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Analysis of a Balanced Breech System for the M1A1 Main Gun System Using Finite Element Techniques

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A DYNA3D finite element (FE) analysis was used to help determine the observed behavior of the M256 gun system during the balanced breech experiment. The experiment was conducted to see if balancing the breech block on the M256 would improve the overall gun system's performance. The experiment, although partially successful, revealed some unsuspected results. The analysis in this report uses an advanced numerical model of the entire M256 system to deduce a possible explanation of the observed behavior. Results generated during this study also indicate possible modifications that can be made to the recoil which will enhance its performance.

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1. INTRODUCTION

A series of experiments were conducted in an attempt to reduce the dynamic motions of the M256 gun system during firing. Data collected during these experiments included the motion of the gun tube and breech mechanism for both the standard (unbalanced) configuration and a modified system in which mass was added such that the breech center-of-gravity (CG) was coincident with the gun tube centerline. The results indicated a noticeable change in the dynamic motions between these two configurations. Prior experiments indicated that the unbalanced breech drops several tenths of a millimeter during the firing cycle. Also, the gun tube whipping motion, which is induced by the powder pressure couple, vibrates the gun in a similar fashion regardless of ammunition type. Furthermore, the gun tube shape at shot exit always resembles a distorted sine wave. This behavior was noted for both high explosive anti-tank (HEAT) and kinetic energy (KE) munitions in previous unbalanced breech tests conducted with the M256 gun. However, when the breech is balanced, the dynamics of the entire system change in both shape and magnitude of displacement.

This report attempts to simulate the results of those tests. This was accomplished using a three-dimensional (3-D), transient, finite element (FE) model of the entire system which included breech, gun tube, trunnion mount, recoil, and projectile. Results from these calculations provided an explanation of the observed behavior of the system. Insight acquired about the nature of the system behavior was then used to propose several simple improvements to the M256 gun system which can be applied to gun systems in general. Implementation of these changes should decrease the shot-to-shot variability associated with ammunition dispersion.

2. BACKGROUND

To better understand the approach taken in this report, a brief review of prior efforts which led to the development of the 3-D model is required. For example, the M256 gun system has numerous parts with clearances for assembly and sliding interfaces. The behavior and initial conditions of these parts are crucial in understanding the mechanisms which can result in shot-to-shot variations and also to determine if their influences are critical in achieving a more accurate gun system. In addition to examining the M256 assemblies, parts, and interfaces, it was also necessary to conduct several experiments in order to determine the system response under closely controlled external loading. A review of these experiments is also included. The purpose of the FE calculations was to numerically replicate the results observed during the experiments (Held and Erline 1991). The series of firing tests during which the breech was balanced with additional mass will be referred to as the "balanced breech experiments." These experiments provided valuable insight into how the system behavior was modified when compared to the standard configuration. The reported findings summarized changes observed in the M256 gun system through noncontact displacement measurements of the gun tube and breech block. Also, using a pair of displacement records, it was possible to calculate the muzzle pointing angle throughout the firing cycle. Finally, due to inconsistencies in the firing cycle, shot-to-shot variability in the system was observed for both the balanced and unbalanced systems. Interestingly, the magnitude of variability in pointing angle between shots was shown to decrease for the balanced breech. Some speculation on the possible mechanisms leading to this result are given at the conclusion of this report.

2.1 Model Assembly. Figure 1 shows a cutaway view of the M256 120-mm gun system. As can be seen in the figure, the system consists of a complicated series of components that have varying clearances which can slide relative to one another during the recoil and counter-recoil strokes. To model these parts using FE techniques required careful scrutiny of the drawings and actual hardware. Observing the assembly and disassembly of parts during routine maintenance provided additional insight about clearances between associated parts. The primary parts (labeled in Figure 1) were first modeled using a Computer-Aided-Design (CAD) package (Autodesk Inc. 1987). These CAD models served as the basis for the FE representation of the M256. Figure 2 shows the CAD approximations of the M256 major components. The FE model of these parts was constructed primarily from eight nodded brick elements as well as linear spring elements.

The first two pieces modeled were the gun tube and breech. In the actual assembly, these two parts are engaged with an interrupted thread. The gun tube slides inside the breech and is then rotated 45°. The opposing threads on the breech and gun tube tightly connect the two parts. Finally, a bolt is threaded through the upper portion of the breech and into a corresponding notch in the gun tube to limit relative rotation between the two parts. While these components have some clearances between them for ease of installation, their axial movement is heavily coupled. The relative vertical and horizontal motion between the parts where the clearances would have an effect are also very closely coupled.

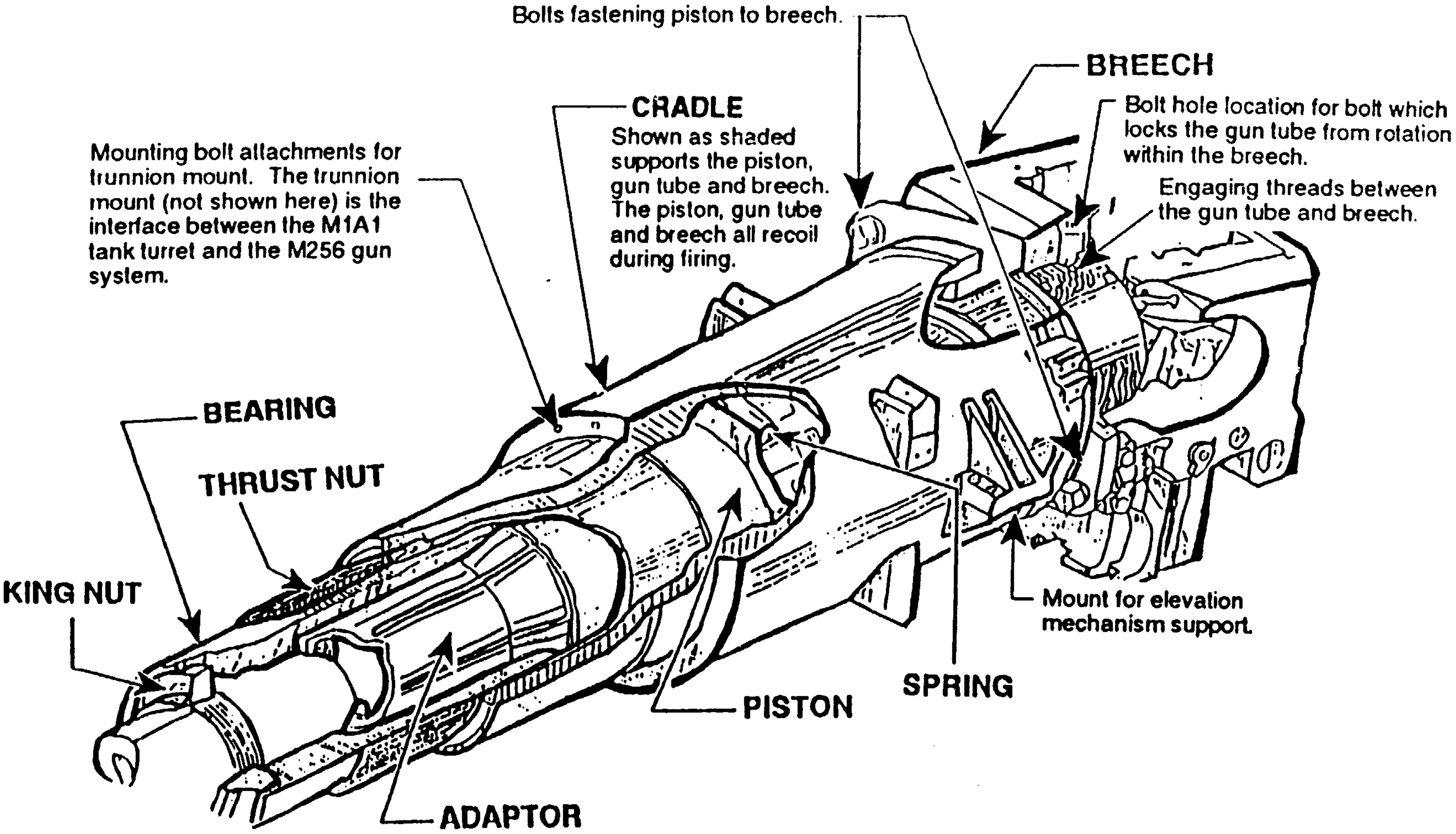

Figure 1. Cutaway view of the M256 120-mm gun recoil system.

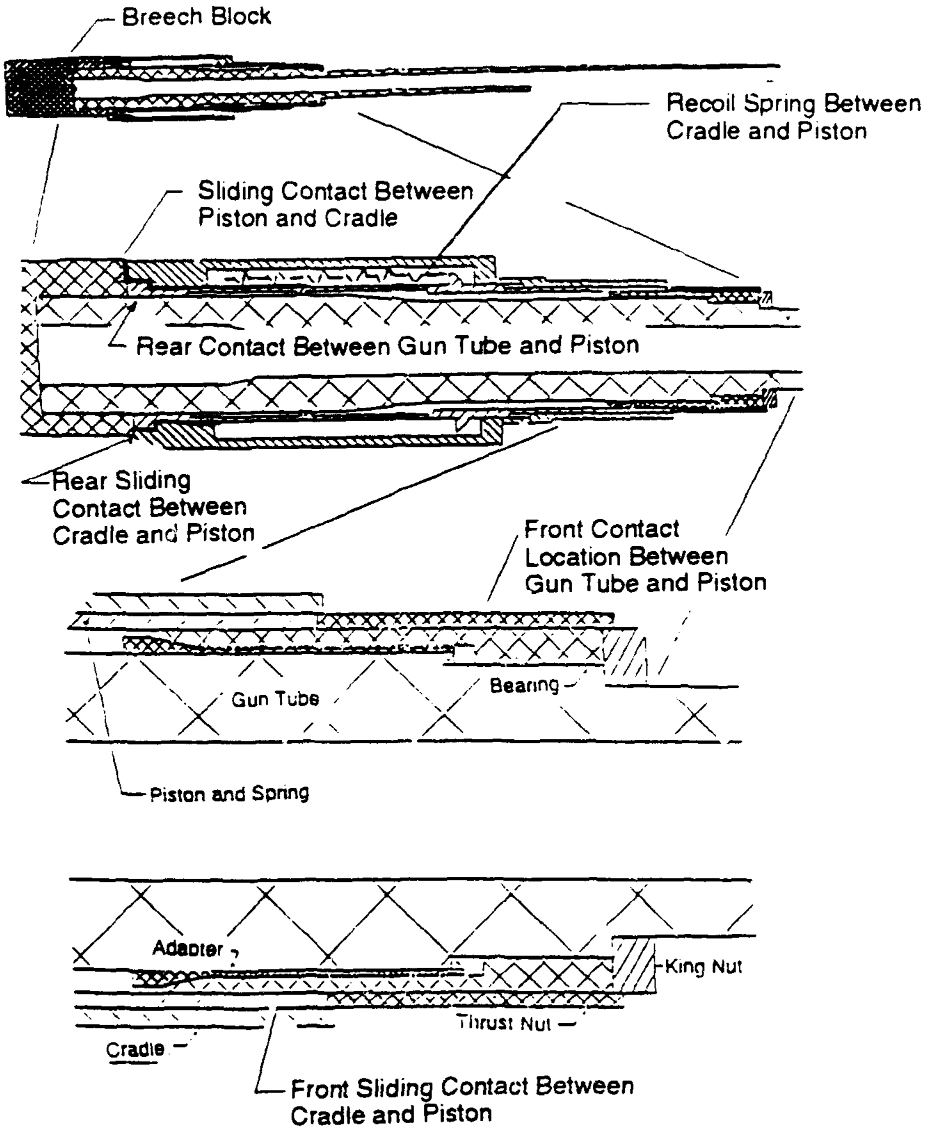

Figure 2. CAD drawing of M256 main components.

Being unable to ascertain the exact amount of movement between the piston and gun tube along their rear contact points, it was assumed that these interfaces acted as if they were rigidly fastened together. In addition, the piston bolts to the breech at two locations across its rear face. This adds rigidity to the connection between the piston and breech. Just forward of that location on the gun tube. the piston radially supports the gun tube at two contact points. To simplify the model, these two axial locations are combined into one. Along the forward end of the piston, a series of parts are used to tie the gun tube to the piston. This clamping device consists of the adapter, bearing, king nut, and thrust nut (Figures 2 and 3). These parts form a fairly rigid clamp between the piston and gun tube. In addition to the

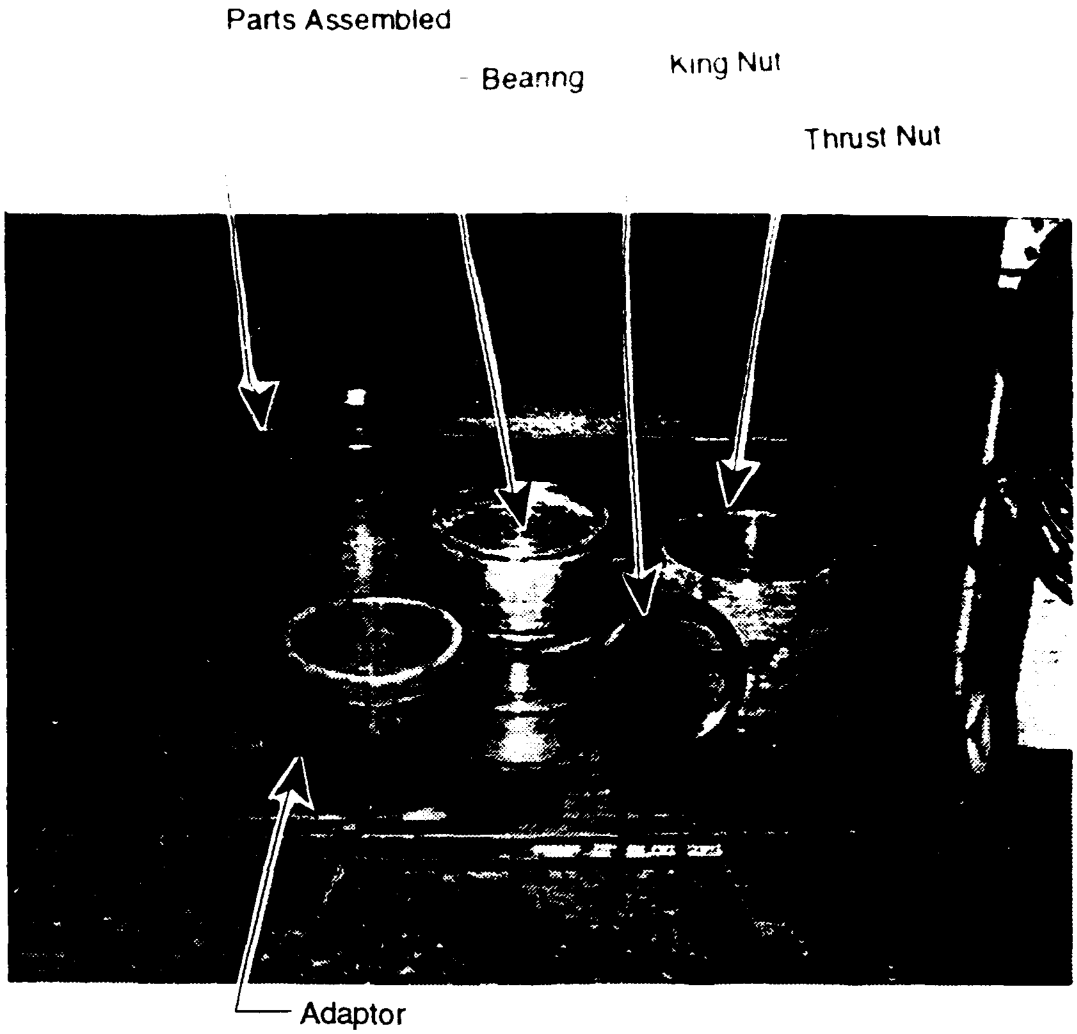

Figure 3. Parts connecting the piston to the gun tube at the piston and gun tube's front contact location.

piston and gun tube attachment, the piston is supported inside the cradle. The cradle allows the gun, breech, and piston to recoil during firing. Creating a model of the cradle attachment points, particularly at the front of the piston, is nontrivial.* Therefore, a series of static load experiments were conducted to determine how to best model the supporting interfaces between the piston and cradle. The results of these experiments are reported in Wilkerson, Fulton, and Thiravong (1993). These experiments validated the assumption that the piston and gun needed to be modeled as two parts using rigid attachment points between them. Measurements confirmed that when out-of-plane forces are applied to the gun tube, the gun and piston essentially move together. However, the measurements also indicated that the same

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* These parts are not, in most cases, rigidly attached to one another.

out-of-plane forces produced relative motion between the piston and cradle. This series of static load experiments confirmed that the gun tube, breech, and piston interfaces could be modeled, at least initially, as rigid contact points. Finally, the FE model of the piston which includes the adapter, bearing, king nut, and thrust nut was modeled as a single part. In the model, these parts connect the gun tube and piston at the same location as the actual contact points on the M256. The assumption of a rigid contact undoubtedly makes the overall system stiffer than the actual gun. The effect of this approximation will be better addressed in future models. Nonetheless, for the purpose of this study, the effects of this assumption are negligible. Figure 4 shows the FE model developed for these three primary parts.

The gun tube, breech, and piston are supported in the tank turret by the cradle. The cradle connects to the tank turret through the mantlet which has a pair of trunnions, supported by the turret and the elevating mechanism. The trunnions allow rotation of the cradle while the elevating mechanism controls that rotation. The cradle sliding support for the piston also allows the gun tube, breech, and piston to recoil during firing. Therefore, it was necessary to model these interfaces using the sliding contact capabilities in DYNA3D (Hallquist and Whirley 1989). The clearances between these sliding contacts, which were observed to influence movement of the system during the static load experiments, are of paramount importance in estimating the changes in response between the balanced and unbalanced systems. The incorporation of this important attribute is discussed in detail in section 2.3.

The recoil consists of a large spring and damper which absorbs the gun recoil energy. The gun tube, breech, and piston recoil approximately 11 inches during gun firing. A number of simpler beam element models have been utilized to determine the best method to model the recoil behavior. During the 11-inch recoil considerable energy is absorbed from the system through damping. Therefore, to model the entire recoil stroke, it is necessary to include a preloaded spring, as in the actual system, and a damper unit. However, since the gun recoils only about 1.5 inch before the bullet exits the gun and this study is primarily interested in the gun system motion while the bullet is still in-bore, the entire recoil stroke was not modeled in the simulation. Consequently, this model utilized only a simple undamped spring to simulate the recoil system behavior while the bullet remained in-bore. The validity of these assumptions was ascertained by comparing axial recoil motion predicted by the model with experimental data from an actual firing cycle. This comparison confirms that neglecting damping during early time motion (approximately the first 7 ms) has little effect on the model's accuracy.*

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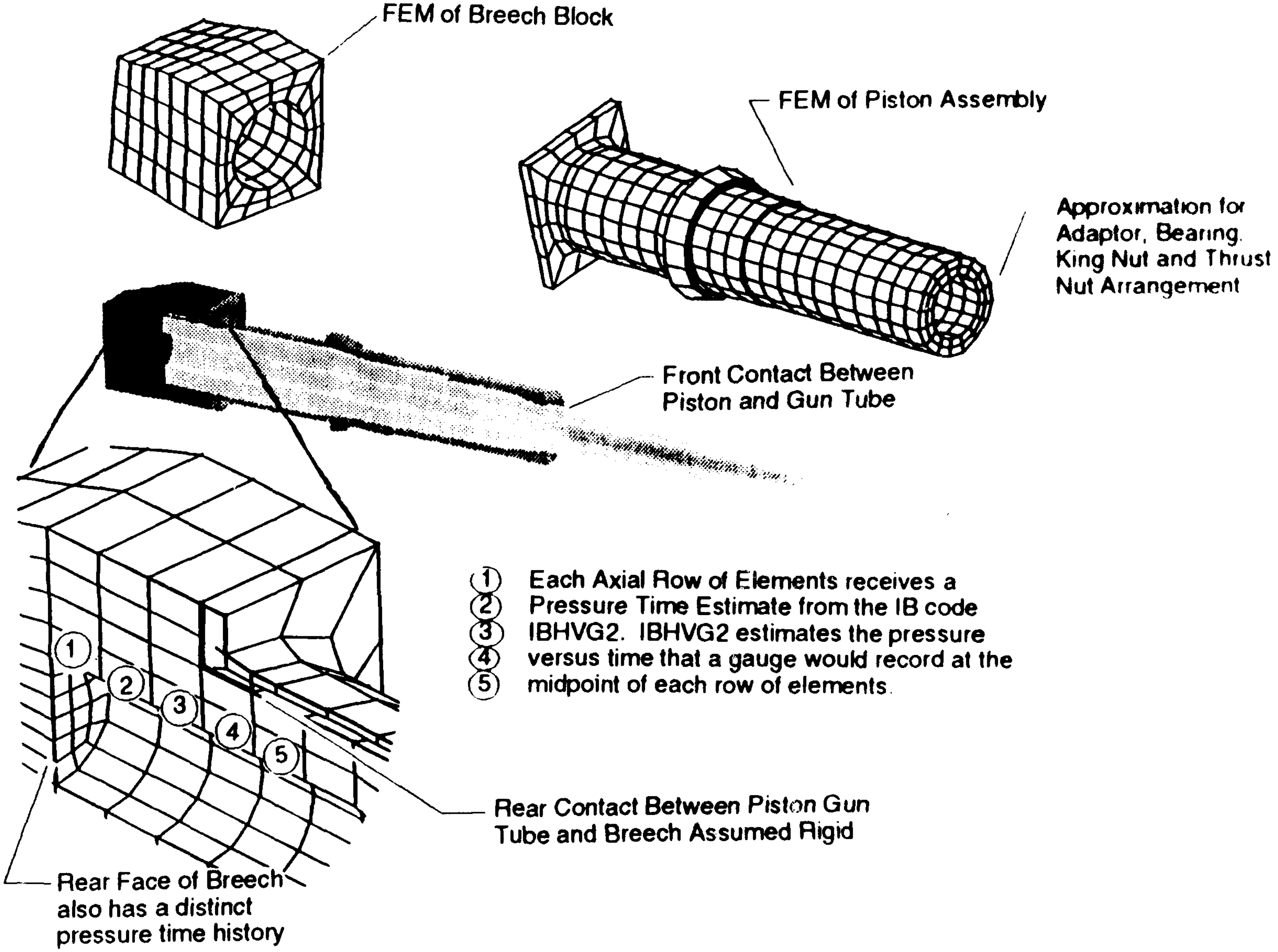
* These calculations were made during the study in Wilkerson, Berman, and Li (1993), although the results were not recorded in that report.



① ② ③ ④ ⑤ Each Axial Row of Elements receives a Pressure Time Estimate from the IB code IBHVG2. IBHVG2 estimates the pressure versus time that a gauge would record at the midpoint of each row of elements.

Figure 4. FE representation of gun tube breech and piston assembly.

The M256 cradle and recoil assembly is bolted to a metal mount with trunnions. The gun system is free to rotate about the trunnions with only the elevation mechanism restricting movement in this plane. The elevation mechanism is a hydraulic actuator used to aim the weapon in the vertical plane. The model includes approximations for these important boundary constraints. Figure 5 shows the trunnion and elevating mechanism as they are represented in the FE model. As can be seen in the figure, the model is supported by trunnions whose axis of rotation in the x-y plane is at the same approximate location as the actual system. The model is also supported by a spring connected to the left side of the cradle, when viewed from the breech looking forward. While it is recognized that the dynamics of the elevation mechanism are nonlinear, they were modeled using linear approximations based on results from the static load experiments (Wilkerson, Fulton, and Thiravong 1993). Furthermore, this assumption seems reasonable since the system only displaces tenths of a millimeter during a firing, while the nonlinear attributes of the elevating mechanism are evident only for much larger displacements. Therefore, the assumption of linearity for the cases represented here is acceptable. The components of the final model have the same approximate thickness, weight, moments of inertia, and CG as the actual parts in the M256 (Wilkerson 1993b). The DYNA3D FE program was used to run the simulation while the PATRAN and PATDYN translators were used to post-process the results (Hallquist and Whirley 1989; PDA Engineering 1987a, 1987b).

The centerline profile of gun tube no. 5064 was used in this analysis in accordance with the techniques discussed by Wilkerson (1993a). Basically, the techniques used to incorporate a particular gun tube centerline profile correlate the technologies used to measure gun tube centerlines with FE calculation of gravity droop. In particular, gun tubes are measured while being supported in a fashion that is similar to the actual gun tube support in the gun mount. However, when the gun is fired, there are devices attached at various locations along the gun tube (such as the bore evacuator, thermal shrouds, and muzzle reference system) that change the tube centerline profile from that originally measured. The methods discussed in Wilkerson (1993a) make allowances for additional mass to be included in the model of the gun tube by recalculating the change to the centerline profile accordingly. For this study, tube no. 5064 was chosen because it was also one of the tubes used during the balanced breech experiments (Held and Erline 1991).

The projectile model was a simplified version of the DM13 projectile (Figure 6) because it was one of the KE projectiles used during the balanced breech experiments. The procedures used in the projectile model were similar to the procedures used by Kaste and Wilkerson (1992) for the XM900E1 projectile (Kaste and Wilkerson 1992). The one notable difference was how the treatment of interferences between

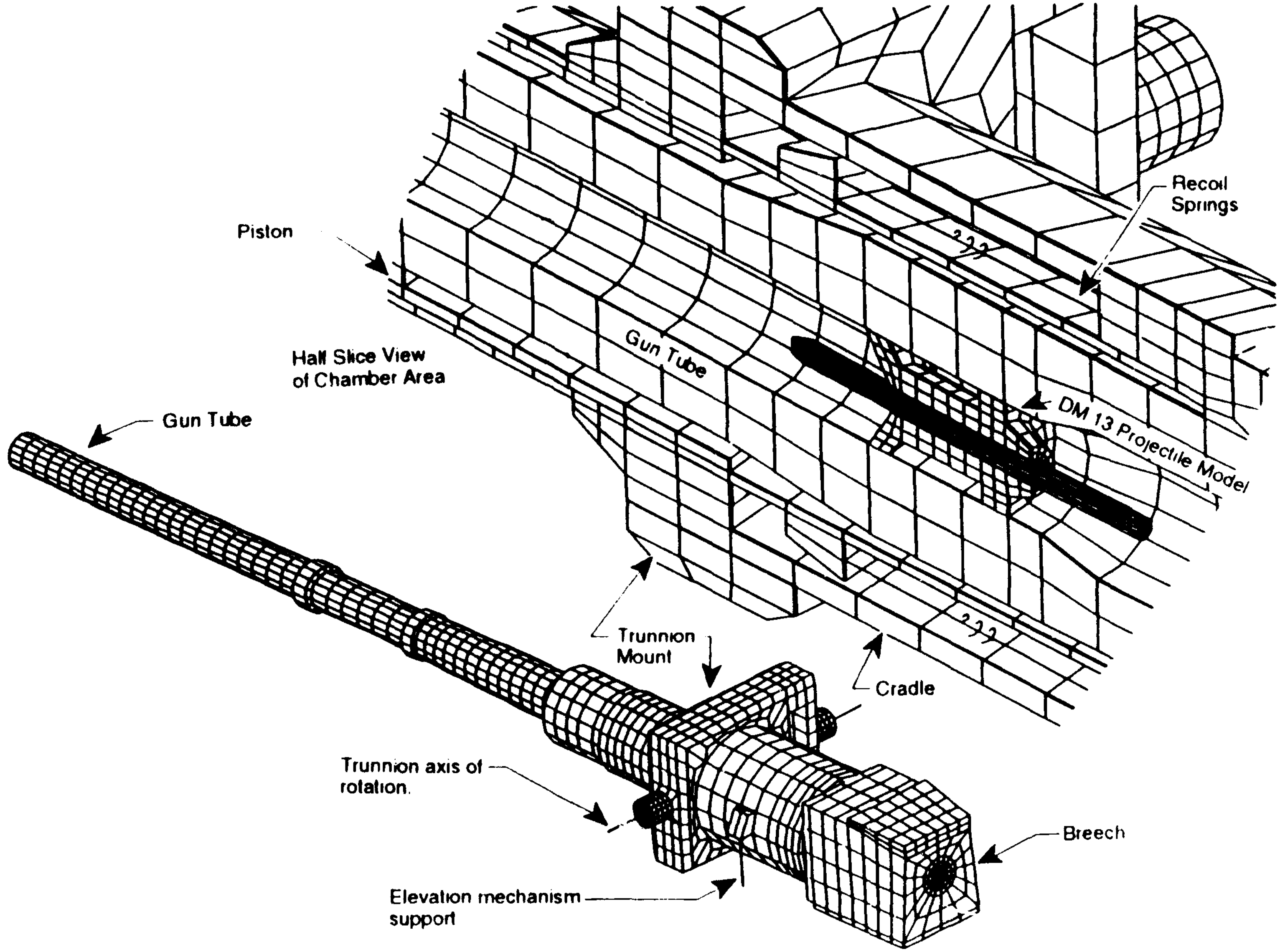


Figure 5. DYNA3D FE model with cutaway view of chamber area.

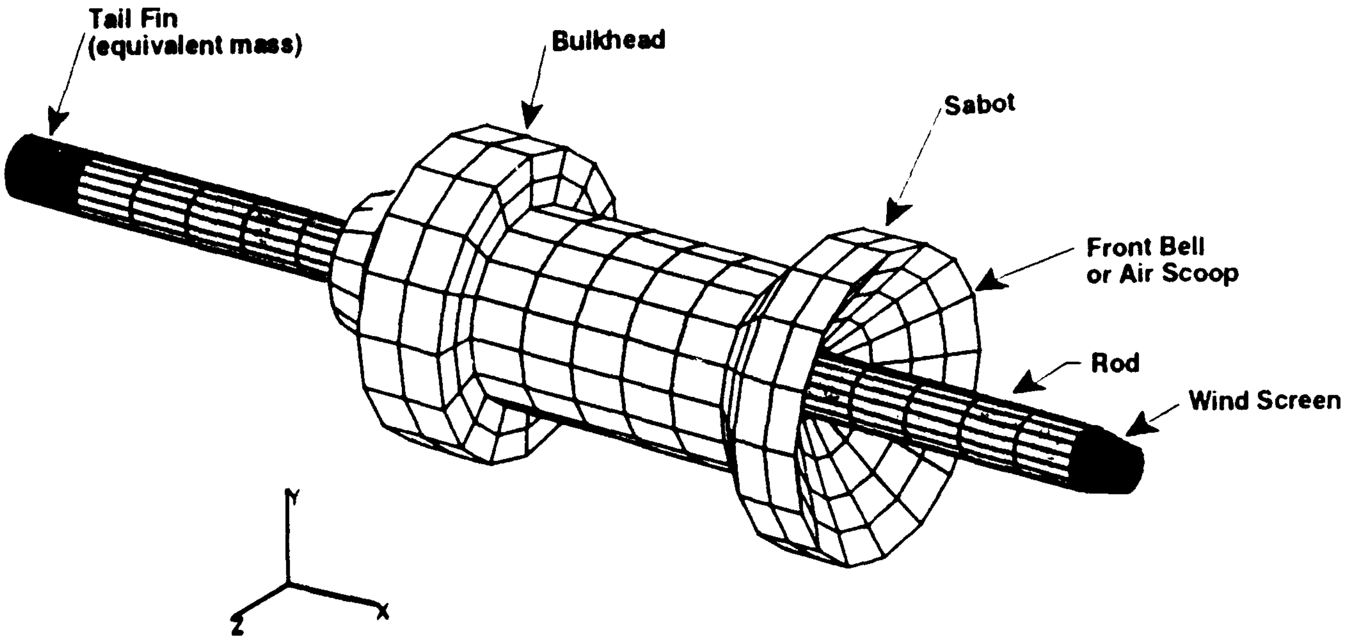


Figure 6. Model of the DM13 KE projectile.

the sabot petals was handled. In this study, the motion of the gun system was of primary importance; with the projectile motion and its interactions with the gun system being of secondary importance. Hence, to reduce run times, the interfaces between the sabot petals are not modeled. In other words, the sabot itself is modeled as a single component. However, the rod, wind screen, tail fins, and interfaces between the sabot and rod were also included in this model as was done for the XM900E1 projectile by Kaste and Wilkerson.

2.2 Model Loading and Boundary Constraints. To simulate the proper ballistic environment inside the 120-mm gun during a firing event, pressure time estimates based on an actual shot were made using the IBHVG2 interior ballistic (IB) code (Anderson and Fickie 1984). The calculations provided pressure time histories as a function of projectile travel along the axial length of the gun tube. In the model, each axial row of elements along the gun tube length received a unique pressure-time curve to simulate the actual pressure a gauge would record at that location. Additionally, the breech face which is exposed to the chamber pressure also had a distinct pressure loading history. Finally, an estimate of the pressure along the rear surface of the projectile was included. The rear surface of the projectile is considered to be any portion of the projectile which would be exposed to the burning propellant gasses. In all, 70 unique pressure time load curves were used in the FE model simulations.

It has been shown that calculations made using the DYNA and NIKE family of codes for projectile displacement, velocity, and acceleration, using the above assumptions, very closely duplicate the predictions from an IB code (Wilkerson 1991). Results are typically within 1% to 2% of more accurate modeling approaches (Hopkins and Wilkerson 1993). Noting that the pressure at any axial location of the tube is primarily dependent on the projectile position and that this attribute has been shown to be accurately predicted by the DYNA and NIKE codes, the pressurization of the gun barrel is also reasonably accurate. As a check of this assumption, calculations were made on a generic gun tube to estimate the influence of axial grid spacing. Calculations were made using the unique pressure-time curve at each axial location and compared to a coupled calculation where the FE and IB codes are linked together. In the latter calculation, DYNA results for projectile displacement, velocity, and accelerations are fed back into the IB code and the pressure at every location is calculated based on this information at each time step (Hopkins and Wilkerson 1993). Without this coupling, the IB code uses a lumped mass approach to model the projectile in its equations of motion. When the codes are coupled, the pressure along the interior gun tube wall can be calculated very accurately as the projectile moves down the tube, exposing the surface to the propellant gas pressure. It was found that for any reasonably finite discretization, the FE model and its associated set of load curves resulted in reasonable estimates for displacements, stresses, and strains. The current process of applying individual pressure curves at various axial locations along the tube length was adapted here for its simplicity in application, although future models may include the more accurate coupled approach.

2.3 Discussion. The balanced breech experiments provided valuable insight into how to change the dynamic behavior of the M256 system. Measurements from the experiments focused on the breech and gun tube motion using proximity transducer rings along the length of the gun tube and two sets of transducers on the back of the breech block (Held and Erline 1991). These measurements provided time-history information on the vertical displacement of the gun tube and the breech both with and without a balanced breech. Based on these results, possible configurations of the M256 gun tube initial position inside of the cradle were proposed (Held and Erline 1991). The focus of this report is the differences between those two systems and some physical explanation for the change in the system response when it is balanced.

To understand the mechanisms which led to the observed response in the balanced breech experiments, a matrix of simulations was performed with varying boundary conditions. The logical baseline calculation was for an unbalanced breech configuration. This represents a standard condition under which the M256 might operate. In the experiment, the weapon was loaded, aimed, and fired while the displacements of the gun tube were recorded at several locations and the vertical and horizontal motion of the breech was observed. The results in the vertical plane indicated that the breech block dropped several tenths of a millimeter during the 6 ms it took the KE bullet to traverse and exit the gun tube. Figure 7 shows a plot of a typica ical measurement of breech motion during the in-bore cycle for both the balanced and unbalance gurations. Figure 8 shows three estimates of the tube shape based on data from eddy probes use easure the gun motion at five locations along its length for the unbalanced breech case. The three curves represent data taken at 2-ms intervals—one at shot exit, one at 2 ms before shot exit, and the last was 4 ms before shot exit.

To bracket the behavior that was observed in the balanced breech experiments, five numerical simulations were made. A brief description of the differences between each of the simulations is given here. The results are then compared with experiments to provide an explanation of what occurred. As a first attempt to simulate the M256 system, the cradle piston interface in the FE model was developed with zero clearances between the cradle and piston. Although this is an unrealistic assumption, this case was calculated first as a lower bound of the system response. Then, by adding clearances, a direct comparison could be made to the response between a breech with clearances and one without; thereby showing what effect tolerances in the system have on the dynamic behavior of the system. This approach allows determination as to whether the clearances were largely responsible for the observed change in behavior between balanced and unbalanced configurations. Finally, this approach provides insight as to how the system could be modified to improve shot-to-shot variability and why the variability was reduced by balancing the breech.

The second calculation involved modifying the unbalanced breech to result in a balanced configuration. This was done by adding a wedge of material to the rear top of the breech block as was done in the actual experiment. Once again this calculation was initially done without clearances between the piston and gun tube. Results from these two calculations did not explain what occurred in the experiment. For the unbalanced case, the breech dropped as would be expected. However, when the system was balanced, there was basically no movement other than some low-amplitude, high-frequency ringing (see Figures 9 and 10).

The next case allowed clearances between the cradle and piston. In this calculation, approximately 0.0035 inch in the vertical and horizontal planes was added to the cradle inside diameter where it supports

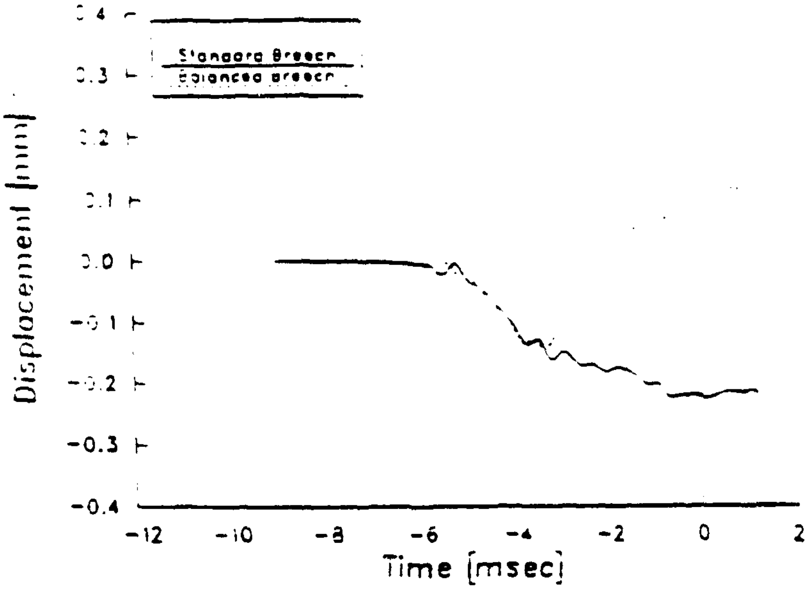


Figure 7. Vertical translation of the breech, KE round.

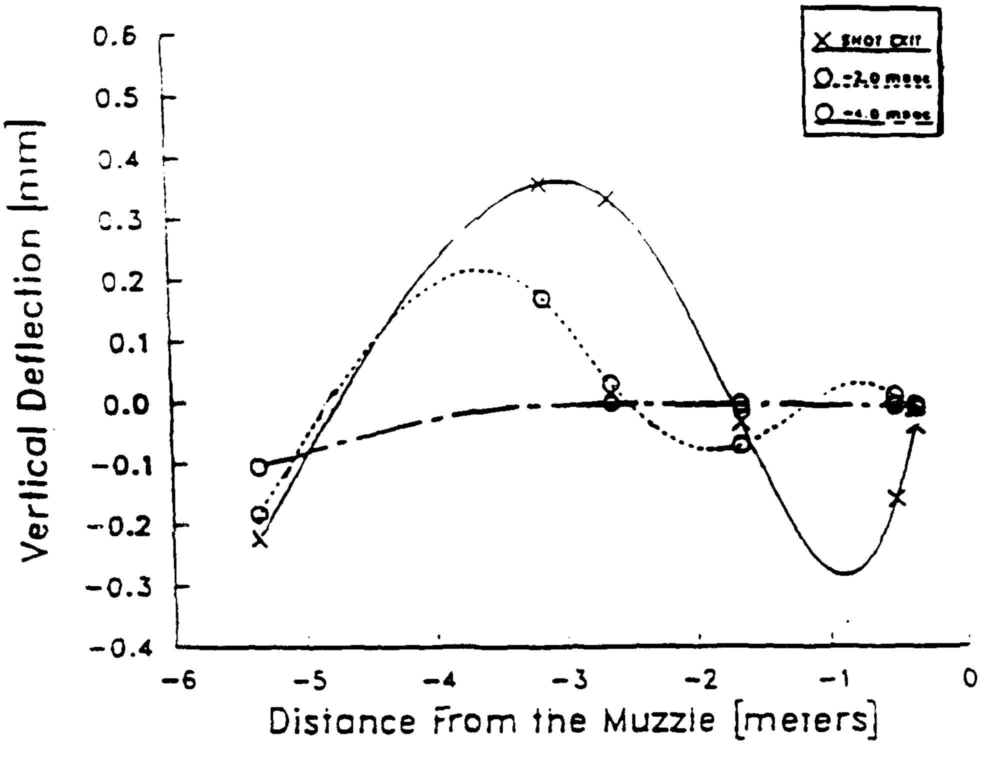


Figure 8. Time-history of tube shape, standard breech, KE round.

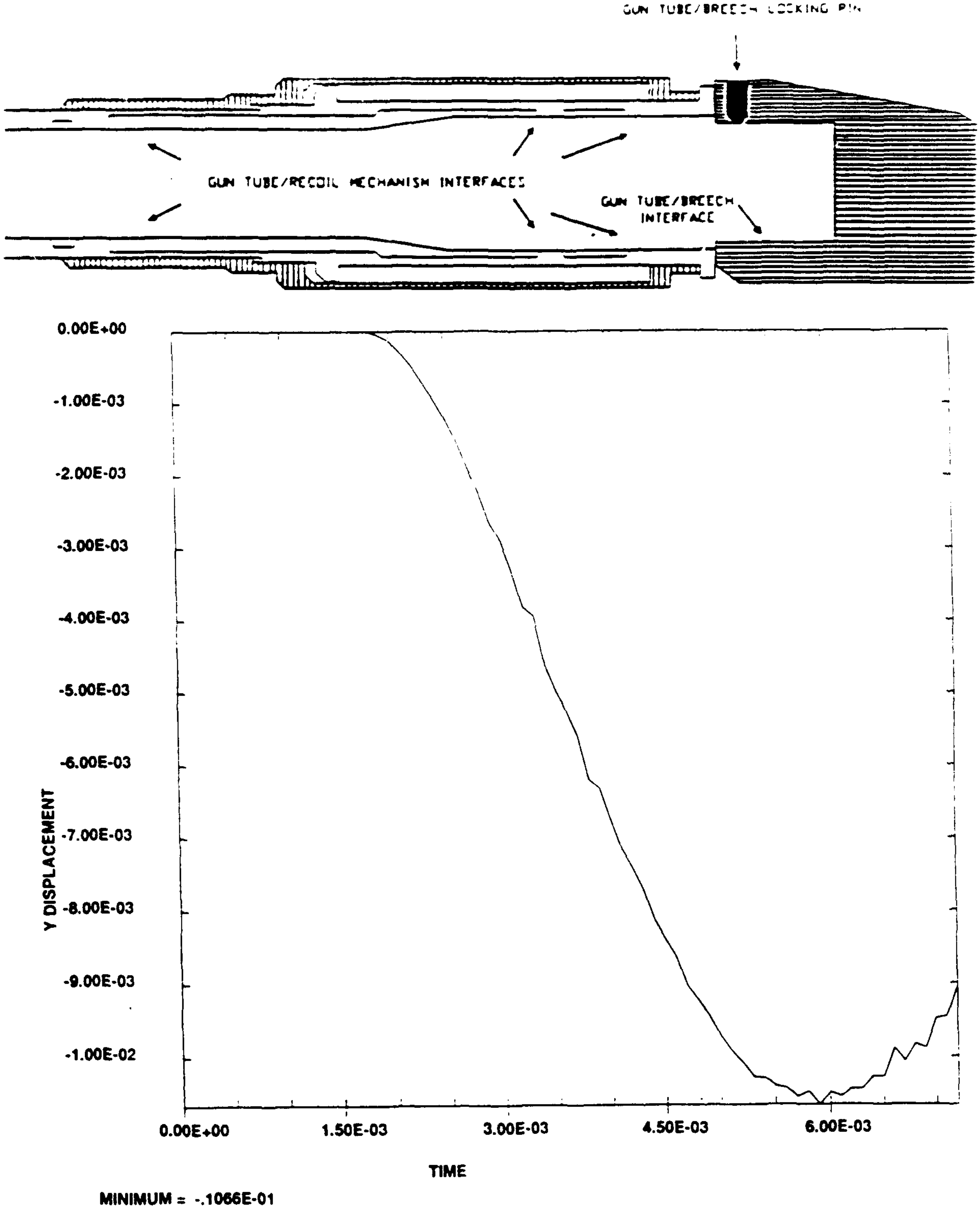


Figure 9. Unbalanced breech; gun system with no clearances between cradle and piston.

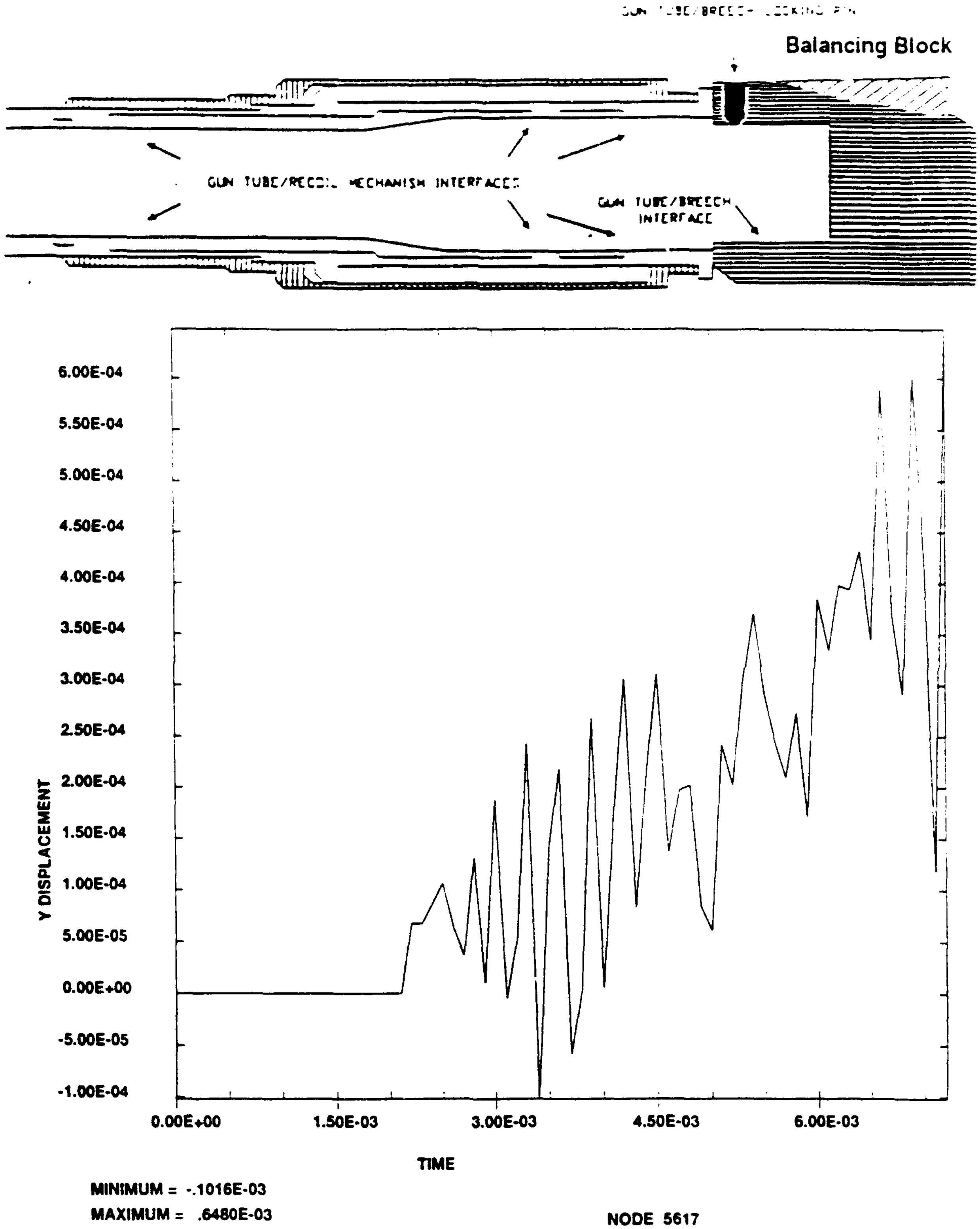


Figure 10. Balanced breech; gun system with no clearances between cradle and piston.

the piston. In the first simulation, the gun was left in a neutral position. That is, equal clearance was used between the piston and the cradle around its circumference. The simulation predicted a rise in the breech during the early recoil of the gun system (see Figure 11). The reason this was occurring is that the gun tube was free to move approximately three thousandths of an inch in either direction in the vertical plane. However, the model of the system must have been slightly biased. This bias, and the clearances, allowed the breech to recenter itself after peak pressure.

It had been speculated that the gun tube was initially canted inside of the cradle (Held and Erline 1991); therefore, after the first two calculations, the cradle assembly was disassembled and examined to determine where the cradle and piston were wearing. It was observed that the gun piston did indeed rest in a muzzle-down configuration* (i.e., the rear of the piston was riding high in the cradle, while the front sat down on the forward section of the cradle where the piston is supported). This coincides with the fact that a wedged block on the rear of the cradle engages the breech as it seats after recoil on the actual system. This wedge also tends to direct those components into the same orientation. This arrangement pushes the breech and piston toward the top of the cradle as the breech comes back into battery. However, during the early time firing and as the gun tube begins to recoil, the wedge disengages the breech, and allows the breech to move in accordance with the clearances between the piston and cradle.

For the last two calculations, the gun tube, piston, and breech were tilted along within the cradle to the allowable 0.0035-inch clearance between those parts. In the calculations, one case was run for the unbalanced breech and the second was run for the balanced breech configuration. With these initial conditions, the model predictions resembled what was observed in the experiment. Figure 12 shows a comparison between the unbalanced breech experiment and the calculated displacements of the breech. As can be seen, both the calculation and experiment have the same downward trend. However, the magnitude of the calculated response is greater than the experimental values. This difference could be partly due to other clearances in the system or from factors such as the wedged block between the breech and cradle. These attributes of the system were not included in the FE model. The 0.0035-inch clearance on the cradle diameter was chosen as a nominal of what might be possible, but this value could certainly vary in either direction. Another contributing factor is the amount of offset in the CG location of the location of the breech. The contour line of the tube could also be slightly different in the model than in the actual system.

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* Examination of a disassembled cradle was performed by the Recuperation Section of the Combat Systems Test Activity, Aberdeen Proving Ground, MD.

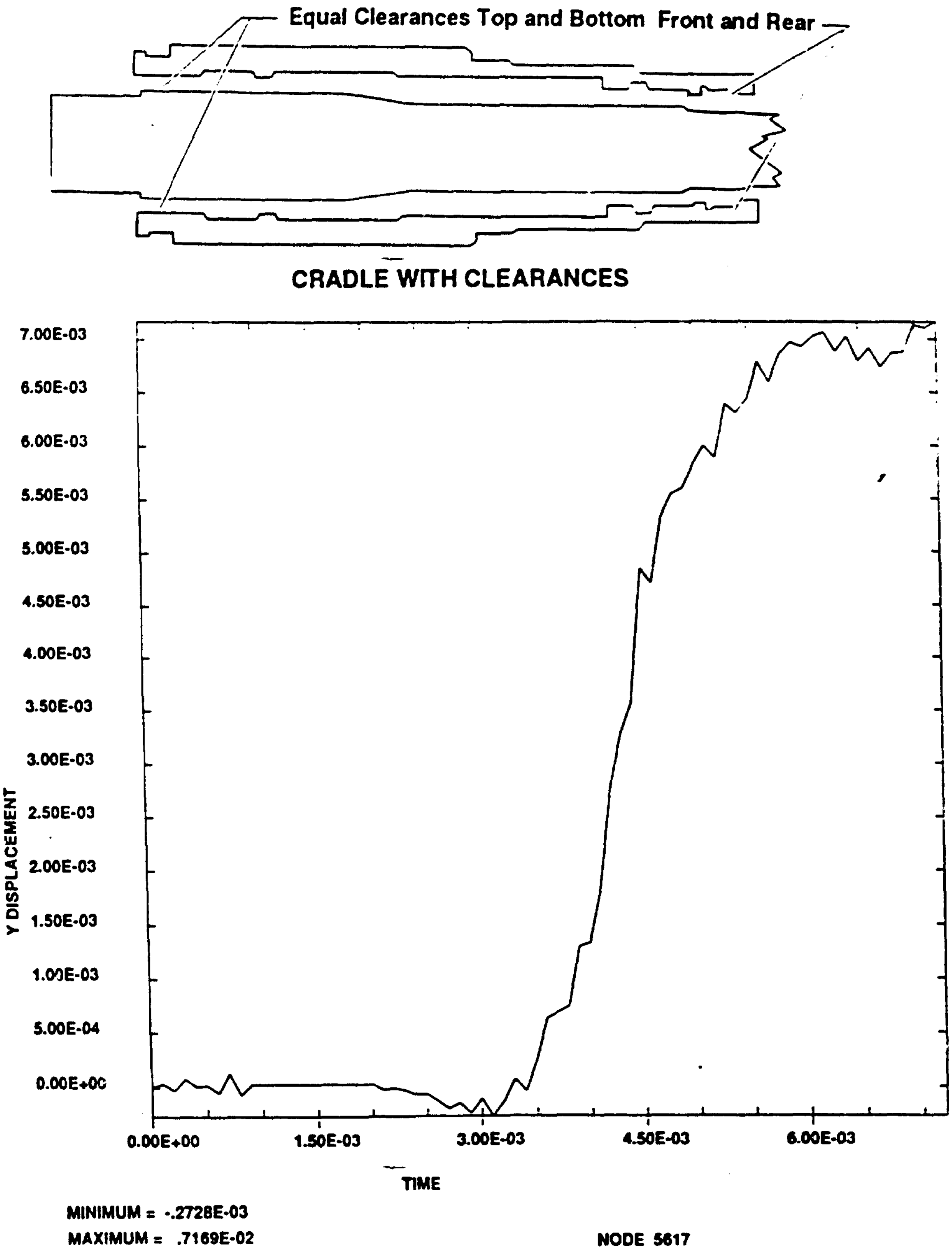
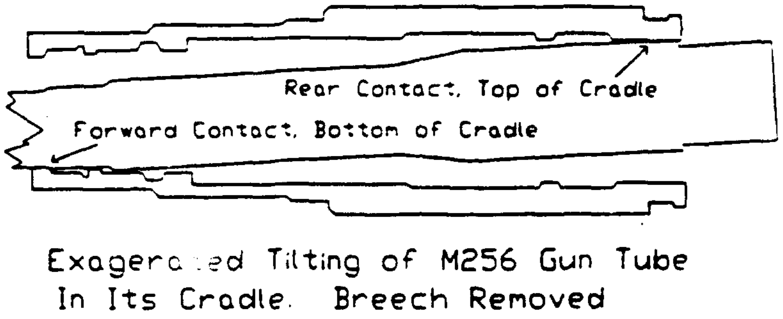


Figure 11. <u>Balanced breech with clearances between and cradle and piston.</u>



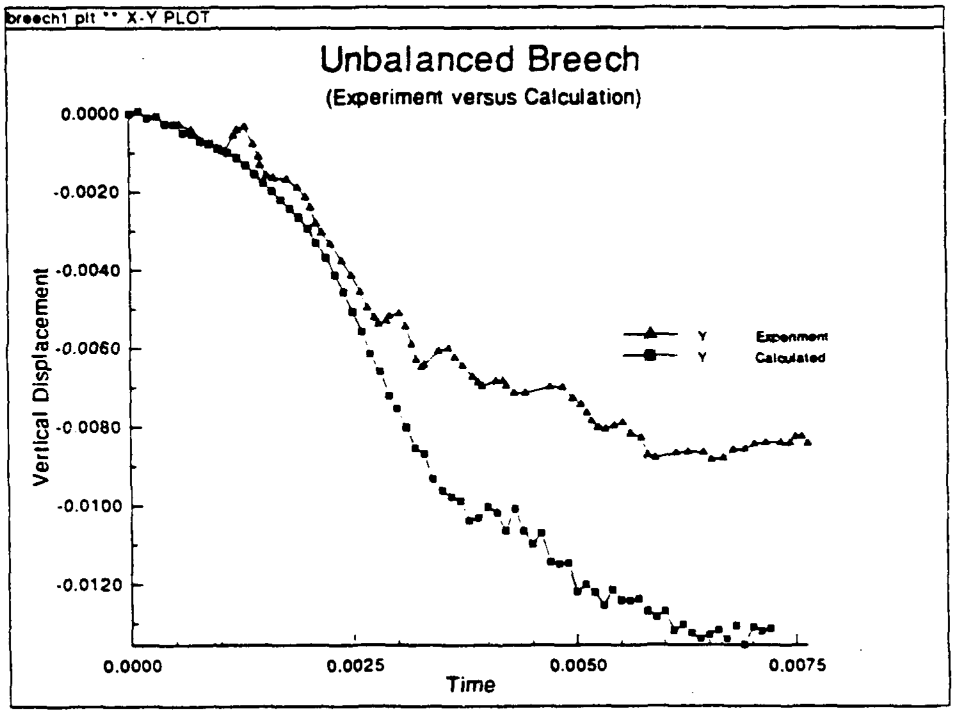


Figure 12. Unbalanced breech with clearances and gun/piston tilted high in the rear of the cradle and low in the front of the cradle.

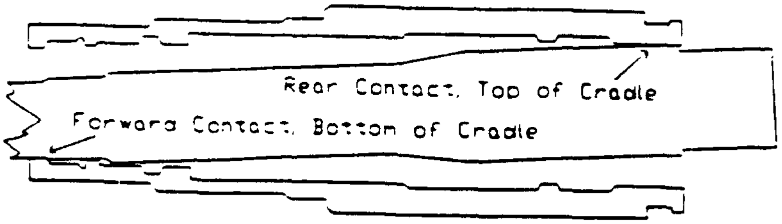
Predictions used here correspond to the values estimated in the balanced breech experiments (Held and Erline 1991). An inaccurate estimate could lead to an erroneous couple which could produce different rotations than those observed. The objectives of these numerical simulations were not simply to duplicate the observed displacements, but rather to simulate and understand the observed characteristics of the system. The last case for the balanced system clearly indicates that the tilted forward initial condition could indeed be the manner in which the cradle supports the piston. Furthermore, the combination of clearances, initial seating, and tube pressurization could account for the observed behavior of the balanced breech system. Figure 13 shows a comparison of breech displacement vs. time histories for the experiment and calculation. As in the prior case, the calculation predicted displacements with trends similar to those observed in the experiment. However, these calculation over estimated the negative displacement (downward) by the breech, and, therefore, the model does not rebound back in the vertical direction as far as the breech does in the experiment. Once again this could be caused by excessive clearance in the cradle which permits the breech to drop too quickly before rebounding off the opposite cradle support. It could also be as simple as grid refinement used to model the gun tube. A course grid refinement, such as the one used here, can result in a overestimate of the displacements at the boundary of an element (note: the integration point for DYNA3D eight nodded brick elements is in the center of the element, hence, values at the boundary are calculated through interpolation).

The differences between the predicted and experimental results could also be due to other subtle boundary conditions which were not taken into account in the model. These boundary conditions include:

(1) Elevation mechanism stiffness, damping and nonlinearities
(2) Recoil mechanism damping and nonlinear attributes
(3) Increased or decreased clearances between parts
(4) Friction between the sliding interfaces
(5) Effects of the adapter, bearing, king nut, and thrust nut arrangement
(6) CG offset
(7) Effects of the wedged block between the cradle and breech.

However, it is still significant that by using the boundary conditions represented by simply tilting the gun within the cradle with clearances and the pressurization of the gun tube, a reasonable match to what occurred in the experiment was achieved.

Finally, Figure 14 shows an exaggerated representation of the gun tube profile for the unbalanced breech simulation in which the gun tube was tilted in the cradle and appropriate clearances were utilized. Although the gun tube shape seen in this figure appears similar to the one observed in the experiment (see



Exaggerated Tilting of M256 Gun Tube
In Its Cradle Breech Removed

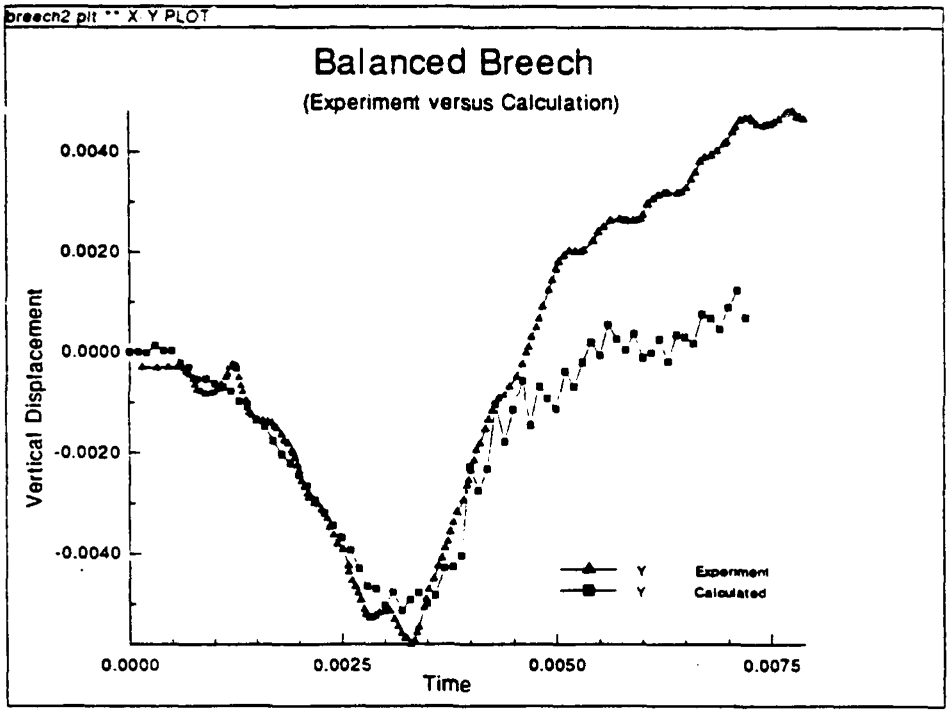


Figure 13. Balanced breech with clearances and gun/piston tilted high in the rear of the cradle and low in the front of the cradle.

Figure 8*, more work remains to be performed with the data reduction techniques used to produce this plot.

This will allow a direct comparison between the calculation and experiment.

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* Note that the shape in Figure 8 is a spline interpolation of five data points and is not a perfect representation of the gun actual shape.

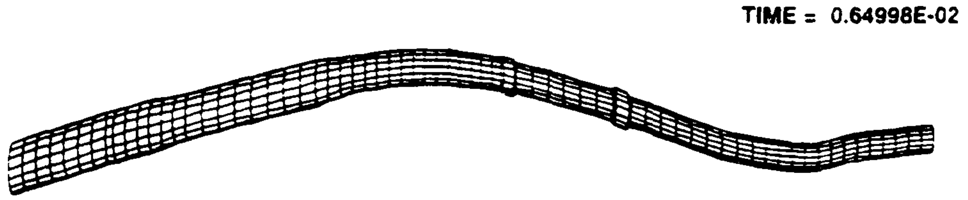

Figure 14. Gun tube profile at the approximate time that the bullet exits the gun tube.

3. CONCLUSION

The first two cases indicated that, if clearances did not play a role in the balanced breech experiment, then the overall vertical movement of the breech and gun tube would have been drastically reduced. However, with clearances and a tilted gun tube, the system behaved unexpectedly (i.e., the gun breech initially dropped and then rose later during the in-bore cycle). Based on the FE simulations, it is postulated that the gun rests in a canted position in the cradle. This is due to gravity and the centering block in the rear that must be engaged by the breech block as the system comes back into battery after firing. In that position, and with the clearances that actually exist in the system, the pressurization of the gun tube pushes the piston rear surface away from the cradle top support as the gun begins to recoil. Then, as the gun becomes free of the centering block, it is free to move downward, forced by the in-bore pressurization. After peak pressure when the tube is no longer expanding, the breech is free to rise again, as the system attempts to recenter itself.

One of the primary objectives of gun accuracy research is determining the causes of shot-to-shot variation. The balanced breech experiment represents an attempt to lessen the variational magnitude of quantities, such as pointing angle, by reducing the forces which act out-of-plane, namely, the powder pressure couple. What was observed during the associated experiments, was a reduction in round-to-round variation in pointing angle between the balanced and unbalanced breech firing conditions. However, it is interesting that there still remained significant motion in the breech. That is, the total movement of the breech in the vertical plane was nearly equal in magnitude between the balanced breech and the unbalanced breech cases. This phenomenon could be a function of the clearances in the system and the way in which the gun tube/piston rests inside the cradle.

What can be learned from these experiments and the calculations is that variations in the system initial conditions undoubtedly lead to shot-to-shot variations in projectile exit conditions. To what degree each attribute of the system contributes to these variations is not completely understood. Sophisticated FE models such as a DYNA3D representation is a good step toward exploring what mechanical variables have sufficient effect to warrant further exploration. Such changes should then focus on reducing undesirable effects which decrease accuracy. For example, the current model suggests that reducing the clearances necessary for assembling the gun system, as well as balancing the breech, would be improvements. However, this may be impractical, whereas changing the method of biasing the system to one in which out-of-plane forces are minimized may be a more realistic solution. In general, out-of-plane forces produce out-of-plane motion on the gun tube. Since the exact bullet exit time can not be rigidly controlled, this attribute will cause shot-to-shot variations which reduce accuracy. Hence, by simply controlling the magnitude of the gun tube transverse velocities, shot-to-shot variations can be reduced.

Experimentation and observations of hardware, as well as test results, remain important accompaniments to the calculations for validating models and providing further guidance about probable causes and effects. What must be determined prior to a firing experiment, is the total number of shots that are required to observe a particular level of improvement. The past practice of using three to five round groups may not be sufficient, particularly in the observation of subtle changes. It is paramount to make good use of accompanying calculations with experiments to distinguish the magnitude of results expected from the changes made. Such experimentation could miss a potential improvement or predict one when none existed.

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