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ANALYTICAL PERFORMANCE OF STEEL, ALUMINUM AND PLASTIC FOR A NEW DESIGN HIGH PRESSURE THIN-WALLED CARTRIDGE CASE

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June 1974

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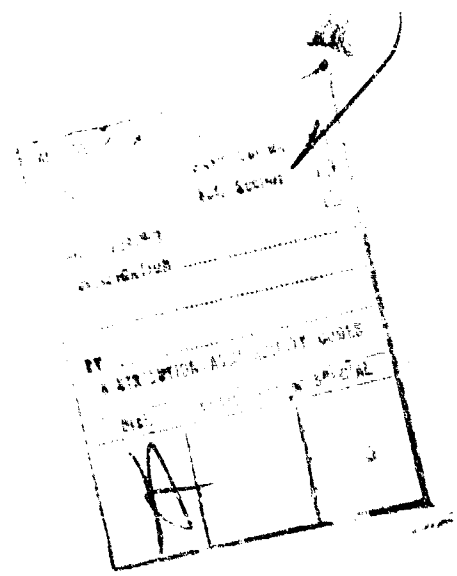

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A new 30mm cartridge case is evaluated at an operating pressure of 75,000 psi. The case is thin-walled throughout (0.03 in.) and is designed principally to obturate propellant pressure and prevent corrosion of the chamber. Steel, plastic and aluminum alloys were evaluated at design conditions with the result that aluminum is best suited for the job. An analysis was also performed assuming a support gap between chamber and bolt which indicated survival of the case.

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INTRODUCTION

The purpose of the High Pressure Thin-Walled Cartridge Case task of the Automatic Cannon Technology (ACT) program, 1J662604AH97, is to develop a new cartridge case concept which will meet pressure requirements of 75,000 to 100,000 psi.

One of the most difficult parts of performing a stress analysis is the proper application of loads or boundary conditions. This is particularly true in the analysis of a cartridge case under firing conditions when the case is to function near the material capacity. Under a previous effort[4] a preliminary structural analysis on a 1030 steel case was conducted assuming the chamber to be rigid. At 75,000 psi the effective stress in the case reached approximately ninety percent of the breaking strength of the material. The increase in deformation which would occur with a deformable chamber could be sufficient to allow the case to rupture. This necessitated the modeling of the interaction between the case and chamber.

A simplified model was developed using membrane stresses[1] for a conical membrane and the Prandtl-Reuss[2] equations to determine the deformation of a section of the case. The equations[3] for the expansion of a thick-walled cylinder under uniform pressure were used to represent the chamber. Continuity of stresses and displacements at the case-chamber interface allowed the determination of the interference pressure as a function of propellant pressure. Since the base of the cartridge case is hemispherical (Figure 1), the procedure was

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[1] Wilhelm Flügge, "Stresses in Shells," Springer Verlag, Fourth Printing, New York, 1967.

[2] Alexander Mendelson, "Plasticity: Theory and Application," Macmillan, New York, 1968.

[3] Raymond J. Roark, "Formulas for Stress and Strain," McGraw-Hill, Third Edition, New York, 1954.

[4] Leonard M. Gold, "Cartridge Case - Chamber Interaction During Firing," Frankford Arsenal Memorandum Report M73-35-1, December 1973.

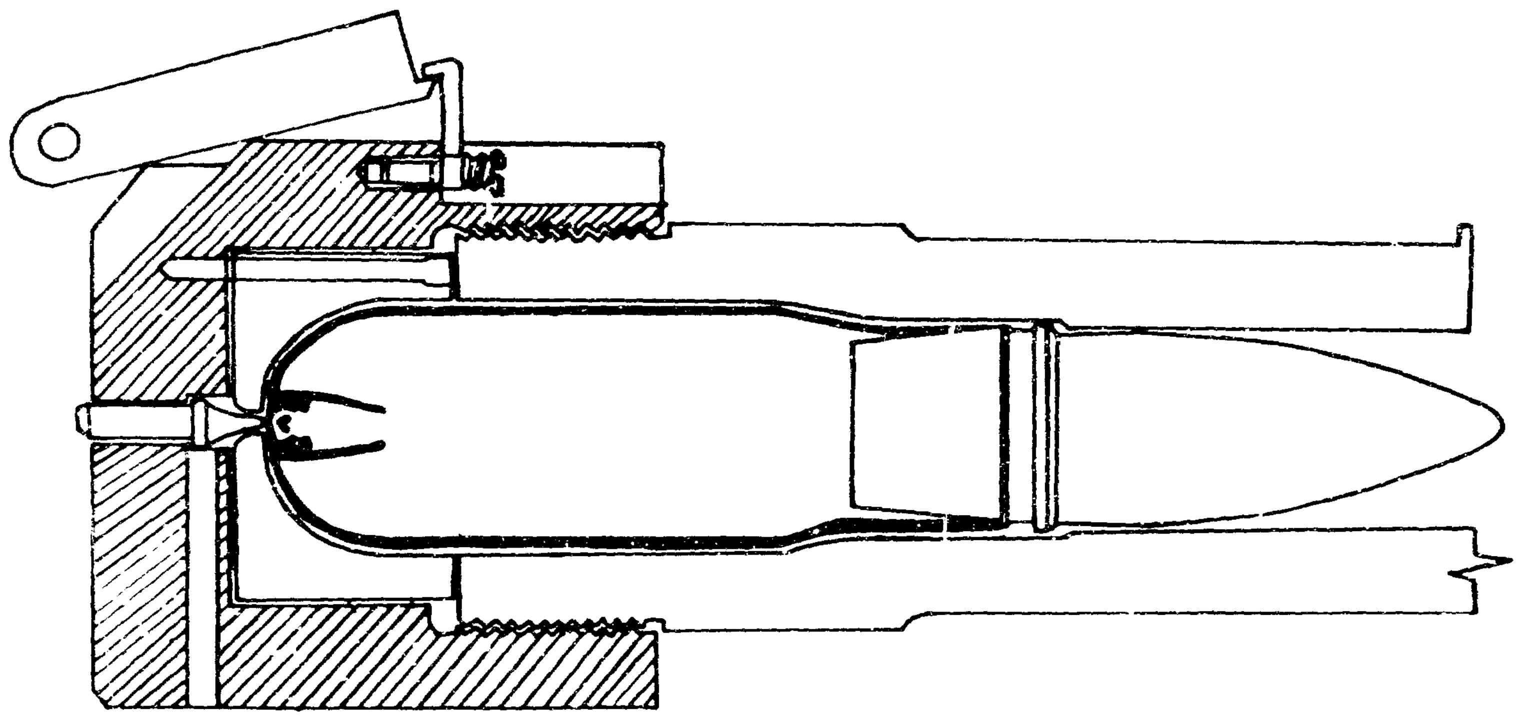

Figure 1. Thin-walled ACT Cartridge Case Design

repeated using the membrane stresses for a spherical membrane and the equations for the elastic deformation of a thick-walled sphere under uniform internal pressure. The mathematical model along with its resulting computer code is presented in Reference 4. The application of that model to various materials is the subject of this report.

PROCEDURE

In this analysis, the case is assumed to be plastic when contact is made with the chamber. Both chamber and case expand until peak pressure is reached. At this point the case geometry is modified to reflect permanent deformation. Case and chamber then unload elastically until the propellant pressure goes to zero and a determination is made as to whether or not the case separates from the chamber.

The case under consideration (Figure 1) is 0.030 inches in wall-thickness throughout with a hemispherical base which gives maximum propellant volume in the base for a minimum of metal and weight. The clearance between case and chamber is 0.003 inches throughout. The case is approximately six mm larger in diameter and 5/8 inches longer than a standard 30 mm case but contains approximately twice the volume. The chamber used is also shown in Figure 1.

The results of the boundary condition analysis indicated that extraction forces for a 1030 steel case in a steel chamber would be excessive. Therefore, it was decided to examine several plastics and then aluminum. The analysis of various amounts of glass-filled Tefzel and Zytl plastics indicated probable failure near the primer cup and no further investigation of plastics ensued.

Three aluminum alloys were examined: (1) MA08-T6, (2) 7075-T6 and (3) 7475-T6. The best of the three alloys was 7475-T6. The other alloys were eliminated and the computer analysis continued with 7475-T6 as the final case material. Finally, a section of the case was then programmed with a gap between the chamber and bolt.

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[4] Leonard M. Gold, "Cartridge Case - Chamber Interaction During Firing," Frankford Arsenal Memorandum Report M73-35-1, December 1973.

ANALYSIS AND RESULTS

The grid used for the finite element analysis (Figure 2) consisted of 294 elements and 385 nodes. The wall is comprised of three elements throughout the case with the one exception at the primer cup seat lip which consists of six elements.

The initial analysis of the case was performed for a 1030 steel case in a rigid chamber. Because of the thin-walled profile of the case there was very little variation in effective stress through the wall thickness. The effective stress for the middle element at each location in the case is plotted in Figure 3 for the steel case. The analysis indicates interference pressure between case and chamber of almost 16,000 psi after unloading. Because of the excessive interference pressure which causes a high extraction force the steel case was not considered a suitable candidate.

Several plastics were analyzed using the rigid chamber boundary conditions. All were found inadequate and failure was indicated either in the hemispherical base or in the primer cup region.

The rigid chamber analysis was conducted for MAO8-T6, 7075-T6 and 7475-T6 aluminum cases. Each case analysis indicated satisfactory behavior with very small variation in effective stress through the wall and along the length of the case. At peak pressure the effective stress throughout each case stayed approximately 5 percent or less above the yield stress with some locations just at yield. The effective stress for the 7475-T6 case is plotted as a function of location in Figure 4.

The breaking strength of the 7075-T6 is considerably lower than for MAO-8-T6 or for 7475-T6. Considering this and the fact that the boundary is not rigid eliminated 7075-T6. There is very little difference between the MA08-T6 and the 7475-T6. The factors leading to the choice of 7475-T6 over MAO8-T6 were:

1. 7475-T6 is more easily obtained and

2. The modulus of 7475-T6 is less than the modulus of MAO8-T6 which implies lower interference pressures between case and chamber and as a result easier case extraction.

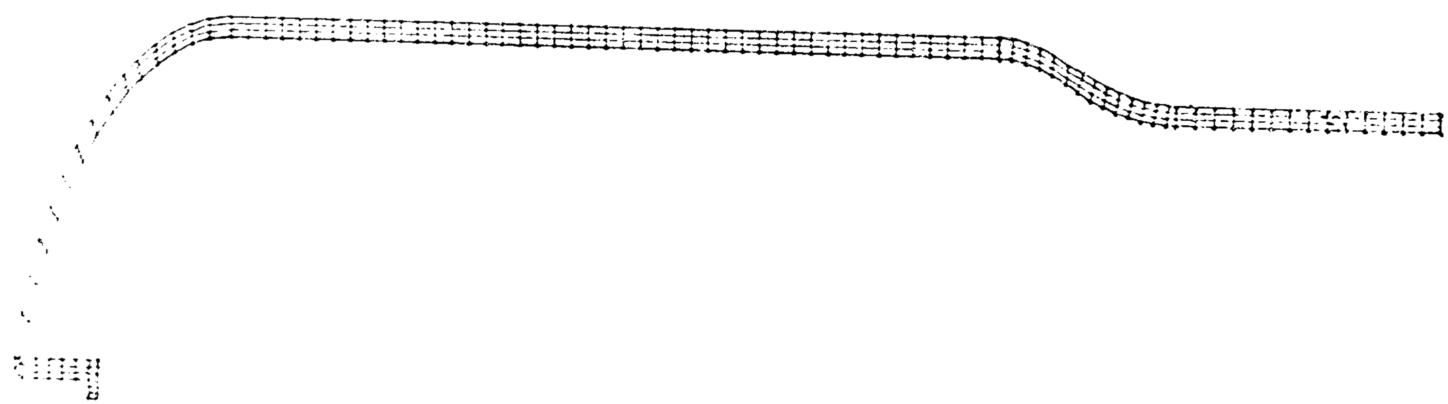

Figure 2. Finite Element Grid for ACT Case

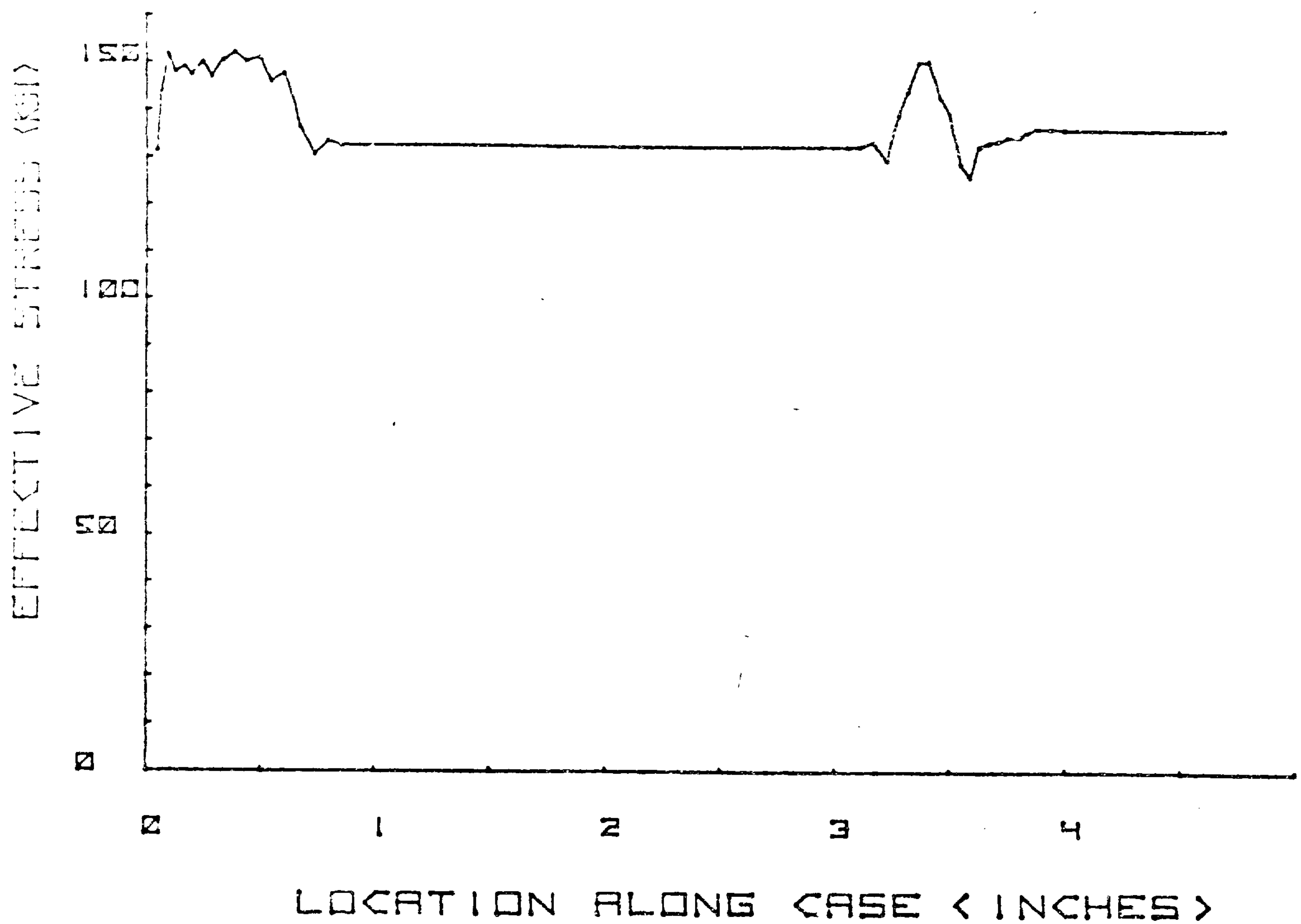

Figure 3. Effective Stress as a Function of Position for a 1030 Steel Case

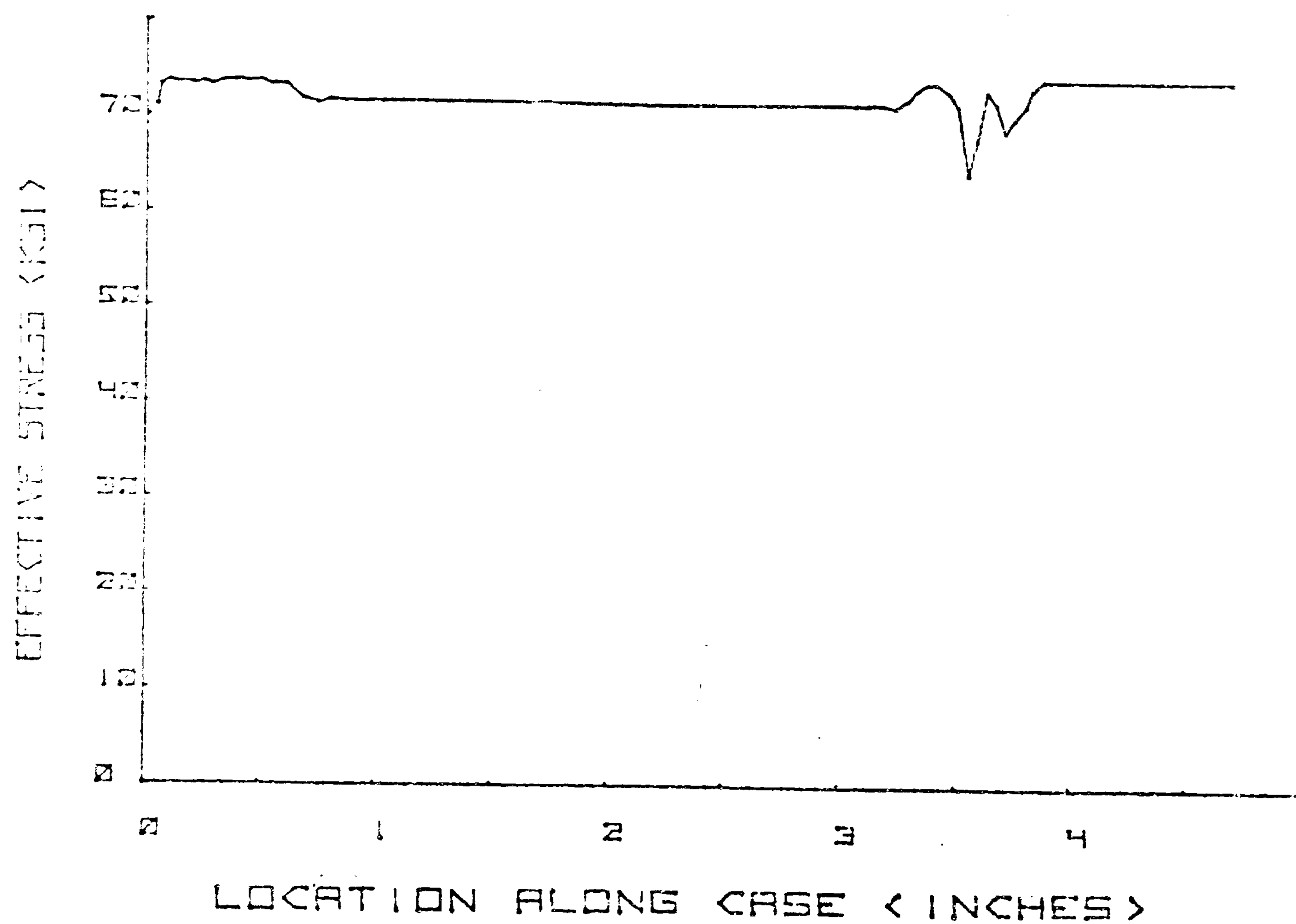

Figure 4. Effective Stress as a Function of Position for a 7475-T6 Aluminum Case

The boundary condition analysis was performed for the 7475-T6 case in a steel chamber and the interference pressures, after unloading, varied from three to five times lower than the steel case in a steel chamber at the same locations. The results of this analysis were then used as boundary conditions in the finite element analysis.

The data for the hemispherical base was used as a displacement boundary condition while the data for the rest of the case was used as pressure boundary conditions for the 7475-T6 alloy. The boundary interference pressure history varied along the length of the case and could not be input to the finite element program as one set of data. The maximum interference pressure was placed in the finite element program and the analysis was run six times with the interference pressure history for each of six sections used as the history for one run. The results generally indicated satisfactory behavior of the case. Also, the case survived pressurization with a support gap of 0.02 inches between the chamber and bolt.

Some minor problems were encountered during unloading of the case such as excess tensile stresses near the chamber-bolt interface and at the case shoulder. These results seem to be caused by excessive boundary condition loading. The inaccuracies inherent in using simplified shell theory and geometric approximations for the chamber would indicate that the problems are a result of the boundary condition program rather than actual case behavior.

CONCLUSIONS AND FUTURE WORK

As a result of this study the following conclusions can be drawn concerning cartridge case materials for the design concept described in this report:

1. Extraction forces for a 1030 steel case are excessive.

2. Glass-filled Tefzel and Zytl plastics indicate probable failure near the primer cup.

3. The aluminum alloys MAO-8, 7075-T6, and 7475-T6 performed satisfactorily for the rigid boundary analysis.

4. The aluminum alloy 7475-T6, having a higher breaking strength than MAO-8 and 7075-T6 was studied with the non-rigid boundary analysis including a small support gap between the chamber and bolt; and the case performed satisfactorily.

5. The interference pressure between the 7475-T6 case and chamber was found to be about four times lower than that for the steel case.

With the case design verified by computer analysis, working drawings of the case may be made and the cases manufactured. A standard 30mm Mann barrel is available for modification. Figure 1 shows the essential features of the modified barrel and breech mechanism. Dimensions need to be provided for the breech mechanism. The moving parts such as spring, hammer and firing pin may be used from the existing breech. After case manufacture and modification of barrel and breech, the cases must be fired to demonstrate the feasibility of the case concept.

REFERENCES

1. Wilhelm Flügge, "Stresses in Shells," Springer Verlag, Fourth Printing, New York, 1967.

2. Alexander Mendelson, "Plasticity: Theory and Application," Macmillan, New York, 1968.

3. Raymond J. Roark, "Formulas for Stress and Strain," McGraw-Hill, Third Edition, New York, 1954.

4. Leonard M. Gold, "Cartridge Case - Chamber Interaction During Firing," Frankford Arsenal Memorandum Report M73-35-1, December 1973.