.	53965.	20053.	123904.
0.015	76268.	-13344.	30420.	27588.	100946.	65367.	65080.	23672.	147076.
0.020	76106.	-12350.	29636.	26877.	100139.	64498.	64737.	23546.	145122.
0.025	75228.	-11282.	28750.	26073.	98625.	63065.	64003.	23219.	141895.
0.030	75426.	-10316.	28194.	25569.	98403.	62485.	64090.	23206.	140591.
0.035	77393.	-8314.	24923.	22602.	96522.	62245.	62236.	23455.	140051.
0.040	78040.	-6848.	22923.	20789.	94989.	61534.	61038.	23451.	138452.
0.045	79838.	-5156.	20083.	18213.	93416.	61422.	59435.	23693.	138199.
0.050	82028.	-3514.	17120.	15526.	91996.	61615.	57809.	24034.	138633.
0.055	84936.	-1963.	14160.	12842.	91151.	62379.	56435.	24570.	140353.
0.060	87885.	-609.	11638.	10554.	90836.	63341.	55495.	25152.	142517.
0.065	91279.	696.	9019.	8180.	90753.	64645.	54590.	25848.	145452.
0.070	95819.	2211.	4841.	4391.	89696.	66509.	52344.	26742.	149646.
0.075	100441.	3574.	605.	549.	88581.	68535.	49947.	27659.	154204.
0.080	106460.	4922.	-4456.	-4041.	92039.	71505.	47096.	28896.	160886.
0.085	107899.	5776.	-8366.	-7587.	92426.	71661.	43345.	28996.	161237.
0.090	118883.	7144.	-15159.	-13747.	100165.	78013.	40466.	31449.	175530.
0.095	123702.	7955.	-21167.	-19196.	102775.	80452.	35478.	32318.	181017.
0.100	124417.	8307.	-25862.	-23454.	102163.	80400.	30032.	32187.	180900.
0.105	105468.	7148.	-23929.	-21701.	86445.	67947.	23339.	27267.	152881.
0.110	71182.	4830.	-15733.	-14269.	59261.	45882.	17089.	18686.	103235.
0.115	42994.	2896.	-8098.	-7344.	37157.	27820.	13079.	11691.	62596.
0.120	25614.	1700.	-3147.	-2854.	23596.	16703.	10916.	7394.	37581.
0.125	16021.	1039.	-346.	-314.	16130.	10571.	9809.	5027.	23786.
0.130	10919.	688.	1165.	1056.	13333.	7311.	9248.	3770.	16450.
0.135	8338.	510.	1935.	1755.	12101.	5662.	8971.	3134.	12740.
0.140	7344.	442.	2189.	1986.	11573.	5025.	8811.	2887.	11306.

TABLE 11.3

FORCES ON UPPER CARRIAGE *****

ORCOEF = 14.40 Q.E. = 45.00 (DEGREES) F2_X CHOSEN= 0.

TIME	F12_X	F12_Y	F11_X	F11_Y	F9_Y	F1_X	F2_Y	F3_Y
0.000	558.	5672.	-558.	-11432.	11432.	0.	279.	-5951.
0.005	-24786.	-12825.	-1218.	-24943.	24943.	26003.	-14057.	26882.
0.010	-53456.	-37764.	-1612.	-33014.	33014.	55068.	-30253.	68017.
0.015	-63365.	-44494.	-2003.	-41018.	41018.	65367.	-35866.	80360.
0.020	-62547.	-45083.	-1951.	-39960.	39960.	64498.	-35402.	80484.
0.025	-61172.	-45216.	-1893.	-38766.	38766.	63065.	-34622.	79838.
0.030	-60629.	-46040.	-1856.	-38016.	38016.	62485.	-34313.	80353.
0.035	-60604.	-48846.	-1641.	-33605.	33605.	62245.	-34286.	83132.
0.040	-60025.	-50340.	-1509.	-30909.	30909.	61534.	-33951.	84291.
0.045	-60100.	-52808.	-1322.	-27080.	27080.	61422.	-33981.	86789.
0.050	-60488.	-55518.	-1127.	-23085.	23085.	61615.	-34187.	89705.
0.055	-61447.	-58672.	-932.	-19093.	19093.	62379.	-34716.	93387.
0.060	-62575.	-61714.	-766.	-15693.	15693.	63341.	-35341.	97055.
0.065	-64052.	-65037.	-594.	-12162.	12162.	64645.	-36163.	101200.
0.070	-66191.	-69318.	-319.	-6528.	6528.	66509.	-37352.	106670.
0.075	-68495.	-73550.	-40.	-816.	816.	68535.	-38634.	112184.
0.080	-71798.	-78760.	293.	6008.	0.	71505.	-44944.	117695.
0.085	-72212.	-80381.	551.	11280.	0.	71661.	-49081.	118182.
0.090	-79011.	-89114.	998.	20440.	0.	78013.	-59699.	128374.
0.095	-81846.	-93096.	1394.	28540.	0.	80452.	-67297.	131853.
0.100	-82102.	-93850.	1703.	34872.	0.	80400.	-72131.	131109.
0.105	-69522.	-79632.	1575.	32266.	0.	67947.	-63106.	110472.
0.110	-46918.	-53749.	1036.	21215.	0.	45882.	-42173.	74707.
0.115	-28353.	-32449.	533.	10920.	0.	27820.	-24078.	45608.
0.120	-16910.	-19314.	207.	4244.	0.	16703.	-12680.	27750.
0.125	-10594.	-12063.	23.	467.	0.	10571.	-6321.	17918.
0.130	-7234.	-8207.	-77.	-1570.	1570.	7311.	-4085.	12292.
0.135	-5535.	-6257.	-127.	-2609.	2609.	5662.	-3130.	9386.
0.140	-4881.	-5506.	-144.	-2952.	2952.	5025.	-2762.	8268.

TABLE 11.4

ORCOEF = 14.40 Q.E. = 70.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	4069.	1481.	7961.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	4411.	5725.	40176.	-0.033	0.000	-19.58	0.05	-7849.08	31.53
0.010	88123.	8545.	73841.	-0.233	0.001	-56.47	0.23	-4571.82	52.42
0.015	105873.	11730.	89074.	-0.548	0.003	-65.37	0.56	-102.59	75.89
0.020	104929.	12076.	88499.	-0.871	0.006	-63.76	0.94	418.71	78.12
0.025	103168.	12416.	87322.	-1.183	0.012	-61.07	1.34	533.35	80.17
0.030	102798.	12984.	87308.	-1.481	0.020	-58.41	1.74	531.45	83.75
0.035	101524.	12149.	85473.	-1.766	0.030	-55.17	2.14	694.22	76.82
0.040	100180.	11921.	84104.	-2.033	0.041	-51.73	2.52	685.05	74.28
0.045	99182.	11173.	82558.	-2.283	0.055	-48.32	2.88	678.25	67.79
0.050	98450.	10302.	81109.	-2.516	0.070	-44.94	3.20	673.30	60.29
0.055	98536.	9277.	80116.	-2.732	0.087	-41.57	3.48	674.25	51.55
0.060	99126.	8534.	79710.	-2.932	0.105	-38.19	3.72	679.01	44.79
0.065	100129.	7617.	79457.	-3.114	0.124	-34.78	3.92	686.65	36.65
0.070	100958.	5476.	78090.	-3.279	0.144	-31.23	4.06	723.75	19.44
0.075	102032.	3026.	76633.	-3.426	0.164	-27.60	4.11	729.78	-0.05
0.080	103554.	-160.	74862.	-3.555	0.185	-23.92	4.05	737.56	-24.90
0.085	101469.	-2816.	71023.	-3.666	0.204	-20.26	3.87	718.32	-45.23
0.090	108365.	-8029.	71179.	-3.758	0.223	-16.56	3.55	760.96	-85.14
0.095	107697.	-12786.	66477.	-3.831	0.240	-12.76	3.03	746.55	-120.19
0.100	105620.	-17179.	61099.	-3.886	0.253	-9.10	2.34	721.16	-151.88
0.105	84323.	-15821.	47577.	-3.923	0.263	-5.82	1.59	563.78	-138.66
0.110	55479.	-10556.	32384.	-3.946	0.269	-3.53	1.00	359.09	-96.04
0.115	34046.	-5845.	21834.	-3.959	0.273	-2.14	0.62	209.20	-58.67
0.120	21525.	-2875.	15877.	-3.968	0.276	-1.33	0.39	122.30	-35.29
0.125	14764.	-1207.	12721.	-3.973	0.277	-0.85	0.25	75.58	-22.22
0.130	11149.	-296.	11053.	-3.977	0.278	-0.54	0.16	50.68	-15.10
0.135	9228.	195.	10173.	-3.979	0.279	-0.32	0.10	37.45	-11.26
0.140	8268.	393.	9692.	-3.980	0.279	-0.15	0.04	32.03	-9.69
0.145	7992.	464.	9567.	-3.980	0.279	0.01	0.00	30.13	-9.13

TABLE 12.1

ORCOEF = 14.40 Q.E. = 70.00 (DEGREES)

TIME	U	Z	RPU	RPZ	TRU1	TRZ1	TRU2	TRZ2	FU	FZ
0.000	0.000	0.000	4069.	0.	0.	1379.	0.	102.	4069.	1481.
0.005	-0.033	0.000	44111.	0.	29.	10922.	-14.	-5197.	44126.	5724.
0.010	-0.233	0.001	88123.	8.	86.	20705.	-50.	-12160.	88158.	8537.
0.015	-0.548	0.003	105873.	34.	219.	25485.	-118.	-13755.	105974.	11696.
0.020	-0.871	0.006	104929.	79.	377.	25503.	-199.	-13429.	105107.	11995.
0.025	-1.183	0.012	103168.	142.	555.	25387.	-284.	-12973.	103439.	12271.
0.030	-1.481	0.020	102798.	224.	766.	25662.	-379.	-12684.	103185.	12754.
0.035	-1.766	0.030	101523.	320.	979.	25236.	-508.	-13096.	101995.	11820.
0.040	-2.033	0.041	100179.	428.	1222.	25050.	-641.	-13144.	100760.	11479.
0.045	-2.283	0.055	99180.	549.	1475.	24750.	-810.	-13596.	99845.	10605.
0.050	-2.516	0.070	98447.	680.	1742.	24470.	-1011.	-14194.	99179.	9596.
0.055	-2.732	0.087	98533.	826.	2034.	24314.	-1260.	-15069.	99306.	8419.
0.060	-2.932	0.105	99121.	984.	2373.	24387.	-1546.	-15893.	99947.	7510.
0.065	-3.114	0.124	100123.	1156.	2761.	24493.	-1908.	-16924.	100976.	6413.
0.070	-3.279	0.144	100949.	1333.	3134.	24102.	-2428.	-18672.	101655.	4097.
0.075	-3.426	0.164	102021.	1518.	3524.	23656.	-3078.	-20662.	102467.	1475.
0.080	-3.555	0.185	103540.	1713.	3897.	23033.	-3924.	-23191.	103513.	-1871.
0.085	-3.666	0.204	101452.	1840.	4164.	21807.	-4692.	-24573.	100924.	-4606.
0.090	-3.758	0.223	108344.	2127.	4633.	21635.	-6314.	-29486.	106663.	-9978.
0.095	-3.831	0.240	107674.	2256.	4723.	19917.	-7673.	-32358.	104723.	-14697.
0.100	-3.886	0.253	105594.	2326.	4635.	17984.	-8922.	-34619.	101307.	-18961.
0.105	-3.923	0.263	84301.	1923.	3749.	13690.	-7927.	-28950.	80123.	-17182.
0.110	-3.946	0.269	55464.	1293.	2565.	9008.	-5457.	-19160.	52573.	-11445.
0.115	-3.959	0.273	34037.	804.	1689.	5786.	-3326.	-11397.	32399.	-6415.
0.120	-3.968	0.276	21519.	513.	1177.	3973.	-1994.	-6729.	20702.	-3269.
0.125	-3.973	0.277	14760.	354.	902.	3014.	-1248.	-4170.	14414.	-1510.
0.130	-3.977	0.278	11146.	268.	755.	2507.	-840.	-2791.	11061.	-551.
0.135	-3.979	0.279	9225.	222.	677.	2240.	-621.	-2053.	9282.	-35.
0.140	-3.980	0.279	8266.	199.	633.	2089.	-519.	-1713.	8380.	177.
0.145	-3.980	0.279	7990.	193.	622.	2050.	-487.	-1606.	8125.	251.

TABLE 12.2

FORCES ON CRADLE AND TRAIL/LOWER CARRIAGE *****
 ORCOEF = 14.40 Q.E. = 70.00 (DEGREES)

TIME	F14_U	F14_Z	F13_U	F13_Z	F7_Y	R2_X	R2_Y	R1_Y	M2
0.000	-485.	-2127.	5898.	4097.	8878.	0.	7961.	1039.	0.
0.005	25148.	-7904.	20321.	14117.	48811.	9713.	40176.	7917.	21854.
0.010	60361.	-11218.	29141.	20244.	90851.	22130.	73841.	16590.	49791.
0.015	69362.	-14184.	37956.	26368.	109216.	25255.	89074.	19179.	56823.
0.020	69363.	-13280.	37088.	25765.	108179.	24677.	88499.	19043.	55522.
0.025	68738.	-12280.	36045.	25041.	106373.	23847.	87322.	18746.	53655.
0.030	69043.	-11409.	35486.	24652.	105967.	23306.	87308.	18687.	52439.
0.035	72304.	-9251.	31034.	21560.	103705.	23777.	85473.	19084.	53498.
0.040	73776.	-7712.	28328.	19679.	101859.	23675.	84104.	19175.	53269.
0.045	76781.	-5861.	24407.	16956.	99990.	24183.	82558.	19562.	54412.
0.050	80165.	-4057.	20358.	14143.	98318.	24903.	81109.	20042.	56033.
0.055	84541.	-2283.	16109.	11191.	97313.	26053.	80116.	20751.	58619.
0.060	88660.	-776.	12631.	8774.	96972.	27127.	79710.	21448.	61035.
0.065	93434.	729.	8886.	6173.	96917.	28509.	79457.	22293.	64145.
0.070	100141.	2601.	2858.	1986.	95972.	30918.	78090.	23506.	69564.
0.075	107280.	4375.	-3470.	-2411.	98116.	33659.	76633.	24829.	75734.
0.080	115739.	6178.	-10883.	-7560.	103658.	37161.	74862.	26439.	83613.
0.085	118779.	7353.	-16511.	-11470.	104822.	38846.	71023.	26910.	87405.
0.090	135423.	9557.	-27416.	-19046.	116786.	45857.	71179.	30309.	103178.
0.095	142129.	10845.	-36062.	-25052.	120437.	49628.	66477.	31574.	111662.
0.100	146100.	11713.	-43450.	-30185.	121980.	52466.	61099.	32283.	118049.
0.105	119563.	9773.	-38096.	-26466.	99574.	43549.	47577.	26507.	97986.
0.110	78956.	6439.	-25039.	-17395.	66623.	28736.	32384.	17774.	64655.
0.115	47765.	3815.	-14023.	-9741.	41582.	17109.	21834.	11087.	38496.
0.120	29282.	2246.	-7236.	-5027.	26814.	10153.	15877.	7128.	22843.
0.125	19228.	1390.	-3471.	-2411.	18802.	6349.	12721.	4977.	14285.
0.130	13832.	929.	-1428.	-992.	14507.	4301.	11053.	3822.	9677.
0.135	10957.	684.	-331.	-230.	12221.	3208.	10173.	3207.	7217.
0.140	9585.	569.	139.	96.	11237.	2700.	9692.	2912.	6075.
0.145	9171.	534.	298.	207.	11047.	2542.	9567.	2824.	5721.

TABLE 12.3

FORCES ON UPPER CARRIAGE *****

ORCOEF = 14.40 Q.E. = 70.00 (DEGREES) F2_X CHOSEN = 0.

TIME	F12_X	F12_Y	F11_X	F11_Y	F9_Y	F1_X	F2_Y	F3_Y
0.000	-1833.	1183.	1833.	-6943.	6943.	0.	-916.	-267.
0.005	-16028.	-20928.	6316.	-23924.	23924.	9713.	-8636.	29564.
0.010	-31186.	-52884.	9057.	-34307.	34307.	22130.	-17009.	69893.
0.015	-37051.	-60328.	11796.	-44686.	44686.	25255.	-20142.	80470.
0.020	-36203.	-60638.	11526.	-43663.	43663.	24677.	-19681.	80319.
0.025	-35049.	-60392.	11202.	-42436.	42436.	23847.	-19051.	79443.
0.030	-34335.	-60977.	11029.	-41778.	41778.	23306.	-18659.	79636.
0.035	-33422.	-64780.	9645.	-36537.	36537.	23777.	-18233.	83012.
0.040	-32479.	-66689.	8804.	-33350.	33350.	23675.	-17755.	84444.
0.045	-31768.	-70146.	7585.	-28734.	28734.	24183.	-17432.	87578.
0.050	-31230.	-73943.	6327.	-23967.	23967.	24903.	-17209.	91152.
0.055	-31060.	-78661.	5007.	-18966.	18966.	26053.	-17197.	95859.
0.060	-31052.	-83048.	3925.	-14870.	14870.	27127.	-17262.	100310.
0.065	-31271.	-88049.	2762.	-10461.	10461.	28509.	-17460.	105509.
0.070	-31806.	-94991.	888.	-3365.	3365.	30918.	-17882.	112873.
0.075	-32581.	-102307.	-1078.	4085.	0.	33659.	-21483.	119705.
0.080	-33779.	-110873.	-3382.	12812.	0.	37161.	-28796.	126857.
0.085	-33715.	-114131.	-5131.	19439.	0.	38846.	-33800.	128492.
0.090	-37336.	-130525.	-8521.	32277.	0.	45857.	-45607.	143855.
0.095	-38420.	-137267.	-11208.	42456.	0.	49628.	-53960.	148772.
0.100	-38963.	-141295.	-13504.	51153.	0.	52466.	-60882.	151024.
0.105	-31709.	-115695.	-11840.	44851.	0.	43549.	-51997.	122841.
0.110	-20954.	-76397.	-7782.	29479.	0.	28736.	-34239.	81157.
0.115	-12751.	-46190.	-4358.	16509.	0.	17109.	-19748.	49429.
0.120	-7904.	-28284.	-2249.	8518.	0.	10153.	-10937.	30703.
0.125	-5270.	-18544.	-1079.	4086.	0.	6349.	-6080.	20538.
0.130	-3857.	-13316.	-444.	1681.	0.	4301.	-3454.	15089.
0.135	-3105.	-10530.	-103.	390.	0.	3208.	-2048.	12188.
0.140	-2743.	-9201.	43.	-164.	164.	2700.	-1544.	10746.
0.145	-2635.	-8800.	92.	-350.	350.	2542.	-1480.	10281.

TABLE 12.4

ORCOEF = 14.40 Q.E. = 5.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	377.	4314.	9327.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	42751.	8570.	8832.	-0.032	0.000	-19.45	0.05	-7831.71	31.62
0.010	70701.	11423.	8438.	-0.232	0.001	-56.50	0.23	-4673.74	52.77
0.015	92753.	14810.	9334.	-0.548	0.003	-65.91	0.57	-172.44	77.75
0.020	96723.	15273.	9012.	-0.875	0.006	-64.56	0.96	385.54	80.86
0.025	97238.	15700.	9082.	-1.191	0.012	-61.99	1.37	517.28	83.56
0.030	97385.	16402.	9488.	-1.495	0.020	-59.39	1.80	519.47	88.15
0.035	95308.	15741.	8583.	-1.784	0.030	-56.22	2.22	676.58	82.53
0.040	92101.	15724.	8593.	-2.057	0.042	-52.89	2.63	653.94	81.63
0.045	88611.	15378.	8270.	-2.313	0.057	-49.68	3.03	629.16	78.24
0.050	84895.	15084.	8054.	-2.554	0.073	-46.60	3.41	602.78	75.21
0.055	81010.	15085.	8202.	-2.779	0.091	-43.66	3.78	575.39	74.36
0.060	81078.	15559.	8257.	-2.991	0.110	-40.78	4.16	577.93	76.67
0.065	81068.	15853.	8097.	-3.187	0.132	-37.89	4.54	580.14	77.52
0.070	79718.	15630.	7573.	-3.369	0.156	-34.89	4.92	604.36	74.53
0.075	77249.	15687.	7512.	-3.536	0.181	-31.90	5.29	588.85	73.59
0.080	79221.	16671.	7623.	-3.688	0.209	-28.92	5.67	608.24	78.61
0.085	79926.	17501.	7673.	-3.825	0.238	-25.84	6.07	619.36	82.15
0.090	78400.	18040.	7686.	-3.947	0.270	-22.75	6.49	615.02	83.25
0.095	74481.	18232.	7636.	-4.053	0.303	-19.72	6.90	593.83	81.43
0.100	68717.	17632.	7044.	-4.144	0.339	-16.84	7.28	558.23	73.49
0.105	9674.	123.	2205.	-4.223	0.376	-15.09	7.42	68.16	-33.51
0.110	9079.	392.	2506.	-4.297	0.412	-14.77	7.26	64.63	-31.77
0.115	9113.	402.	2465.	-4.370	0.448	-14.45	7.10	64.90	-31.90
0.120	9145.	411.	2424.	-4.442	0.483	-14.12	6.94	65.16	-32.03
0.125	9178.	420.	2384.	-4.511	0.518	-13.79	6.78	65.42	-32.16
0.130	9208.	428.	2345.	-4.580	0.551	-13.47	6.62	65.67	-32.28
0.135	9238.	437.	2308.	-4.646	0.584	-13.14	6.46	65.91	-32.40
0.140	9267.	370.	2208.	-4.711	0.616	-12.80	6.29	67.17	-33.02
0.145	9294.	378.	2173.	-4.774	0.647	-12.47	6.13	67.39	-33.13
0.150	9320.	386.	2140.	-4.836	0.677	-12.13	5.96	67.61	-33.23
0.155	9344.	395.	2108.	-4.895	0.706	-11.79	5.80	67.80	-33.33
0.160	9369.	403.	2076.	-4.954	0.735	-11.45	5.63	68.00	-33.43
0.165	9391.	411.	2047.	-5.010	0.763	-11.11	5.46	68.19	-33.52

TABLE 13

0.170	9412.	419.	2018.	-5.065	0.790	-10.77	5.29	68.36	-33.61	0.
0.175	9433.	426.	1990.	-5.118	0.816	-10.43	5.13	68.53	-33.69	0.
0.180	9451.	434.	1965.	-5.169	0.841	-10.08	4.96	68.69	-33.77	0.
0.185	9471.	440.	1938.	-5.219	0.865	-9.74	4.79	68.85	-33.85	0.
0.190	9489.	448.	1914.	-5.266	0.889	-9.40	4.62	68.99	-33.92	0.
0.195	9505.	456.	1892.	-5.313	0.911	-9.05	4.45	69.12	-33.98	0.
0.200	9520.	462.	1869.	-5.357	0.933	-8.71	4.28	69.26	-34.05	0.
0.205	9532.	469.	1850.	-5.400	0.954	-8.36	4.11	69.37	-34.10	0.
0.210	9545.	477.	1831.	-5.440	0.974	-8.01	3.94	69.47	-34.15	0.
0.215	9555.	484.	1813.	-5.480	0.994	-7.66	3.77	69.57	-34.20	0.
0.220	9563.	491.	1797.	-5.517	1.012	-7.32	3.60	69.64	-34.24	0.
0.225	9569.	499.	1783.	-5.553	1.030	-6.97	3.43	69.70	-34.27	0.
0.230	9571.	507.	1771.	-5.587	1.046	-6.62	3.25	69.75	-34.29	0.
0.235	9574.	515.	1760.	-5.619	1.062	-6.27	3.08	69.79	-34.31	0.
0.240	9572.	524.	1752.	-5.649	1.077	-5.92	2.91	69.80	-34.31	0.
0.245	9568.	534.	1746.	-5.678	1.091	-5.57	2.74	69.79	-34.31	0.
0.250	9561.	544.	1742.	-5.705	1.104	-5.22	2.57	69.77	-34.30	0.
0.255	9547.	555.	1742.	-5.730	1.117	-4.87	2.40	69.70	-34.26	0.
0.260	9534.	566.	1743.	-5.754	1.128	-4.53	2.22	69.64	-34.23	0.
0.265	9513.	580.	1748.	-5.776	1.139	-4.18	2.05	69.52	-34.18	0.
0.270	9485.	596.	1758.	-5.796	1.149	-3.83	1.88	69.36	-34.10	0.
0.275	9457.	610.	1768.	-5.814	1.158	-3.48	1.71	69.20	-34.02	0.
0.280	9419.	629.	1785.	-5.831	1.166	-3.14	1.54	68.97	-33.91	0.
0.285	9372.	649.	1806.	-5.845	1.173	-2.79	1.37	68.70	-33.77	0.
0.290	9325.	670.	1829.	-5.859	1.180	-2.45	1.21	68.41	-33.63	0.
0.295	9269.	694.	1858.	-5.870	1.185	-2.11	1.04	68.06	-33.46	0.
0.300	9207.	718.	1889.	-5.880	1.190	-1.77	0.87	67.69	-33.27	0.
0.305	9143.	743.	1923.	-5.888	1.194	-1.43	0.70	67.29	-33.08	0.
0.310	9085.	765.	1953.	-5.894	1.197	-1.10	0.54	66.94	-32.91	0.
0.315	9034.	785.	1980.	-5.899	1.200	-0.76	0.38	66.63	-32.75	0.
0.320	8997.	800.	2001.	-5.902	1.201	-0.43	0.21	66.39	-32.64	0.
0.325	8979.	806.	2010.	-5.903	1.202	-0.10	0.05	66.29	-32.59	0.

TABLE 13 (Continued)

ORCOEF = 15.00 Q.E. = 20.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	1481.	4069.	9209.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	44274.	8319.	18267.	-0.032	0.000	-19.47	0.05	-7828.60	31.58
0.010	73339.	11170.	24253.	-0.232	0.001	-56.48	0.23	-4662.35	52.71
0.015	96095.	14518.	30143.	-0.548	0.003	-65.82	0.57	-155.83	77.40
0.020	99953.	14929.	30665.	-0.874	0.006	-64.39	0.96	401.29	80.11
0.025	100206.	15310.	30805.	-1.189	0.012	-61.74	1.36	531.06	82.45
0.030	100078.	15952.	31191.	-1.491	0.020	-59.08	1.78	531.17	86.59
0.035	97660.	15244.	29766.	-1.779	0.030	-55.85	2.19	685.68	80.62
0.040	94104.	15140.	28969.	-2.050	0.042	-52.49	2.60	660.37	79.07
0.045	90293.	14823.	27913.	-2.304	0.056	-49.25	2.98	633.16	75.91
0.050	86289.	14451.	26796.	-2.543	0.072	-46.16	3.35	604.52	72.32
0.055	82151.	14295.	25932.	-2.766	0.089	-43.21	3.71	575.07	70.33
0.060	81684.	14688.	25950.	-2.975	0.109	-40.35	4.06	573.45	72.10
0.065	81475.	14989.	25869.	-3.169	0.130	-37.48	4.43	574.01	73.06
0.070	79940.	14749.	25092.	-3.349	0.153	-34.52	4.78	596.62	70.01
0.075	77322.	14622.	24373.	-3.515	0.178	-31.57	5.13	579.53	67.81
0.080	78275.	15262.	24677.	-3.665	0.204	-28.67	5.47	590.44	70.60
0.085	78893.	16011.	25022.	-3.801	0.233	-25.68	5.83	600.09	73.81
0.090	77444.	16441.	24854.	-3.922	0.263	-22.69	6.21	595.19	74.48
0.095	73795.	16349.	23966.	-4.028	0.295	-19.76	6.57	574.15	71.15
0.100	68133.	15936.	22595.	-4.120	0.328	-16.97	6.91	538.37	65.26
0.105	28953.	13871.	18423.	-4.198	0.364	-14.62	7.18	248.15	55.65
0.110	9026.	673.	4847.	-4.270	0.399	-14.26	7.01	56.95	-28.00
0.115	9061.	681.	4813.	-4.341	0.434	-13.98	6.87	57.23	-28.13
0.120	9094.	689.	4779.	-4.410	0.468	-13.69	6.73	57.49	-28.26
0.125	9127.	697.	4746.	-4.478	0.501	-13.40	6.59	57.76	-28.39
0.130	9159.	704.	4714.	-4.544	0.534	-13.11	6.45	58.02	-28.52
0.135	9189.	712.	4683.	-4.609	0.566	-12.82	6.30	58.26	-28.64
0.140	9220.	644.	4580.	-4.672	0.597	-12.53	6.16	59.53	-29.26
0.145	9248.	651.	4551.	-4.734	0.627	-12.23	6.01	59.76	-29.37
0.150	9277.	658.	4523.	-4.795	0.657	-11.93	5.86	59.98	-29.49
0.155	9304.	665.	4495.	-4.854	0.686	-11.63	5.72	60.20	-29.59
0.160	9329.	673.	4468.	-4.911	0.714	-11.33	5.57	60.40	-29.69
0.165	9356.	679.	4442.	-4.967	0.741	-11.02	5.42	60.61	-29.80

TABLE 14

0.170	9380.	686.	4417.	-5.021	0.768	-10.72	5.27	60.80	-29.89	0.
0.175	9404.	692.	4392.	-5.074	0.794	-10.42	5.12	60.99	-29.98	0.
0.180	9427.	698.	4368.	-5.125	0.819	-10.11	4.97	61.18	-30.07	0.
0.185	9447.	704.	4345.	-5.175	0.844	-9.81	4.82	61.35	-30.16	0.
0.190	9471.	710.	4323.	-5.224	0.868	-9.50	4.67	61.53	-30.25	0.
0.195	9492.	715.	4301.	-5.270	0.891	-9.19	4.52	61.69	-30.33	0.
0.200	9512.	720.	4280.	-5.315	0.913	-8.88	4.37	61.85	-30.41	0.
0.205	9532.	725.	4260.	-5.359	0.934	-8.57	4.21	62.01	-30.48	0.
0.210	9550.	732.	4242.	-5.401	0.955	-8.26	4.06	62.14	-30.55	0.
0.215	9569.	735.	4222.	-5.442	0.975	-7.95	3.91	62.30	-30.63	0.
0.220	9584.	740.	4204.	-5.481	0.994	-7.64	3.75	62.43	-30.69	0.
0.225	9600.	745.	4188.	-5.518	1.012	-7.33	3.60	62.54	-30.75	0.
0.230	9615.	749.	4171.	-5.554	1.030	-7.01	3.45	62.67	-30.81	0.
0.235	9625.	755.	4158.	-5.588	1.047	-6.70	3.29	62.76	-30.85	0.
0.240	9639.	759.	4143.	-5.621	1.063	-6.38	3.14	62.87	-30.91	0.
0.245	9649.	764.	4130.	-5.652	1.078	-6.07	2.98	62.95	-30.95	0.
0.250	9658.	769.	4118.	-5.682	1.093	-5.76	2.83	63.03	-30.98	0.
0.255	9665.	774.	4107.	-5.710	1.107	-5.44	2.67	63.10	-31.02	0.
0.260	9667.	780.	4098.	-5.736	1.120	-5.12	2.52	63.13	-31.04	0.
0.265	9674.	785.	4089.	-5.761	1.132	-4.81	2.36	63.19	-31.06	0.
0.270	9673.	792.	4083.	-5.784	1.143	-4.49	2.21	63.19	-31.07	0.
0.275	9671.	798.	4077.	-5.806	1.154	-4.18	2.05	63.20	-31.07	0.
0.280	9667.	805.	4073.	-5.826	1.164	-3.86	1.90	63.19	-31.06	0.
0.285	9652.	815.	4073.	-5.844	1.173	-3.54	1.74	63.11	-31.02	0.
0.290	9643.	823.	4072.	-5.861	1.181	-3.23	1.59	63.06	-31.00	0.
0.295	9621.	836.	4076.	-5.877	1.189	-2.91	1.43	62.93	-30.94	0.
0.300	9589.	850.	4083.	-5.890	1.195	-2.60	1.28	62.75	-30.85	0.
0.305	9558.	865.	4092.	-5.903	1.201	-2.29	1.12	62.56	-30.75	0.
0.310	9505.	886.	4108.	-5.913	1.207	-1.97	0.97	62.24	-30.60	0.
0.315	9438.	913.	4131.	-5.922	1.211	-1.66	0.82	61.83	-30.39	0.
0.320	9366.	941.	4156.	-5.930	1.215	-1.36	0.67	61.38	-30.17	0.
0.325	9269.	977.	4191.	-5.936	1.218	-1.05	0.52	60.79	-29.88	0.
0.330	9161.	1017.	4230.	-5.940	1.220	-0.75	0.37	60.12	-29.55	0.
0.335	9066.	1052.	4265.	-5.943	1.222	-0.45	0.22	59.53	-29.26	0.
0.340	9008.	1073.	4286.	-5.945	1.222	-0.15	0.08	59.17	-29.09	0.

TABLE 14 (Continued)

ORCOEF = 14.40 Q.E. = 0.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	0.	4330.	9335.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	62799.	10019.	3133.	-0.034	0.000	-24.66	0.07	-10074.72	42.26
0.010	84048.	13064.	2251.	-0.272	0.001	-63.31	0.29	-4125.08	64.82
0.015	99420.	15273.	1392.	-0.607	0.003	-67.89	0.66	232.06	81.01
0.020	102861.	16259.	1469.	-0.942	0.008	-66.11	1.08	403.99	87.94
0.025	103394.	16565.	1295.	-1.266	0.014	-63.38	1.52	556.98	89.65
0.030	102480.	16765.	1271.	-1.575	0.023	-60.32	1.97	650.63	90.44
0.035	100192.	16696.	1210.	-1.869	0.034	-57.00	2.42	706.83	89.11
0.040	96669.	16465.	1230.	-2.145	0.047	-53.53	2.86	581.91	86.53
0.045	92842.	16072.	1142.	-2.404	0.062	-50.19	3.28	654.75	82.69
0.050	88775.	15769.	1223.	-2.647	0.080	-46.99	3.69	625.89	79.50
0.055	85602.	15493.	1146.	-2.874	0.099	-43.78	4.07	644.33	76.42
0.060	85492.	15966.	1162.	-3.085	0.120	-40.56	4.46	645.80	78.58
0.065	84375.	16124.	1045.	-3.280	0.144	-37.34	4.86	639.96	78.35
0.070	82219.	16217.	1075.	-3.459	0.169	-34.17	5.25	626.79	77.58
0.075	81975.	16885.	1195.	-3.622	0.196	-31.06	5.64	629.06	80.61
0.080	83684.	18023.	1202.	-3.769	0.225	-27.86	6.05	647.75	86.36
0.085	83104.	18653.	1112.	-3.900	0.257	-24.61	6.49	650.33	88.05
0.090	79907.	18913.	1154.	-4.015	0.290	-21.39	6.93	634.50	86.68
0.095	74138.	18531.	1093.	-4.114	0.326	-18.29	7.35	599.61	80.26
0.100	30691.	15996.	9056.	-4.199	0.364	-15.65	7.69	278.01	67.47
0.105	9117.	279.	1739.	-4.276	0.402	-15.24	7.49	66.32	-32.60
0.110	9153.	288.	1693.	-4.351	0.439	-14.91	7.33	66.61	-32.74
0.115	9187.	297.	1648.	-4.425	0.475	-14.58	7.17	66.89	-32.88
0.120	9222.	306.	1604.	-4.497	0.510	-14.24	7.00	67.16	-33.02
0.125	9255.	315.	1562.	-4.567	0.545	-13.91	6.84	67.42	-33.14
0.130	9287.	323.	1520.	-4.636	0.579	-13.57	6.67	67.68	-33.27
0.135	9318.	332.	1480.	-4.703	0.612	-13.23	6.50	67.93	-33.39
0.140	9348.	340.	1441.	-4.768	0.644	-12.89	6.34	68.18	-33.51
0.145	9378.	348.	1403.	-4.832	0.675	-12.55	6.17	68.41	-33.63

TABLE 15

0.150	9405.	355.	1366.	-4.894	0.705	-12.20	6.00	68.64	-33.74	0.
0.155	9433.	362.	1330.	-4.954	0.735	-11.86	5.83	68.86	-33.85	0.
0.160	9459.	370.	1296.	-5.012	0.764	-11.52	5.66	69.07	-33.95	0.
0.165	9484.	377.	1263.	-5.069	0.792	-11.17	5.49	69.27	-34.05	0.
0.170	9509.	384.	1231.	-5.124	0.819	-10.82	5.32	69.46	-34.15	0.
0.175	9530.	255.	1097.	-5.177	0.845	-10.47	5.15	71.49	-35.14	0.
0.180	9554.	261.	1067.	-5.229	0.870	-10.11	4.97	71.67	-35.23	0.
0.185	9574.	267.	1039.	-5.278	0.895	-9.75	4.79	71.84	-35.32	0.
0.190	9594.	274.	1013.	-5.326	0.918	-9.39	4.62	71.99	-35.39	0.
0.195	9613.	280.	987.	-5.372	0.941	-9.03	4.44	72.15	-35.47	0.
0.200	9630.	286.	964.	-5.416	0.962	-8.67	4.26	72.29	-35.54	0.
0.205	9647.	292.	941.	-5.459	0.983	-8.31	4.08	72.43	-35.60	0.
0.210	9659.	299.	921.	-5.499	1.003	-7.95	3.91	72.53	-35.66	0.
0.215	9674.	305.	901.	-5.538	1.022	-7.58	3.73	72.65	-35.71	0.
0.220	9684.	310.	883.	-5.575	1.041	-7.22	3.55	72.75	-35.76	0.
0.225	9694.	317.	867.	-5.611	1.058	-6.86	3.37	72.83	-35.80	0.
0.230	9701.	324.	853.	-5.644	1.074	-6.49	3.19	72.90	-35.83	0.
0.235	9705.	331.	840.	-5.675	1.090	-6.13	3.01	72.95	-35.86	0.
0.240	9710.	338.	829.	-5.705	1.104	-5.76	2.83	73.00	-35.88	0.
0.245	9706.	347.	824.	-5.733	1.118	-5.40	2.65	72.99	-35.88	0.
0.250	9706.	354.	816.	-5.759	1.131	-5.03	2.47	73.01	-35.89	0.
0.255	9697.	364.	814.	-5.783	1.143	-4.67	2.29	72.97	-35.87	0.
0.260	9685.	374.	814.	-5.806	1.154	-4.30	2.11	72.92	-35.85	0.
0.265	9669.	385.	818.	-5.826	1.164	-3.94	1.94	72.84	-35.81	0.
0.270	9639.	402.	831.	-5.845	1.173	-3.57	1.76	72.65	-35.72	0.
0.275	9614.	415.	842.	-5.862	1.182	-3.21	1.58	72.52	-35.65	0.
0.280	9572.	434.	863.	-5.877	1.189	-2.85	1.40	72.26	-35.52	0.
0.285	9516.	458.	894.	-5.891	1.196	-2.49	1.22	71.93	-35.36	0.
0.290	9457.	481.	926.	-5.902	1.201	-2.13	1.05	71.57	-35.18	0.
0.295	9377.	513.	973.	-5.912	1.206	-1.77	0.87	71.07	-34.94	0.
0.300	9280.	551.	1031.	-5.920	1.210	-1.42	0.70	70.47	-34.64	0.
0.305	9188.	585.	1085.	-5.926	1.213	-1.07	0.53	69.91	-34.37	0.
0.310	9096.	619.	1141.	-5.931	1.215	-0.72	0.35	69.34	-34.08	0.
0.315	9025.	645.	1184.	-5.933	1.217	-0.37	0.18	68.89	-33.87	0.
0.320	8995.	656.	1202.	-5.934	1.217	-0.03	0.02	68.71	-33.78	0.

TABLE 15 (Continued)

ORCOEF = 14.40 Q.E. = 0.00 (DEGREES)

TIME	RP	FTRACK	F-FLOAT_Y	U	Z	VU	VZ	AU	AZ
0.000	0.	4330.	9335.	0.000	0.000	0.00	0.00	0.00	0.00
0.005	25192.	6696.	6950.	-0.022	0.000	-11.33	0.02	-4656.81	17.58
0.010	44619.	8685.	5257.	-0.153	0.000	-40.27	0.14	-5433.62	32.34
0.015	59141.	10578.	4381.	-0.391	0.002	-52.60	0.32	-1298.65	46.34
0.020	63456.	11187.	4022.	-0.656	0.004	-52.84	0.56	100.85	50.73
0.025	64835.	11483.	3878.	-0.917	0.007	-51.62	0.81	257.18	52.73
0.030	64434.	11389.	3631.	-1.170	0.012	-49.66	1.07	399.56	51.78
0.035	63771.	11539.	3722.	-1.414	0.018	-47.67	1.33	395.19	52.59
0.040	62947.	11635.	3773.	-1.647	0.025	-45.71	1.60	389.71	52.95
0.045	61972.	11846.	3980.	-1.871	0.034	-43.78	1.86	383.18	54.12
0.050	60036.	11235.	3462.	-2.084	0.044	-41.57	2.11	439.45	49.18
0.055	57945.	10987.	3400.	-2.287	0.055	-39.41	2.35	424.54	46.93
0.060	55775.	10706.	3327.	-2.478	0.067	-37.32	2.58	409.04	44.42
0.065	53547.	10451.	3307.	-2.660	0.081	-35.32	2.80	393.13	42.10
0.070	51571.	10431.	3495.	-2.832	0.095	-33.39	3.01	379.26	41.52
0.075	51475.	10610.	3467.	-2.994	0.111	-31.49	3.22	379.60	42.25
0.080	51048.	10701.	3411.	-3.147	0.127	-29.60	3.43	377.56	42.31
0.085	50135.	10502.	3159.	-3.290	0.145	-27.67	3.63	382.37	40.24
0.090	48873.	10378.	3065.	-3.423	0.164	-25.78	3.83	374.17	38.71
0.095	47292.	10254.	3045.	-3.548	0.183	-23.94	4.02	363.70	37.18
0.100	47874.	10517.	2887.	-3.663	0.204	-22.10	4.21	370.02	38.15
0.105	47888.	10702.	2755.	-3.769	0.225	-20.24	4.40	372.37	38.48
0.110	47189.	10793.	2670.	-3.865	0.248	-18.39	4.59	369.71	38.05
0.115	45743.	10622.	2486.	-3.953	0.271	-16.56	4.77	361.38	35.68
0.120	43574.	10265.	2287.	-4.031	0.296	-14.78	4.94	347.60	31.94
0.125	40777.	9820.	2150.	-4.101	0.321	-13.09	5.09	329.07	27.53
0.130	37190.	8579.	1536.	-4.162	0.346	-11.50	5.21	302.26	17.76
0.135	9356.	38.	1514.	-4.216	0.373	-10.53	5.18	69.38	-34.11
0.140	8573.	376.	1968.	-4.268	0.398	-10.21	5.02	64.68	-31.79
0.145	8583.	388.	1947.	-4.318	0.423	-9.88	4.86	64.78	-31.84
0.150	8592.	399.	1927.	-4.367	0.447	-9.56	4.70	64.86	-31.89
0.155	8599.	410.	1907.	-4.414	0.470	-9.23	4.54	64.96	-31.93

TABLE 16

0.160	8605.	421.	1890.	-4.459	0.492	-8.91	4.38	65.03	-31.97	0.
0.165	8610.	431.	1873.	-4.503	0.514	-8.58	4.22	65.11	-32.01	0.
0.170	8614.	442.	1857.	-4.545	0.534	-8.26	4.06	65.16	-32.03	0.
0.175	8617.	453.	1843.	-4.586	0.554	-7.93	3.90	65.21	-32.06	0.
0.180	8619.	463.	1830.	-4.625	0.573	-7.61	3.74	65.26	-32.08	0.
0.185	8620.	473.	1818.	-4.662	0.592	-7.28	3.58	65.30	-32.10	0.
0.190	8620.	483.	1807.	-4.697	0.609	-6.95	3.42	65.33	-32.11	0.
0.195	8619.	493.	1797.	-4.731	0.626	-6.63	3.26	65.35	-32.12	0.
0.200	8618.	503.	1788.	-4.764	0.642	-6.30	3.10	65.36	-32.13	0.
0.205	8615.	513.	1781.	-4.794	0.657	-5.97	2.94	65.37	-32.14	0.
0.210	8612.	521.	1773.	-4.823	0.671	-5.65	2.78	65.38	-32.14	0.
0.215	8609.	531.	1767.	-4.851	0.684	-5.32	2.62	65.38	-32.14	0.
0.220	8605.	540.	1762.	-4.877	0.697	-4.99	2.45	65.37	-32.14	0.
0.225	8600.	548.	1757.	-4.901	0.709	-4.67	2.29	65.37	-32.13	0.
0.230	8595.	556.	1754.	-4.923	0.720	-4.34	2.13	65.35	-32.13	0.
0.235	8590.	564.	1751.	-4.944	0.730	-4.01	1.97	65.33	-32.12	0.
0.240	8585.	571.	1748.	-4.963	0.740	-3.69	1.81	65.32	-32.11	0.
0.245	8579.	578.	1746.	-4.981	0.748	-3.36	1.65	65.30	-32.10	0.
0.250	8574.	584.	1744.	-4.997	0.756	-3.03	1.49	65.28	-32.09	0.
0.255	8569.	590.	1743.	-5.011	0.763	-2.71	1.33	65.26	-32.08	0.
0.260	8564.	595.	1742.	-5.024	0.770	-2.38	1.17	65.24	-32.07	0.
0.265	8560.	600.	1742.	-5.035	0.775	-2.05	1.01	65.22	-32.06	0.
0.270	8556.	604.	1741.	-5.045	0.780	-1.73	0.85	65.20	-32.05	0.
0.275	8553.	607.	1741.	-5.052	0.784	-1.40	0.69	65.19	-32.05	0.
0.280	8550.	610.	1741.	-5.059	0.787	-1.08	0.53	65.18	-32.04	0.
0.285	8548.	599.	1730.	-5.063	0.789	-0.75	0.37	65.35	-32.12	0.
0.290	8547.	600.	1730.	-5.066	0.790	-0.42	0.21	65.34	-32.12	0.
0.295	8546.	600.	1730.	-5.067	0.791	-0.10	0.05	65.35	-32.12	0.

TABLE 16 (Continued)

Claims

1. A gun system (10) having a firing cycle and comprising:

- a carriage portion (12) fixed in relation to the position of the gun system;
- a cradle portion (22) for elevating the gun supported by said carriage portion (12) and relatively fixed during the firing cycle;
- a recoiling cannon assembly (32) having a centre of mass, an initial prefiring position, and an initial prefiring orientation;

* C L M S *

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and

1. A gun system (10) having a firing cycle and comprising:

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- means for movably mounting said cannon assembly (32) in relation to the said cradle portion (22) for travel of the cannon assembly on a recoil path;
- recoil braking means (34,36) for decelerating the cannon assembly (32) during recoil;
- means (34,36) for returning said cannon assembly (32) to its initial prefiring configuration;
- 5 - the means for movably mounting the cannon assembly (32) including at least a pair of parallel campaths (66a, 66b) and associated cam follower means (56a, 56b), one each either side of the recoiling cannon assembly (32) which constrain travel of the cannon assembly on a recoil path defined by the configuration of each campath, characterised in that:
- 10 - the recoil path is a two-stage curvilinear path (66), the first stage having a curved configuration portion to produce an upward force and vertical acceleration component to the centre of mass of the said recoiling cannon assembly (32) and the second stage contiguous with and following the first stage, having a configuration different from the said first stage for causing controlled vertical deceleration of said cannon assembly (32) during recoil, and
- 15 - the recoil braking system (34,36) has deceleration means for generating a retarding force for predictably and controllably decelerating said cannon assembly (32), adapted such that the magnitude of the retarding force is matched in a predetermined relationship to the configuration of the two-stage curvilinear recoil path, such that
- 20 - in the first stage the instantaneous destabilizing moment of the recoil forces is overcome by the instantaneous stabilising moment of the forces resulting from the reaction to the upward force of the recoiling cannon assembly (32) in the curved configuration portion of the first stage of the curvilinear recoil path (66) and the moment of the static weight of the gun system (10), and
- in the second stage of the curvilinear recoil path (66) the instantaneous destabilizing moments of both the recoil forces and the reaction to the downward force of the recoiling cannon assembly (32) during the controlled vertical deceleration is overcome by the moment of the static weight of the gun system (10).
- 25
- 2. A gun system as claimed in Claim 1 characterised in that the first stage of the curvilinear recoil path (66) has a linear portion shaped to maintain the prefiring orientation of the said cannon assembly (32) at the beginning of recoil.
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- 3. A gun system as claimed either in Claim 1 or 2 characterised in that the curved configuration portion of the first stage of the curvilinear recoil path (66) has a portion of decreasing radius of curvature in the direction of recoil travel of the said cannon assembly (32).
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- 4. A gun system as claimed in any or more of the preceding claims characterised in that the second stage of the curvilinear recoil path (66) has a portion of linear configuration.
- 5. A gun system as claimed in any one or more of the preceding claims characterised in that the said second stage of the curvilinear recoil path (66) has a portion curved in the opposite direction from that of the said curved configuration portion of the first stage.
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- 6. A gun system as claimed in any of the preceding Claims 1 to 5 characterised in that the said second stage of curvilinear recoil path (66) has a portion curved in the same direction as the said curved configuration portion of the first stage, the curve of the said portion of the second stage being shallower than the curve of the said curved configuration portion of the first stage.
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- 7. A gun system as claimed in any of the preceding claims characterised in that said means for movable mounting said cannon assembly (32) in relation to the said cradle portion (22) comprises means for maintaining the axis of the cannon assembly (32) parallel to the initial prefiring orientation throughout said recoil cycle.
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- 8. A gun system as claimed in any one or more of the preceding claims characterised in that the campath (66) is fixedly mounted on said cradle portion (22) and said cam follower means (56) is fixedly mounted on said cannon assembly (32).
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- 9. A gun system as claimed in any one or more of the preceding Claims 1 to 7 characterised in that the campath (64) is fixedly mounted on said cannon assembly (32) and said cam follower means (54) is



fixedly mounted on said cradle portion (22).

10. A gun system as claimed in Claim 8 characterised in that the cannon assembly (32) comprises yoke means (46) supporting and housing said cannon assembly (32) for attaching the cam follower means (56) to the cannon assembly.

11. A gun system as claimed in Claim 9 characterised in that said cannon assembly (32) comprises yoke means supporting and housing said cannon assembly (32) for attaching the campath (64) to the cannon assembly.

12. A gun system as claimed in Claim 8 or 10 characterised in that the said cam follower means comprises parallel left and right forward cam followers (54a, 54b) attached to said cannon assembly (32) on opposite sides of the longitudinal axis of recoil of the cannon assembly (32) forward of the centre of mass of the cannon assembly (32), and parallel left and right rear cam followers (56a, 56b) attached to said cannon assembly (32) on opposite sides of the longitudinal axis of recoil of the cannon assembly rearward of the centre of mass of the cannon assembly, and having left and right forward campaths (64a, 64b) and parallel left and right rear campaths (66a, 66b) attached to the cradle portion (22) and positioned to movably engage said left and right forward and rear cam followers (54a, 54b, 56a, 56b) respectively.

13. A gun system as claimed in Claim 9 or 11 characterised by having parallel left and right forward campaths attached to the cannon assembly (32) on opposite sides of the longitudinal axis of recoil of the cannon assembly, and parallel left and right rear campaths attached to the cannon assembly on opposite sides of the longitudinal axis of recoil of the cannon assembly, said cam followers means (56) comprising left and right forward cam followers and left and right rear cam followers attached to the cradle portions (22) such that in the initial prefiring position, the centre of mass of the recoiling cannon assembly (32) is located between the forward left and right hand and rear left and right hand cam followers.

14. A gun system as claimed in any one or more of the preceding Claims 8 to 13 characterised in that the said campath (66) comprises at least one track located in a guideway housing and said cam follower means (56) comprises at least one roller assembly (62) for roller engagement in the track.

15. A gun system as claimed in any one or more of the preceding Claims 8 to 14 characterised in that the said campath (66) comprises at least one left hand track (66b) and at least one right hand track (66a), and said cam follower means (56) comprises corresponding left and right hand track followers (56a, 56b).

16. A gun system as claimed in Claim 14 characterised in that the roller assembly (62) comprises a multiple roller set.

17. A gun system as claimed in Claim 16 characterised in that the multiple roller set has a trapezoidal longitudinal cross section.

18. A method for stabilizing a gun system upon firing, the gun system comprising a non-recoiling carriage portion (12), a cradle portion (22) rotably mounted on said carriage portion, a recoiling cannon assembly (32) having a longitudinal tube axis, and a centre of mass and being movably mounted on the cradle portion (22) for constrained travel during recoil along a recoil path by means of at least a pair of parallel campaths (66a, 66b) and associated cam follower means (56a, 56b) defining the shape of the recoil path, and a recoil braking system (34, 36) for braking the cannon assembly during recoil, which method comprises the steps of;

- constraining the centre of mass of the recoiling cannon assembly (32) to move upwards along a curved path in a first stage of recoil to produce an upward force and vertical acceleration component to the centre of mass of the recoiling cannon assembly;
- constraining the recoiling cannon assembly in the second stage of recoil to move along a second path having a configuration different from the curved path of the first stage to apply a controlled vertical deceleration of the cannon assembly (32);



- predictably and controllably decelerating the cannon assembly (32) during recoil by means of the recoil braking system (34, 36) so that the magnitude of the retarding force of the recoil braking system (34,36) is matched in a predetermined relationship to the configuration of the two-stage recoil path, so that
 - 5 - in the first stage the instantaneous destabilizing moment of the recoil forces is overcome by the instantaneous stabilizing moment of the forces resulting from the reaction to the upward force of the recoiling cannon assembly (32) in the curved path of the first stage of recoil, and the stabilizing moment of the static weight of the gun system (10), and
 - 10 - in the second stage of the curvilinear recoil path (66) the instantaneous destabilizing moments of both the recoil forces and the reaction to the downward force of the recoiling cannon assembly (32) during the controlled vertical deceleration is overcome by the moment of the static weight of the gun system (10).
19. The method as claimed in Claim 18 characterised by the additional initial step of constraining the recoiling cannon assembly (32) to move in a linear recoil path at the beginning of recoil to maintain the prefiring orientation of the cannon assembly (32) for the first part of recoil.
20. The method as claimed in Claim 18 or 19, characterised in that the step of constraining the centre of mass of the recoiling cannon assembly (32) to move upward along a curved path in the first stage of recoil is carried out by constraining the centre of mass of the recoiling cannon assembly (32) to move upward along a path which has a portion of decreasing radius of curvature in the direction of recoil travel of the cannon assembly.
21. The method as claimed in any of the Claims 18, 19 or 20 characterised in that the step of constraining the recoiling cannon assembly to move along a second path is carried out by displacing the cannon portion along a second path that has a portion of linear configuration.
22. The method as claimed in any or more of the Claims 18 to 21, characterised in that the step of constraining the recoil cannon assembly (32) to move along a second path is carried out by displacing the cannon portion along a second path that has a portion curved in the opposite direction from that of the curved path of the first stage.
23. The method as claimed in any one or more of the Claims 18 to 21 characterised in that the step of constraining the recoil cannon assembly (32) to move along a second path is carried out by displacing the cannon portion along a second path that has a portion curved in the same direction as that of the curved path of the first stage, but having a shallower curve.
24. The method as claimed in any one or more of the Claims 19 to 23 characterised by the additional step of constraining the tube axis of the recoiling cannon assembly (32) to remain parallel to the initial prefiring orientation throughout the recoil cycle.

Patentansprüche

1. Geschützsystem (10) mit einem Schußzyklus, welches folgendes umfaßt:
- ein Lafetten-Teilstück (12), das relativ zur Position des Geschützsystems feststehend ist;
 - ein vom Lafetten-Teilstück (12) gestütztes und während des Schußzyklus relativ feststehendes Gestell-Teilstück (22) zum Anheben des Geschützes;
 - ein rückstoßender Kanonenrohraufbau (32) mit einem Massenschwerpunkt, einer anfänglichen Position vor dem Schießen und einer anfänglichen Orientierung vor dem Schießen;
 - eine Einrichtung zur relativ zum Gestell-Teilstück (22) beweglichen Halterung des Kanonenrohraufbaus (32) zum Bewegen des Kanonenrohraufbaus entlang eines Rückstoßweges;
 - eine Rückstoß-Bremseinrichtung (34, 36) zum Abbremsen des Kanonenrohraufbaus (32) während des Rückstoßes;
 - eine Einrichtung (34, 36) zum Rückführen des Kanonenrohraufbaus (32) in seine anfängliche Anordnung vor dem Schießen;
 - wobei die Einrichtung zur beweglichen Halterung des Kanonenrohraufbaus (32) zumindest ein Paar paralleler Kurvenwege (66a, 66b) und eine zugeordnete Kurvenrolleneinrichtung (56a, 56b) einschließt, und zwar jeweils eine auf den beiden Seiten des rückstoßenden Kanonenrohraufbaus



(32), welche die Bewegung des Kanonenrohraufbaus auf einen Rückstoßweg zwingt, der durch die Anordnung jeder der Kurvenwege definiert wird, dadurch gekennzeichnet, daß

- es sich bei dem Rückstoßweg um einen krummlinigen Weg (66) in zwei Abschnitten handelt, wobei der erste Abschnitt ein Teilstück in gekrümmter Anordnung aufweist, um eine aufwärtsgerichtete Kraft und eine senkrechte Beschleunigungskomponente auf den Massenschwerpunkt des rückstoßenden Kanonenrohraufbaus (32) auszuüben, und der zweite Abschnitt, der sich an den ersten Abschnitt anschließt und auf diesen folgt, eine sich vom ersten Abschnitt unterscheidende Anordnung dafür aufweist, während des Rückstoßes eine kontrollierte senkrechte Abbremsung des Kanonenrohraufbaus (32) zu veranlassen, und
- das Rückstoß-Bremssystem (34, 36) eine Abbremsvorrichtung zum Erzeugen einer verzögernden Kraft dafür aufweist, den Kanonenrohraufbau (32) vorhersagbar und kontrollierbar abzubremsen, wobei die Abbremsvorrichtung so eingerichtet ist, daß die Größe der verzögernden Kraft in einem vorbestimmten Verhältnis mit der Anordnung des krummlinigen Rückstoßweges in zwei Abschnitten derart abgestimmt ist, daß
- im ersten Abschnitt das sofortige destabilisierende Moment der Rückstoßkräfte vom sofortigen stabilisierenden Moment der Kräfte, die aus der Reaktion auf die aufwärts gerichtete Kraft des rückstoßenden Kanonenrohraufbaus (32) im Teilstück in gekrümmter Anordnung des ersten Abschnitts des krummlinigen Rückstoßweges (66) resultieren, und vom Moment des statischen Gewichts des Geschützsystems (10) überwunden wird, und
- im zweiten Abschnitt des krummlinigen Rückstoßweges (66) die sofortigen destabilisierenden Momente sowohl der Rückstoßkräfte als auch der Reaktion auf die abwärts gerichtete Kraft des rückstoßenden Kanonenrohraufbaus (32) während der kontrollierten senkrechten Abbremsung durch das Moment des statischen Gewichts des Geschützsystems (10) überwunden werden.

2. Geschützsystem gemäß Anspruch 1, dadurch gekennzeichnet, daß der erste Abschnitt des krummlinigen Rückstoßweges (66) einen geradlinigen Abschnitt aufweist, der dafür geformt ist, zu Beginn des Rückstoßes die Orientierung des Kanonenrohraufbaus (32) vor dem Schießen aufrechtzuerhalten.

3. Geschützsystem gemäß Anspruch 1 oder 2, dadurch gekennzeichnet, daß das Teilstück in gekrümmter Anordnung des ersten Abschnitts des krummlinigen Rückstoßweges (66) ein Teilstück mit in der Richtung der Rückstoßbewegung des Kanonenrohraufbaus (32) abnehmendem Krümmungsradius aufweist.

4. Geschützsystem gemäß einem oder mehreren der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der zweite Abschnitt des krummlinigen Rückstoßweges (66) ein Teilstück in geradliniger Anordnung aufweist.

5. Geschützsystem gemäß einem oder mehreren der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der zweite Abschnitt des krummlinigen Rückstoßweges (66) ein Teilstück aufweist, das in die entgegengesetzte Richtung relativ zu derjenigen des Teilstücks in gekrümmter Anordnung des ersten Abschnitts gekrümmt ist.

6. Geschützsystem gemäß einem der vorhergehenden Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der zweite Abschnitt des krummlinigen Rückstoßweges (66) ein Teilstück aufweist, das in die gleiche Richtung wie das Teilstück in gekrümmter Anordnung des ersten Abschnitts gekrümmt ist, wobei die Krümmung des Teilstücks des zweiten Abschnitts schwächer ist als die Krümmung des Teilstücks in gekrümmter Anordnung des ersten Abschnitts.

7. Geschützsystem gemäß einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Einrichtung zur relativ zum Gestell-Teilstück (22) beweglichen Halterung des Kanonenrohraufbaus (32) eine Einrichtung dafür umfaßt, die Achse des Kanonenrohraufbaus (32) während des gesamten Rückstoßzyklus parallel zur anfänglichen Orientierung vor dem Schießen zu halten.

8. Geschützsystem gemäß einem oder mehreren der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der Kurvenweg (66) fest am Gestell-Teilstück (22) gehalten ist und die Kurvenrolleneinrichtung (56) fest am Kanonenrohraufbau (32) gehalten ist.



9. Geschützsystem gemäß einem oder mehreren der vorhergehenden Ansprüche 1 bis 7, dadurch gekennzeichnet, daß der Kurvenweg (64) fest am Kanonenrohraufbau (32) gehalten ist und die Kurvenrolleneinrichtung (54) fest am Gestell-Teilstück (22) gehalten ist.
- 5 10. Geschützsystem gemäß Anspruch 8, dadurch gekennzeichnet, daß der Kanonenrohraufbau (32) zum Anbringen der Kurvenrolleneinrichtung (56) am Kanonenrohraufbau eine Bügeleinrichtung (46) umfaßt, die den Kanonenrohraufbau (32) stützt und umschließt.
11. Geschützsystem gemäß Anspruch 9, dadurch gekennzeichnet, daß der Kanonenrohraufbau (32) zum
10 Anbringen des Kurvenweges (64) am Kanonenrohraufbau eine Bügeleinrichtung umfaßt, die den Kanonenrohraufbau (32) stützt und umschließt.
12. Geschützsystem gemäß Anspruch 8 oder 10, dadurch gekennzeichnet, daß die Kurvenrolleneinrichtung
15 folgendes umfaßt: parallele linke und rechte vordere Kurvenrollen (54a, 54b), die auf gegenüberliegenden Seiten der Längsachse des Rückstoßes des Kanonenrohraufbaus (32) und vor dem Massenschwerpunkt des Kanonenrohraufbaus (32) am Kanonenrohraufbau (32) angebracht sind, und parallele linke und rechte hintere Kurvenrollen (56a, 56b), die auf gegenüberliegenden Seiten der Längsachse des Rückstoßes des Kanonenrohraufbaus und hinter dem Massenschwerpunkt des Kanonenrohraufbaus am
20 Kanonenrohraufbau (32) angebracht sind, und wobei es linke und rechte vordere Kurvenwege (64a, 64b) und parallele linke und rechte hintere Kurvenwege (66a, 66b) aufweist, die am Gestell-Teilstück (22) angebracht sind und so positioniert sind, daß sie die linken und rechten vorderen und hinteren Kurvenrollen (54a, 54b, 56a, 56b) jeweils beweglich in Eingriff nehmen.
13. Geschützsystem gemäß Anspruch 9 oder 11, dadurch gekennzeichnet, daß es folgendes aufweist:
25 parallele linke und rechte vordere Kurvenwege, die auf gegenüberliegenden Seiten der Längsachse des Rückstoßes des Kanonenrohraufbaus am Kanonenrohraufbau (32) angebracht sind, und parallele linke und rechte hintere Kurvenwege, die auf gegenüberliegenden Seiten der Längsachse des Rückstoßes des Kanonenrohraufbaus am Kanonenrohraufbau angebracht sind, wobei die Kurvenrolleneinrichtung (56) linke und rechte vordere Kurvenrollen und linke und rechte Kurvenrollen umfaßt, die so am Gestell-
30 Teilstück (22) angebracht sind, daß sich der Massenschwerpunkt des rückstoßenden Kanonenrohraufbaus (32) in der anfänglichen Position vor dem Schießen zwischen den vorderen linken und rechten und den hinteren linken und rechten Kurvenrollen befindet.
14. Geschützsystem gemäß einem oder mehreren der vorhergehenden Ansprüche 8 bis 13, dadurch
35 gekennzeichnet, daß der Kurvenweg (66) zumindest eine in einem Führungsbahngehäuse befindliche Spur umfaßt und die Kurvenrolleneinrichtung (56) zumindest einen Rollenaufbau (62) zum In-Eingriff-Nehmen der Rollen in der Spur umfaßt.
15. Geschützsystem gemäß einem oder mehreren der vorhergehenden Ansprüche 8 bis 14, dadurch
40 gekennzeichnet, daß der Kurvenweg (66) zumindest eine linke Spur (66b) und zumindest eine rechte Spur (66a) umfaßt und die Kurvenrolleneinrichtung (56) entsprechende linke und rechte Spurrollen (56a, 56b) umfaßt.
16. Geschützsystem gemäß Anspruch 14, dadurch gekennzeichnet, daß der Rollenaufbau (62) einen
45 mehrteiligen Rollensatz umfaßt.
17. Geschützsystem gemäß Anspruch 16, dadurch gekennzeichnet, daß der mehrteilige Rollensatz einen trapezförmigen Längsquerschnitt aufweist.
- 50 18. Verfahren zum Stabilisieren eines Geschützsystems beim Schießen, wobei das Geschützsystem folgendes umfaßt: ein nicht rückstoßendes Lafetten-Teilstück (12), ein Gestell-Teilstück (22), welches drehbar am Lafetten-Teilstück gehalten ist, einen rückstoßenden Kanonenrohraufbau (32), der eine Rohrachse in Längsrichtung und einen Massenschwerpunkt aufweist und beweglich am Gestell-
55 Teilstück (22) dafür gehalten ist, während des Rückstoßes mittels zumindest eines Paares paralleler Kurvenwege (66a, 66b) und einer zugeordneten Kurvenrolleneinrichtung (56a, 56b), die die Form des Rückstoßweges festlegen, eine erzwungene Bewegung entlang eines Rückstoßweges auszuführen, und ein Rückstoß-Bremssystem (34, 36) zum Bremsen des Kanonenrohraufbaus während des Rückstoßes, wobei dieses Verfahren folgende Schritte umfaßt:



- Zwingen des Massenschwerpunktes des rückstoßenden Kanonenrohraufbaus (32) während einer ersten Rückstoßphase zu einer Aufwärtsbewegung entlang eines gekrümmten Weges, um eine aufwärts gerichtete Kraft und eine senkrechte Beschleunigungskomponente auf den Massenschwerpunkt des rückstoßenden Kanonenrohraufbaus zu erzeugen;
 - Zwingen des rückstoßenden Kanonenrohraufbaus während der zweiten Phase des Rückstoßes zu einer Bewegung entlang eines zweiten Weges, der eine andere Anordnung aufweist als der gekrümmte Weg der ersten Phase, um eine kontrollierte senkrechte Abbremsung des Kanonenrohraufbaus (32) zu tätigen;
 - vorhersagbare und kontrollierbare Abbremsung des Kanonenrohraufbaus (32) während des Rückstoßes mittels des Rückstoß-Bremssystems (34, 36), so daß die Größe der verzögernden Kraft des Rückstoß-Bremssystems (34, 36) in einem vorbestimmten Verhältnis derart auf die Anordnung des Rückstoßweges in zwei Abschnitten abgestimmt ist, daß
 - in der ersten Phase das sofortige destabilisierende Moment der Rückstoßkräfte vom sofortigen stabilisierenden Moment der Kräfte, die aus der Reaktion auf die aufwärts gerichtete Kraft des rückstoßenden Kanonenrohraufbaus (32) im gekrümmten Weg der ersten Phase des Rückstoßes resultieren, und vom stabilisierenden Moment des statischen Gewichts des Geschützsystems (10) überwunden wird und daß
 - im zweiten Abschnitt des krummlinigen Rückstoßweges (66) die sofortigen destabilisierenden Momente sowohl der Rückstoßkräfte als auch der Reaktion auf die abwärts gerichtete Kraft des rückstoßenden Kanonenrohraufbaus (32) während der kontrollierten senkrechten Abbremsung vom Moment des statischen Gewichts des Geschützsystems (10) überwunden werden.
19. Verfahren gemäß Anspruch 18, gekennzeichnet durch den zusätzlichen anfänglichen Schritt des Zwingens des rückstoßenden Kanonenrohraufbaus (32) zu Beginn des Rückstoßes zu einer Bewegung entlang einem geradlinigen Rückstoßweg, um während der ersten Rückstoßphase die Orientierung des Kanonenrohraufbaus (32) vor dem Schießen aufrechtzuerhalten.
20. Verfahren gemäß Anspruch 18 oder 19, dadurch gekennzeichnet, daß der Schritt des Zwingens des Massenschwerpunktes des rückstoßenden Kanonenrohraufbaus (32) während der ersten Phase des Rückstoßes zu einer Aufwärtsbewegung entlang eines gekrümmten Weges dadurch ausgeführt wird, daß der Massenschwerpunkt des rückstoßenden Kanonenrohraufbaus (32) gezwungen wird, sich aufwärts entlang eines Weges zu bewegen, der in der Richtung der Rückstoßbewegung des Kanonenrohraufbaus ein Teilstück mit abnehmendem Krümmungsradius aufweist.
21. Verfahren gemäß einem der Ansprüche 18, 19 oder 20, dadurch gekennzeichnet, daß der Schritt des Zwingens des rückstoßenden Kanonenrohraufbaus zu einer Bewegung entlang eines zweiten Weges dadurch ausgeführt wird, daß das Kanonenrohrteilstück entlang eines zweiten Weges verschoben wird, welcher ein Teilstück in geradliniger Anordnung aufweist.
22. Verfahren gemäß einem oder mehreren der Ansprüche 18 bis 21, dadurch gekennzeichnet, daß der Schritt des Zwingens des Rückstoß-Kanonenrohraufbaus (32) zu einer Bewegung entlang eines zweiten Weges dadurch ausgeführt wird, daß das Kanonenrohrteilstück entlang eines zweiten Weges verschoben wird, welcher ein in die entgegengesetzte Richtung relativ zu derjenigen des gekrümmten Weges des ersten Abschnitts gekrümmtes Teilstück aufweist.
23. Verfahren gemäß einem oder mehreren der Ansprüche 18 bis 21, dadurch gekennzeichnet, daß der Schritt des Zwingens des Rückstoß-Kanonenrohraufbaus (32) zu einer Bewegung entlang eines zweiten Weges dadurch ausgeführt wird, daß das Kanonenteilstück entlang eines zweiten Weges verschoben wird, welcher ein Teilstück aufweist, das in die gleiche Richtung wie die des gekrümmten Weges des ersten Abschnitts gekrümmt ist, aber eine schwächere Krümmung aufweist.
24. Verfahren gemäß einem oder mehreren der Ansprüche 19 bis 25, gekennzeichnet durch den zusätzlichen Schritt des Zwingens der Rohrachse des rückstoßenden Kanonenrohraufbaus (32) dazu, während des gesamten Rückstoßzyklus parallel zur anfänglichen Orientierung vor dem Schießen zu bleiben.

Revendications

1. Système à canon (10) ayant un cycle de tir et comprenant :



- une portion d'affût (12) fixée par rapport à la position du système à canon ;
 - une portion de berceau (22) pour élever le canon supporté par ladite portion d'affût (12) et fixée par rapport à celle-ci pendant le cycle de tir ;
 - un ensemble à canon à recul (32) ayant un centre de masse, une position initiale préalable au tir, et une orientation initiale préalable au tir ;
 - un moyen de montage de manière mobile ledit ensemble à canon (32) par rapport à ladite portion de berceau (22) pour le déplacement de l'ensemble à canon sur un trajet de recul ;
 - un moyen de freinage de recul (34, 36) pour décélérer l'ensemble à canon (32) pendant le recul ;
 - un moyen (34, 36) pour ramener l'ensemble à canon (32) à sa configuration initiale préalable au tir ;
 - le moyen de montage de manière mobile l'ensemble à canon (32) comportant au moins une paire de trajets de came (66a, 66b) parallèles et un moyen suiveur de came associé (56a, 56b), l'un de chaque côté de l'ensemble à canon à recul (32) qui restreint le déplacement de l'ensemble à canon sur le trajet de recul défini par la configuration de chaque trajet de came, caractérisé en ce que:
 - le trajet de recul est un trajet (66) curviligne en deux étapes, la première étape ayant une portion à configuration courbée pour produire une force ascendante et un composant d'accélération verticale vers le centre de masse dudit ensemble à canon à recul (32), et la seconde étape contiguë à et suivant la première étape, présentant une configuration différente de ladite première étape pour provoquer la décélération verticale contrôlée dudit ensemble à canon (32) pendant le recul, et
 - le système de freinage de recul (34, 36) possède un moyen de décélération pour générer une force de ralentissement pour décélérer de manière prévisible et contrôlable ledit ensemble à canon (32), adapté de telle façon que la grandeur de la force de ralentissement correspond en un rapport prédéterminé à la configuration du trajet de recul curviligne en deux étapes, tel que
 - la première étape le moment de déstabilisation instantané des forces de recul est vaincu par le moment de stabilisation instantané des forces résultant de la réaction à la force ascendante de l'ensemble à canon à recul (32) dans la portion de configuration curviligne de la première étape du trajet de recul curviligne (66) et le moment du poids statique du système à canon (10), et
 - à la seconde étape du trajet de recul curviligne (66) les moments de déstabilisation instantanés à la fois de la force et de recul et de la réaction à la force vers le bas de l'ensemble à canon à recul (32) pendant la décélération verticale contrôlée sont vaincus par le moment du poids statique du système à canon (10).
2. Système à canon selon la revendication 1, caractérisé en ce que la première étape du trajet de recul curviligne (66) possède une portion linéaire formée pour le maintien de l'orientation préalable au tir dudit ensemble à canon (32) au début du recul.
 3. Système à canon selon la revendication 1 ou 2, caractérisé en ce que la portion de configuration courbée de la première étape du trajet de recul curviligne (66) présente une portion à rayon de courbure décroissant dans le sens de déplacement du recul dudit ensemble à canon (32).
 4. Système à canon selon l'une quelconque ou plusieurs des revendications précédentes, caractérisé en ce que la seconde étape du trajet de recul curviligne (66) présente une portion à configuration linéaire.
 5. Système à canon selon l'une quelconque ou plusieurs des revendications précédentes, caractérisé en ce que ladite seconde étape du trajet de recul curviligne (66) présente une portion courbée dans le sens opposé à celui de ladite portion à configuration courbée de la première étape.
 6. Système à canon selon l'une quelconque des revendications précédentes 1 à 5, caractérisé en ce que ladite seconde étape de trajet de recul curviligne (66) présente une portion courbée dans le même sens que ladite portion à configuration courbée de la première étape, la courbe de ladite portion de la seconde étape étant moins prononcée que la courbe de ladite portion à configuration courbée de la première étape.
 7. Système à canon selon l'une quelconque des revendications précédentes, caractérisé en ce que ledit moyen de montage mobile dudit ensemble à canon (32) par rapport à ladite portion de berceau (22)



comprend un moyen de maintien de l'axe de l'ensemble à canon (32) parallèle à l'orientation initiale préalable au tir pendant tout le cycle de recul.

- 5 8. Système à canon selon l'une quelconque ou plusieurs des revendications précédentes, caractérisé en ce que le trajet de came (66) est monté de manière fixe sur ladite portion de berceau (22) et ledit moyen suiveur de came (56) est monté de manière fixe sur ledit ensemble à canon (32).
- 10 9. Système à canon selon l'une quelconque ou plusieurs des revendications précédentes 1 à 7, caractérisé en ce que le trajet de came (64) est monté de manière fixe sur ledit ensemble à canon (32) et ledit moyen suiveur de came (54) est monté de manière fixe sur ladite portion de berceau (22).
- 15 10. Système à canon selon la revendication 8, caractérisé en ce que l'ensemble à canon (32) comprend un moyen de joug (46) supportant et logeant ledit ensemble à canon (32) pour attacher le moyen suiveur de came (56) à l'ensemble à canon.
- 20 11. Système à canon selon la revendication 9, caractérisé en ce que ledit ensemble à canon (32) comprend un moyen de joug supportant et logeant ledit ensemble à canon (32) pour attacher le trajet de came (64) à l'ensemble à canon.
- 25 12. Système à canon selon la revendication 8 ou 10, caractérisé en ce que ledit moyen suiveur de came comprend des suiveurs de came antérieur parallèles de gauche et de droite (54a, 54b) attachés audit ensemble à canon (32) sur des côtés opposés de l'axe longitudinal de recul de l'ensemble à canon (32) en avant du centre de masse de l'ensemble à canon (32), et des suiveurs de came arrière parallèles de gauche et de droite (56a, 56b) attachés à l'ensemble à canon (32) sur des côtés opposés de l'axe longitudinal de recul de l'ensemble à canon à l'arrière du centre de masse de l'ensemble à canon, et présentant des trajets de came avant de gauche et de droite (64a, 64b) et des trajets de came arrière de gauche et de droite (66a, 66b) attachés à la portion de berceau (22) et positionnés pour engager de manière mobile lesdits suiveurs de came arrière et antérieur de gauche et de droite (54a, 54b, 56a, 56b) respectivement.
- 30 13. Système à canon selon la revendication 9 ou 11, caractérisé en ce qu'il présente des trajets de came avant de gauche et de droite parallèles attachés à l'ensemble à canon (32) sur des côtés opposés de l'axe longitudinal de recul de l'ensemble à canon, et des trajets de came arrière de gauche et de droite parallèles attachés à l'ensemble à canon sur des côtés opposés de l'axe longitudinal de recul de l'ensemble à canon, lesdits moyens suiveurs de came (56) comprenant des suiveurs de came avant de gauche et de droite et des suiveurs de came de gauche et de droite attachés aux portions de berceau (22) de telle sorte que dans la position initiale préalable au tir, le centre de masse de l'ensemble à canon à recul (32) est situé entre les suiveurs de came avant de gauche et de droite et arrière de gauche et de droite.
- 35 40 14. Système à canon selon l'une quelconque ou plusieurs des revendications précédentes 8 à 13, caractérisé en ce que ledit trajet de came (66) comprend au moins une piste située dans un logement de guidage et ledit moyen suiveur de came (56) comprend au moins un ensemble à rouleau (62) pour l'engagement du rouleau dans la piste.
- 45 15. Système à canon selon l'une quelconque ou plusieurs des revendications précédentes 8 à 14, caractérisé en ce que ledit trajet de came (66) comprend au moins une piste (66b) de gauche et au moins une piste (66a) de droite, et ledit moyen suiveur de came (56) comprend des suiveurs de piste de gauche et de droite correspondants (56a, 56b).
- 50 16. Système à canon selon la revendication 14, caractérisé en ce que l'ensemble à rouleau (62) comprend un jeu de rouleaux multiples.
- 55 17. Système à canon selon la revendication 16, caractérisé en ce que le jeu de rouleaux multiples présente une coupe transversale longitudinale trapézoïdale.
18. Méthode de stabilisation d'un système à canon lors du tir, le système à canon comprenant une partie d'affût qui ne recule pas (12), une portion de berceau (22) montée de manière capable de rotation sur



ladite portion d'affût, un ensemble à canon à recul (32) présentant un axe de tube longitudinal, et un centre de masse, et étant monté de manière mobile sur la portion de berceau (22) pour un déplacement limité pendant le recul le long d'un trajet de recul au moyen d'au moins une paire de trajets de came parallèles (66a, 66b) et un moyen suiveur de came associés (56a, 56b) définissant la forme du trajet de recul et un système de freinage de recul (34, 36) pour freiner l'ensemble à canon pendant le recul, cette méthode comprenant les étapes de:

- contraindre le centre de masse de l'ensemble à canon à recul (32) pour qu'il se déplace en ascension le long d'un trajet courbé dans une première étape de recul pour produire une force ascendante et un composant d'accélération verticale vers le centre de masse de l'ensemble à canon à recul ;
- contraindre l'ensemble à canon à recul dans la seconde étape de recul pour qu'il se déplace le long d'un second trajet présentant une configuration différente du trajet courbé de la première étape pour appliquer une décélération verticale contrôlée de l'ensemble à canon (32);
- décélérer de manière contrôlable et prévisible l'ensemble à canon (32) pendant le recul au moyen du système de freinage de recul (34, 36) de sorte que la grandeur de la force de ralentissement du système de freinage de recul (34, 36) correspond dans une relation prédéterminée à la configuration du trajet de recul à deux étapes, de sorte que
- à la première étape le moment de déstabilisation instantané des forces de recul est vaincu par le moment de stabilisation instantané des forces résultant de la réaction à la force ascendante de l'ensemble à canon à recul (32) au trajet courbé de la première étape de recul, et le moment de stabilisation du poids statique du système à canon (10), et
- à la seconde étape du trajet de recul curviligne (66) les moments de déstabilisation instantanés à la fois des forces de recul et de réaction à la force de descente de l'ensemble à canon à recul (32) pendant la décélération verticale contrôlée sont vaincus par le moment du poids statique du système à canon (10).

19. Méthode selon la revendication 18, caractérisée par l'étape initiale additionnelle de contrainte de l'ensemble à canon à recul (32) à se déplacer dans un trajet de recul linéaire au début du recul pour maintenir l'orientation préalable au tir de l'ensemble à canon (32) pendant la première partie du recul.

20. Méthode selon la revendication 18 ou 19, caractérisée en ce que l'étape de contrainte du centre de masse de l'ensemble à canon à recul (32) à se déplacer en ascension le long d'un trajet courbé à la première étape du recul est effectuée en contraignant le centre de masse de l'ensemble à canon à recul (32) à se déplacer en ascension le long d'un trajet qui présente une portion à rayon de courbure décroissant dans le sens du déplacement à recul de l'ensemble à canon.

21. Méthode selon l'une quelconque des revendications 18, 19 ou 20 caractérisée, en ce que l'étape de contrainte de l'ensemble à canon à recul à se déplacer le long d'un second trajet est effectuée en déplaçant la portion de canon le long d'un second trajet qui présente une portion à configuration linéaire.

22. Méthode selon l'une quelconque ou plusieurs des revendications 18 à 21, caractérisée en ce que l'étape de contrainte de l'ensemble à canon à recul (32) à se déplacer le long d'un second trajet est effectuée par le déplacement de la portion de canon le long d'un second trajet qui présente une portion courbée dans le sens opposé à celui du trajet courbé de la première étape.

23. Méthode selon l'une quelconque ou plusieurs des revendications 18 à 21, caractérisée en ce que l'étape de contrainte de l'ensemble à canon à recul (32) à se déplacer le long d'un second trajet est effectuée en déplaçant la portion de canon le long d'un second trajet qui présente une portion courbée dans le même sens que celui du trajet courbé de la première étape, mais présentant une courbe moins prononcée.

24. Méthode selon l'une quelconque ou plusieurs des revendications 19 à 25, caractérisée en ce que l'étape additionnelle de contrainte de l'axe de tube de l'ensemble à canon à recul (32) à demeurer parallèle à l'orientation initiale préalable au tir pendant tout le cycle de recul.