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Pyrotechnic Igniters for Liquid Propellant Gun

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ABSTRACT

The results of a preliminary investigation on the use of liquid propellant for gun application are presented. Both regenerative and bulk loaded liquid propellant guns were used in the study. Pyrotechnic igniters were tried out for igniting the liquid propellant. Existing pyrotechnic igniters were suitably modified to obtain pressure beyond 20 MPa in less than 3 ms in the combustion chamber.

1. INTRODUCTION

Ignition of liquid propellants is more difficult compared to solid propellants, since the former are relatively insensitive[1]. In regenerative liquid propellant gun (RLPG), the igniter serves two functions : (i) It generates the pressure required to start the injection process, and (ii) generates the initial pressure and temperature to ignite the injected liquid. In the case of bulk loaded liquid propellant gun (BLPG), the igniter must supply the required temperature and pressure. A pressure of about 20 MPa has to be attained in less than 3 ms for ignition of atomized liquid propellant in the RLPG system[2,4]. Igniter requirements in BLPG are relatively less stringent and a pressure beyond 2 MPa is sufficient to ignite the liquid propellant. The liquid propellant used in this study was XM 46 (earlier called LGP 1846), a mixture of HAN, TEAN and water[5].

2. CLOSED VESSEL CHAMBER

The ignition of liquid propellant for BLPG mode was studied using the test fixture shown in Fig. 1. It consisted of a chamber having a capacity of 30 ml of liquid propellant, which was coupled to a 0.50 in. ranging machine gun (RMG) barrel. The chamber included ports for housing an igniter and a pressure transducer. The pressure in the chamber was measured using a piezoelectric transducer. In the case of RLPG, a closed vessel was designed to study the performance of igniters. The closed vessel consisted of a cylindrical combustion chamber with closing plugs on either end. Variable insert blocks were introduced at the end plugs to vary the volume up to 100 cc, to simulate the volume of the gun chamber. The igniter port was located at the bottom and the pressure port at the top of the chamber. The closed vessel is shown in

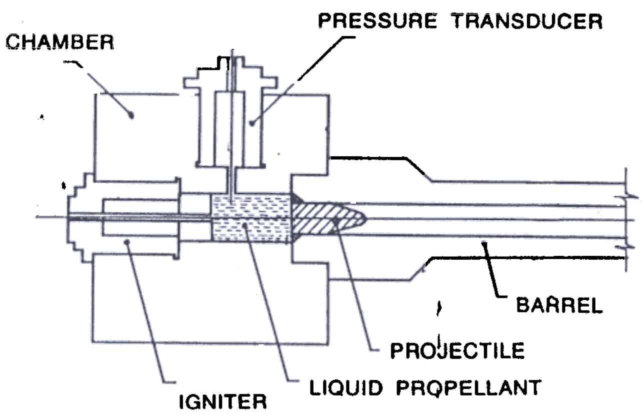

Figure 1. Bulk loaded LP gun with igniter

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Fig. 2. After the ignition characteristics had been verified, the igniters were used in the liquid propellant gun fixture.

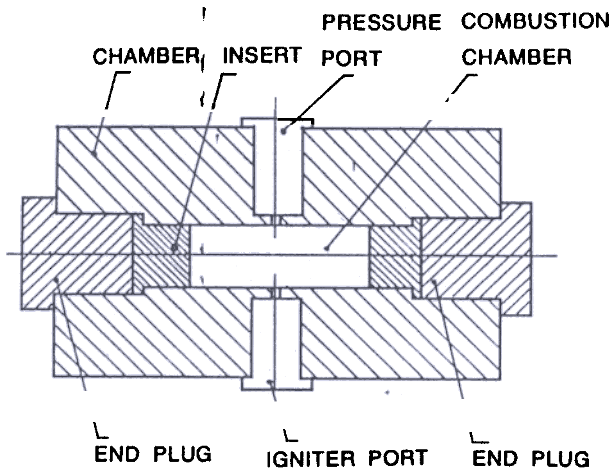

Figure 2. Closed vessel experimental set-up

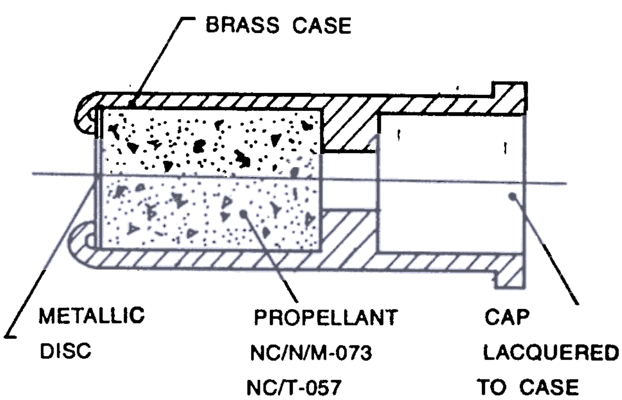

Figure 3(a). PPLT igniter

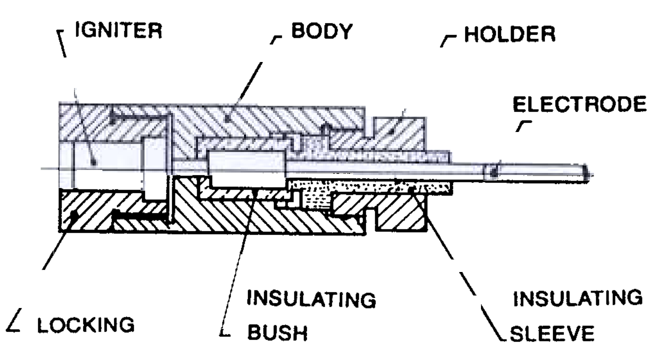

Figure 3(b). Housing assembly of PPLT igniter

3. PYROTECHNIC IGNITERS

The existing pyrotechnic igniters were used to take advantage of their proven performance and minimisation of development time. Two igniters were selected, viz., PPLT using nitrocellulose (NC) composition and primer 1A (electric) using gunpowder. To integrate the igniter into the RLPG and the BLPG test fixtures, suitable adapters were made. The PPLT pyrotechnic igniter and its housing assembly are shown in Figs 3a and 3b respectively. The PPLT igniter consisted of an electric CAP and a cylindrical outer casing made of brass. The igniter casing has capacity to hold 2.5 g NC-based pyrotechnic composition, which is held between the CAP and a metallic disc. At one end, the CAP is inserted and lacquer is applied on the periphery to prevent ingress of moisture; the other end is closed by crimping a disc on to the casing. The initiating composition in the CAP is 3 gr (0.15 g) of CAP composition. This CAP has a resistance between 40 and 400 ohms. Primer 1A (modified) electric and its housing assembly are shown in Figs 4a and 4b, respectively. Two modifications were effected in the igniter: (i) Design of casing, and (ii) quantity of propellant. The original primer, consisting of a multiple vent cylindrical outer casing was replaced by a brass casing with a single vent in the front. The igniter propellant was reduced from 25 to 7 g to give the desired pressure-time profile. A suitable firing circuit incorporating a capacitor capable of

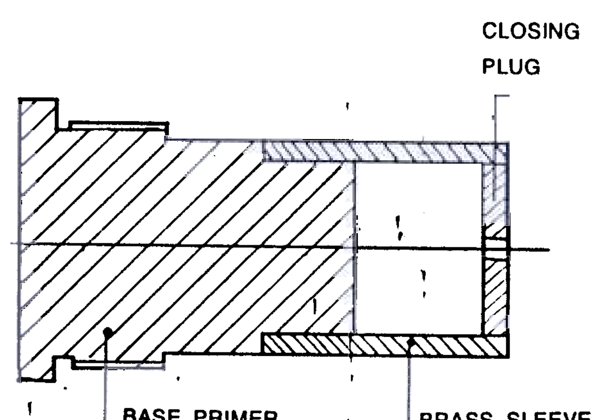

Figure 4(a). Primer 1A electric (modified)

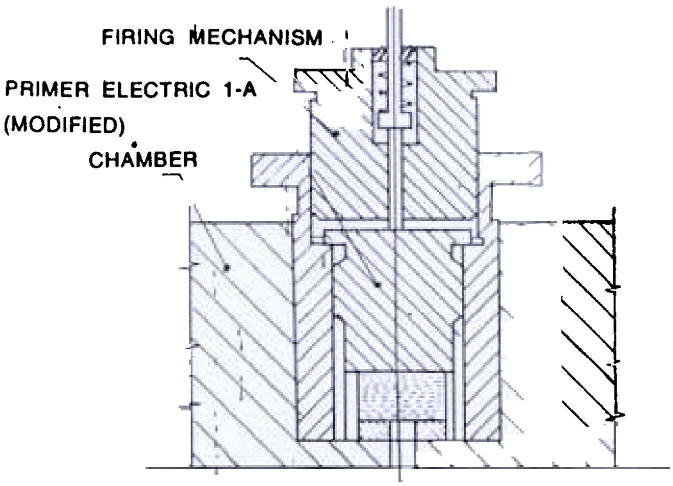

Figure 4(b). Housing assembly of primer IA electric (modified)

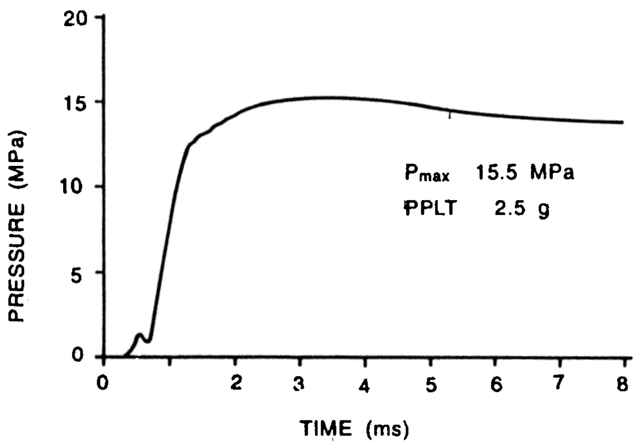

Figure 5. Pressure-time profile of PPLT igniter

delivering 8 J energy was developed for firing these igniters.

4. RESULTS & DISCUSSION

The ignition of the liquid propellants in the BLPG test fixture was achieved with a PPLT igniter. It was used in preference to the primer IA because of its smaller size. It was used to ignite the liquid propellant in the bulk mode to fire a 0.5 in. RMG bullet. A large number of closed vessel trials on PPLT and primer IA were conducted to obtain pressure-time profile. Typical records are presented in Figs 5 and 7, respectively. The results of the trials are given in Table 1. In RLPG, either of the igniters would suffice if the combustion chamber volume was kept at 90-100 cc. With higher

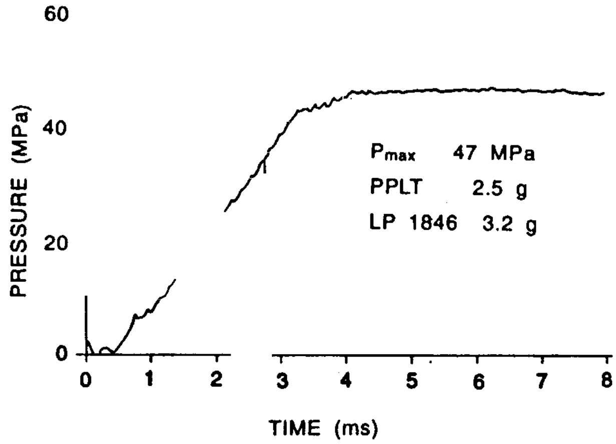

Figure 6. Pressure-time profile of PPLT igniter with liquid propellant bag.

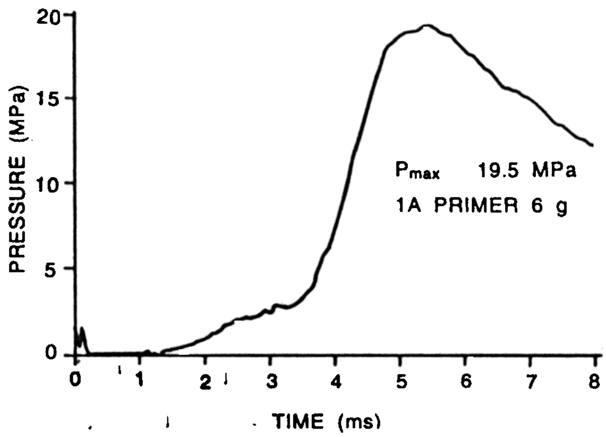

Figure 7. Pressure-time profile of primer IA electric

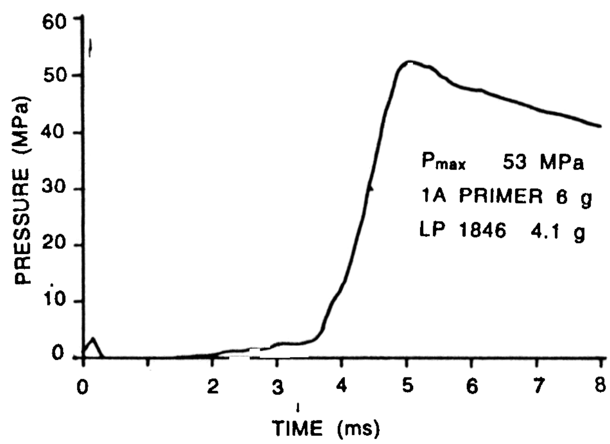

Figure 8. Pressure-time profile of primer IA electric with liquid propellant bag.

combustion chamber volume in RLPG trials, it was observed that the pressure was not enough to ignite the liquid propellants. In such cases, to obtain higher pressure with the same igniters, a supplementary liquid propellant bag was used to maintain the pressure levels. A number of trials were conducted to obtain the pressure-time profile. Figures 6 and 8 give typical records and the results of the trials are presented in Table 2.

Table 1. Performance of igniters

Igniter type	Volume of closed vessel (cc)	Peak pressure (MPa)	Rise time (ms)	Time to P_{max} from trigger (ms)
PPLT	94.0	15.0 to 18.2	1.8 to 2.0	2 to 4.5
1A(mod)	90.0	18.2 to 24.8	1.5 to 2.0	1.7 to 6

Table 2. Performance of igniters with additional liquid propellant bag

Igniter type	Additional LP bag (g)	Volume of closed vessel (cc)	Peak pressure (MPa)	Rise time (ms)	Time to P_{max} from trigger (ms)
PPLT	3.3	94.0	45 - 52	2.5 to 3.5	2.8 to 5.9
1A(mod)	4.2	90 0	50 - 58	1.8 to 2.2	3.2 to 5

In the case of PPLT igniter, there was leakage through the adapter, and loss of pressure was observed in many cases. The primer 1A had a more sturdy design than PPLT and was found more suitable for RLPG trials. It was later successfully used to fire projectiles of 30 mm calibre using the RLPG test fixture. However, there is wide variability in the igniter performance, which can be attributed to failures in seals either in the igniter itself or in the adapters.

5. CONCLUSIONS

The PPLT igniter was found suitable for use in igniting liquid propellants in the bulk mode. Primer 1A electric (modified) with an additional LP bag was suitable for RLPG. Special purpose igniters need to be developed for 30 mm and higher calibre guns. Adding additional LP bags to increase the pressure is a solution which has been successfully used in 30 mm RLPG guns. The suitability of this solution to larger calibre guns, where the loading density of these bags is lower, could be explored. Further, work on how the characteristics of the igniter affect the performance of liquid propellant gun will also be undertaken.

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