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Dynamic Rupture Strength of Lacquer Seal in Flash Tube of 30-mm Ammunition for the M230 Cannon

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Abstract

The M788, M789, and M799 30-mm ammunition use a flash tube to augment the ignition stimulus of the primer and to provide an ignition source for the propellant bed in each round. The flash tube must be fast acting, provide abundant hot gases/particles, and increase the pressure in the propellant bed sufficiently that the initial burn rate of the propellant in the bed is high enough to propel the projectile to the muzzle within the few milliseconds that constitute the action time of the M230 cannon. This investigation studied the dynamic rupture pressure of the lacquer seal on the flash tube. The rupture pressure of the seal was found to be a function of the pressurization rate in the flash tube. At the largest rupture pressure of this study (78 MPa [11,200 psi]), significant gas generation would be achieved before the flash tube vented into the main propellant bed. Gas flow at these pressures is expected to play a significant role in ignition of the main propellant charge and rapid functioning of the round.

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1. Introduction

The M788, M789, and M799 30-mm ammunition use a flash tube (see Figure 1) to augment the ignition stimulus of the primer and to provide an ignition source for the propellant bed in each round. The flash tube must be fast acting, provide abundant hot gases/particles, and increase the pressure in the propellant bed sufficiently that the initial burn rate of the propellant in the bed is high enough to propel the projectile to the muzzle within the few milliseconds that constitute the action time of the M230 cannon.

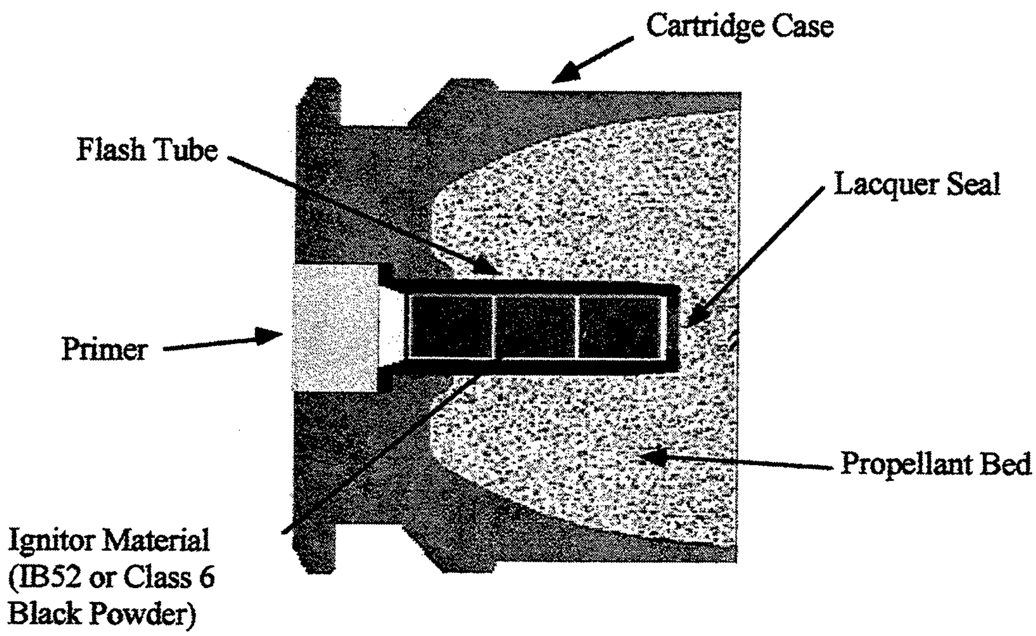

Figure 1. Schematic of breech end of a 30-mm round used in the M230 cannon.

The lacquer seal on the flash tube does more than keep the black powder in the flash tube. It must be sufficiently strong so that the primer output remains in the flash tube until the black powder is ignited and combustion products from the black powder have built up enough pressure and hot particle density. When it does rupture, the pressure released needs to be sufficiently high enough to increase the pressure in the propellant bed so that the initial burn rate of the propellant is high enough to complete the ballistic cycle in the time required. This report examines the rupture strength of the lacquer seal.

2. Experimental

The experiments described in this report were conducted on two test fixtures at the U.S. Army Research Laboratory (ARL). Figure 2 shows a simplified schematic of

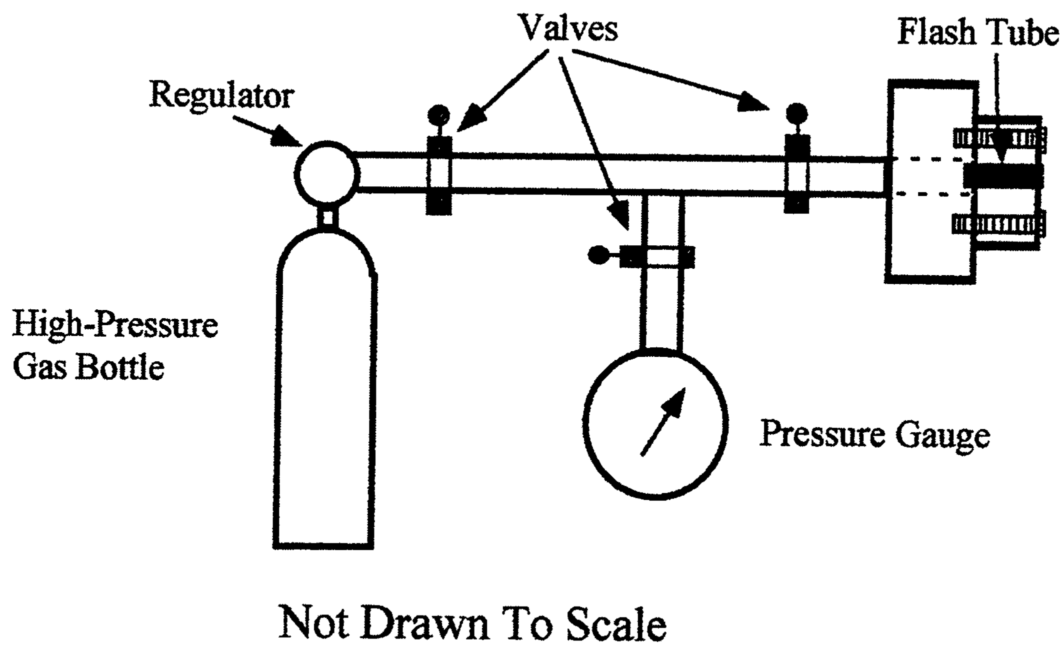

Figure 2. Simplified schematic of fixture to obtain the quasi-static rupture pressure of a flash tube.

a fixture to test the quasi-static rupture pressure of a flash tube used in M788, M789, and M799 30-mm ammunition. The flash tube was held in the fixture, and gas from a high-pressure gas bottle was metered into the volume behind the lacquer seal. The rupture pressure was obtained visually from the pressure gauge at the moment of rupture. The time to rupture of the lacquer seal was varied from approximately 5–45 min with no significant difference in rupture pressure. A photograph of the seal just prior to rupture is shown in Figure 3.

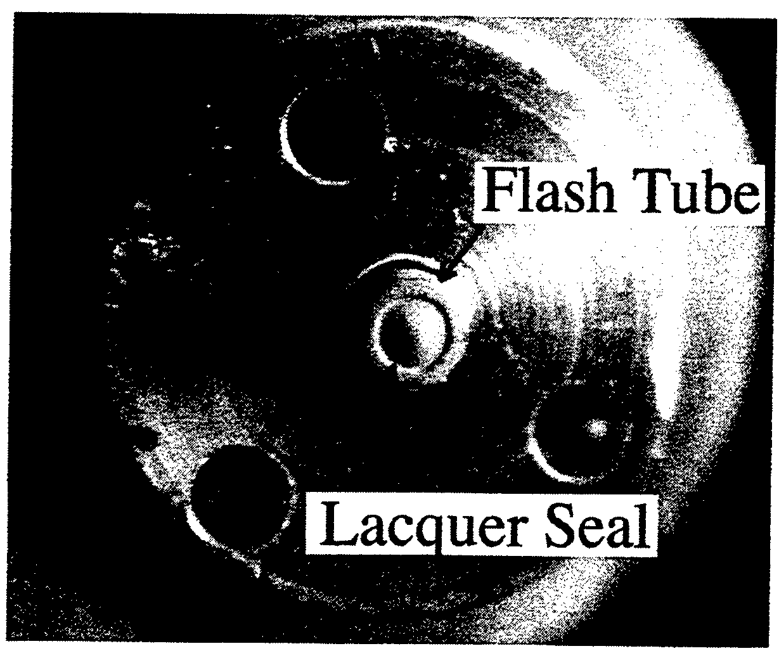

Figure 3. Photograph of a flash tube seal just prior to rupture.

The second fixture was used to obtain the dynamic burst pressure of the lacquer seal. Figure 4 shows a simplified cross section of this fixture. Pressure was generated by an electric match ignition of an igniter mixture containing Class VI black powder (at low pressurization rates only black powder was present; at higher pressurization rates the mixture contained increased fractions of Olin ball powder propellant, lot no. X4766). After the electric match had ignited the black powder, the resulting gases pressurized the fixture until the lacquer seal ruptured. The pressure-time history of the gases was monitored by a Kistler 211B1 pressure gauge and recorded on a Nicolet Integra 20 digital oscilloscope.

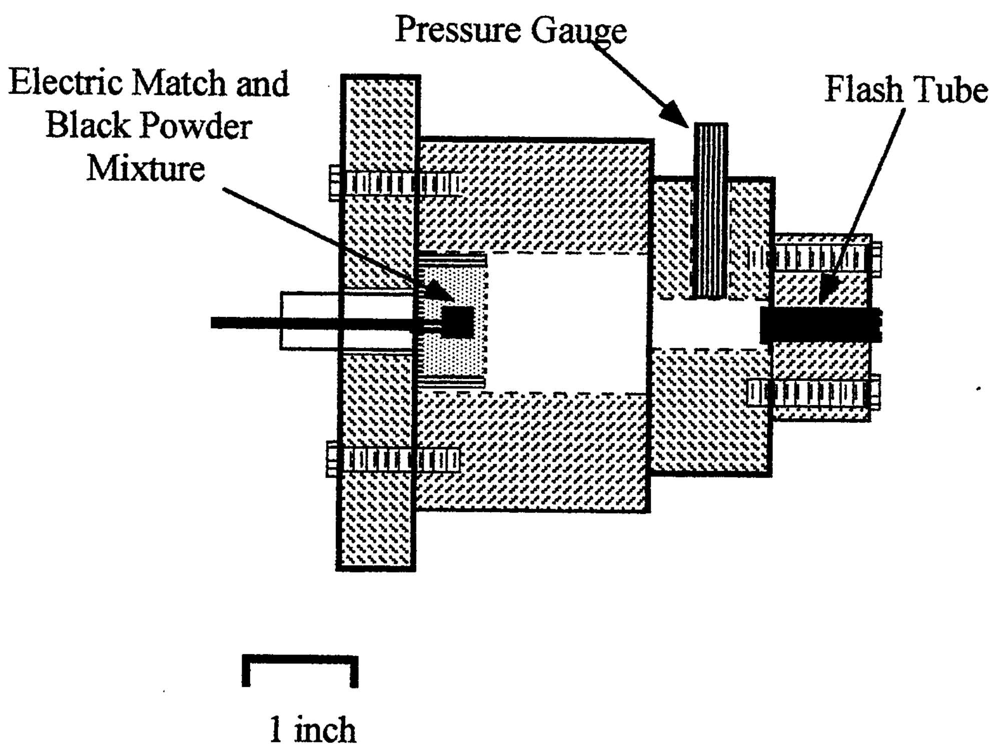

Figure 4. Simplified cross section of fixture to obtain the dynamic rupture pressure of a flash tube.

3. Results and Discussion

Earlier tests by Chang et al. [1] with a lacquer-sealed, vented long metal primer showed that the maximum pressure within such a primer could be obtained with pressure gauge taps in the primer body. However, the current flash tube body is too short to effectively obtain the pressure in this fashion. For these tests the pressure gauge was placed just outside the open end of the flash tube as shown in Figure 4.

In an effort to obtain the strain-related physical properties of the lacquer seal, a number of M789 flash tubes were obtained. To obtain the quasi-static rupture pressure, a flash tube was inserted in the fixture in Figure 2 and the interior was pressurized until the seal ruptured. The average rupture pressure of the lacquer seal was 7.7 ± 0.7 MPa (1100 ± 100 psig).

As the number of available flash tubes for this investigation was limited, tubes with ruptured seals were cleaned and dipped with a nitrocellulose lacquer that approximated the original lacquer seal composition. It was found that three coats of the lacquer dip were required to obtain the approximate rupture pressure of the original lacquer seal. The average of the dipped lacquer seals was 7.0 ± 1.4 MPa (1000 ± 200 psig).

Two of the dipped flash tubes were tested dynamically and compared with two flash tubes with original lacquer seals. The pressure-time histories of these experiments are shown in Figures 5 and 6. The average rupture pressure of the original lacquer seals was 15.2 ± 0.8 MPa and the average rupture pressure of the dipped lacquer seal was 14.9 ± 0.8 MPa. In this sampling the dynamic rupture pressure of the original seals was comparable to that of the dipped seals.

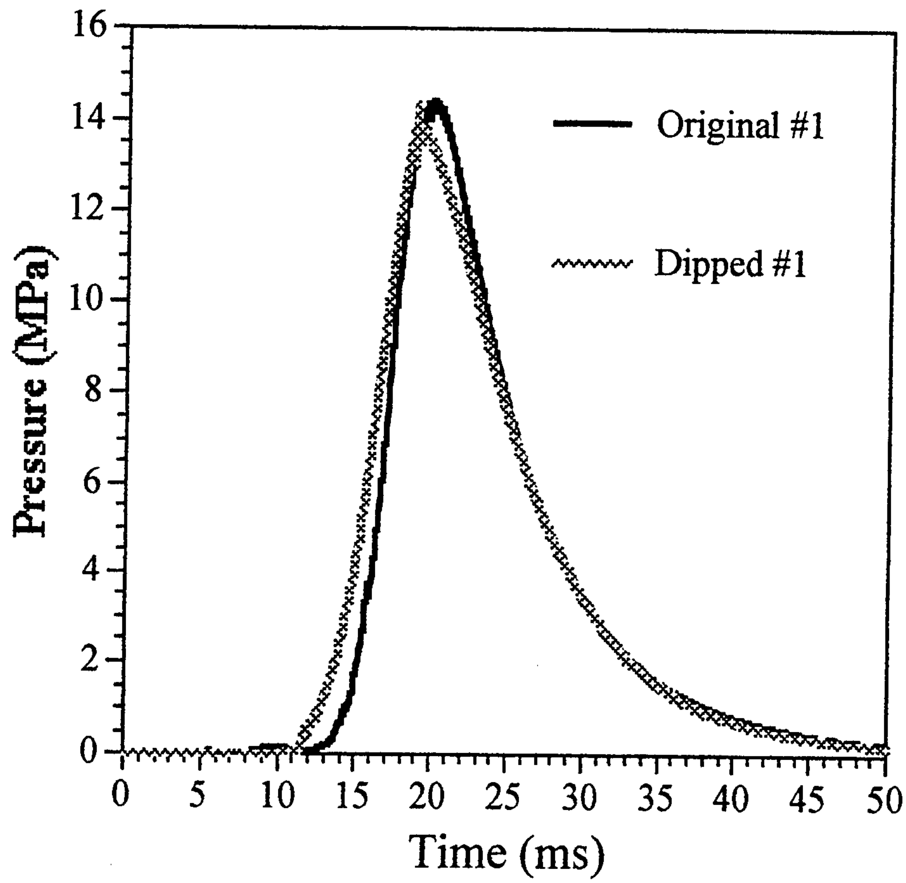

Figure 5. Comparison of pressure-time histories of the rupture of an original lacquer flash tube seal and a dipped seal at a maximum pressurization rate of approximately 4 MPa/ms.

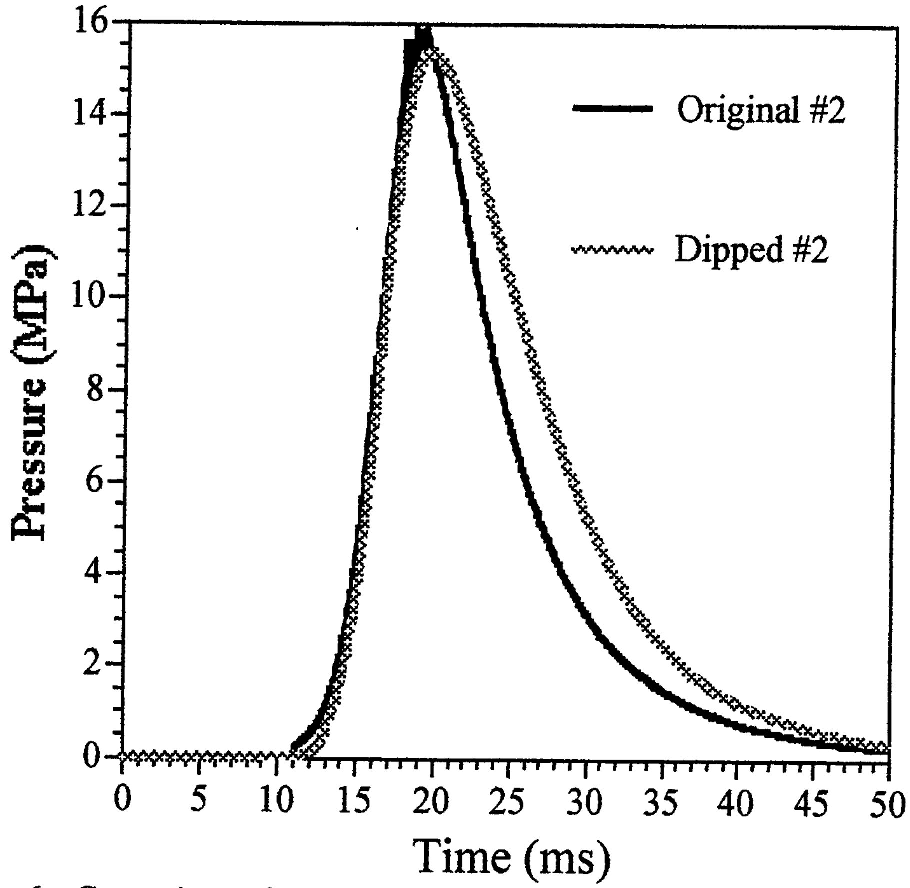

Figure 6. Comparison of pressure-time histories of the rupture of an original lacquer flash tube seal and a dipped seal at a maximum pressurization rate of approximately 4 MPa/ms.

The pressurization rate was obtained from the differential of the pressure-time history of each dynamic rupture test. The differentiation was performed using the method of centered differences and the maximum pressurization rate (megapascal per millisecond) obtained. Figures 7 and 8 show the differential for an original lacquer seal and a dipped lacquer seal, respectively.

Since the yield strength of the lacquer seal can be a function of the strain rate, the pressurization rate of the flash tube was varied. The rate was changed by modifying the black powder mixture surrounding the electric match. The mixture was changed from only Class VI black powder to black powder with a fraction of a ball powder propellant. As the fraction of ball powder propellant in the mixture increased, the pressurization rate increased. The loading density in the fixture was also increased from 0.07 to 0.27 g/cm^3. Although these loading densities were much lower than the specified loading density of 0.90 g/cm^3 [2, 3] for the flash tube itself, the pressures and pressurization rates in this report spanned the range obtained by Morris at 0.92–0.93 g/cm^3 [4]. Figure 9 summarizes the maximum pressure obtained as a function of the maximum pressurization rate.

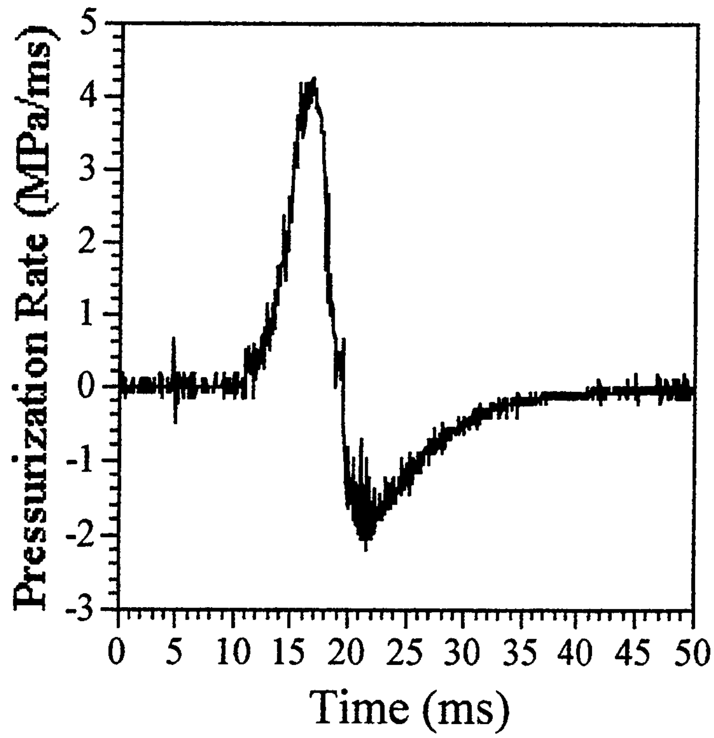

Figure 7. Differential of the pressure-time history of the rupture of an original lacquer flash tube seal.

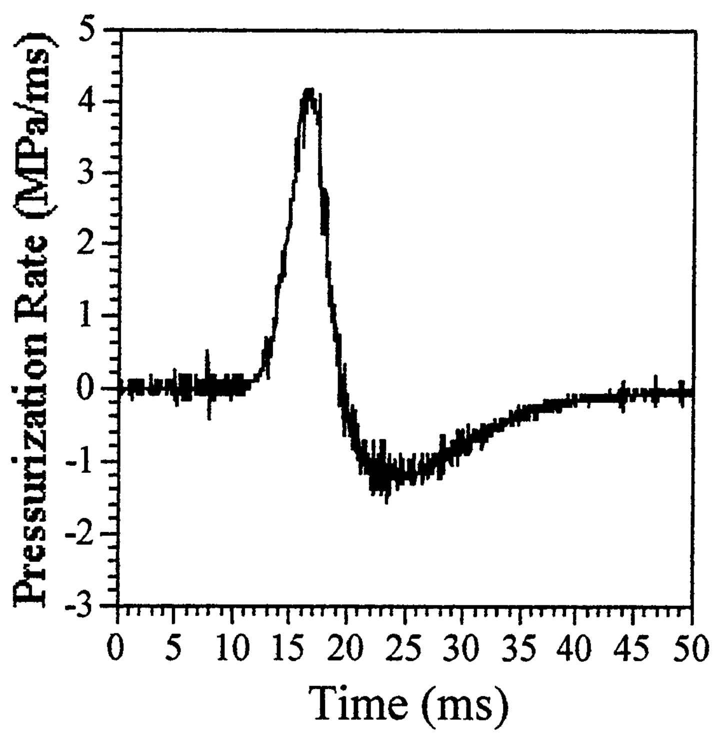

Figure 8. Differential of the pressure-time history of the rupture of a dipped lacquer flash tube seal.

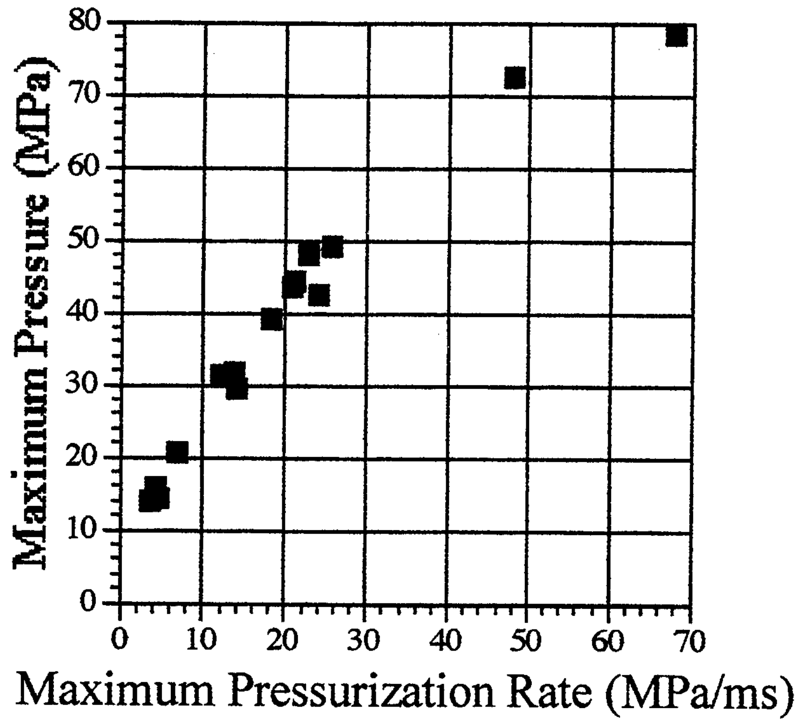

Figure 9. Dynamic rupture pressure of lacquer seal as a function of maximum pressurization rate.

On closer examination, the data obtained at pressurization rates less than 30 MPa/ms appeared to be nearly linear. The data in this region were plotted in Figure 10 and show a strong linear relationship. The intercept (a maximum pressurization rate of zero which could be approximated by quasi-static pressurization) was 9.08 ± 0.98 MPa (1300 ± 140 psi) was nearly the value of 7.0 ± 1.4 MPa (1000 ± 200 psig) obtained in quasi-static tests (within the error limits the two values did coincide).

The data above 30 MPa/ms seem to show that further increasing of the pressurization rate will produce smaller increases in the maximum rupture pressure. A suggested estimate to the limit in maximum rupture pressure would be at or below 91 MPa (13,000 psig).

4. Summary

The flash tube in the 30-mm ammunition used in the M230 chain cannon was examined to determine the rupture pressure of the lacquer seal. The strength of the seal determined the initial pressure levels of hot gases/particles that enter the propellant bed and cause it to combust.

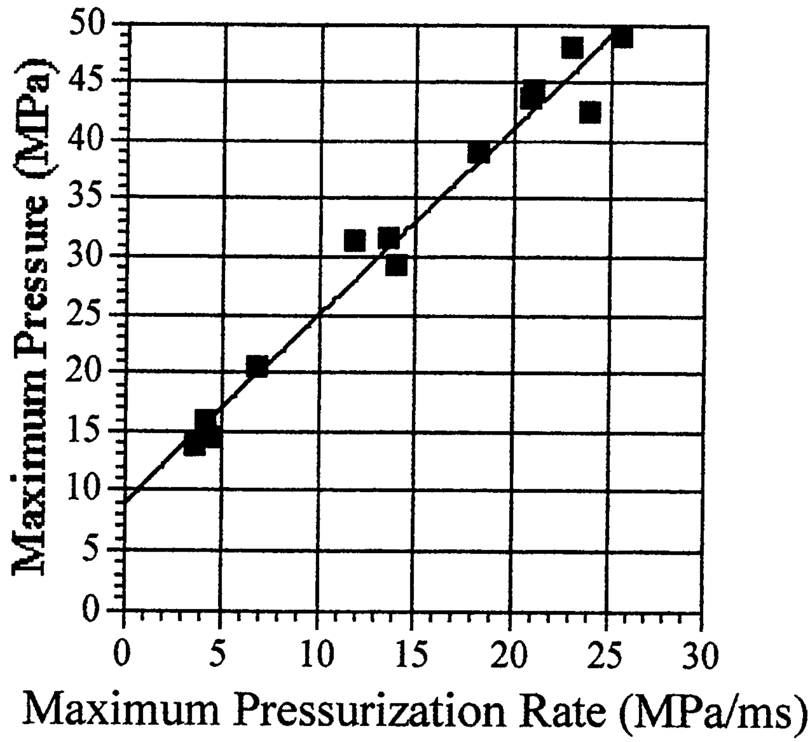

Figure 10. Dynamic rupture pressure of lacquer seal as a function of maximum pressurization rate in the range of 0–30 MPa/ms.

The dynamic rupture pressure of the lacquer seal was found to be a function of the pressurization rate of the flash tube. As the pressurization rate increased, the rupture pressure increased. At the largest rupture pressure of this study (78 MPa [11,200 psi]), significant gas generation would be achieved before the flash tube vented into the main propellant bed. Gas flow at these pressures is expected to play a significant role in ignition of the propellant charge and rapid function of the round.

5. References

1. Chang, L. M., R. Deas, and J. Grosh. "Ignition Studies with Two-Piece Cartridges for an Enhanced 120-mm Gun System." *Proceedings of the 1988 JANNAF Combustion Meeting*, CPIA no. 498, vol. IV, p. 423, 1988.

2. U.S. Army Armament, Research, and Development Center. "Flash Tube Assembly." Part no. 11825903, Dover, NJ, January 1982.

3. U.S. Army Armament, Research, and Development Center. "Flash Tube Assembly." Part no. 11075870, Dover, NJ, December 1976.

4. Morris, J. Personal communication. U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, January 2002.

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