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TECHNICAL MEMORANDUM

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EVALUATION OF IGNITER COMPOSITIONS SR371C AND SR44

L.M. DAVIS

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S U M M A R Y

The ignition performance of compositions SR371C and SR44 in two types of containers was examined in a test vessel. It was found that igniters containing composition SR44 had lower ignition delay times and maximum pressures than those with composition SR371C. It is recommended that further investigations be conducted to determine the minimum mass of composition SR44 required to ignite a given rocket motor.

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1. INTRODUCTION

An end burning, solid propellant rocket motor used for testing cast composite propellant charges was originally ignited using a silk bag containing 16 g of composition SR371C and a Type 'E' electric fuzehead(ref.1). Although no hangfires or misfires occurred with these igniters, ignition delay times and maximum pressures varied widely which indicated an inefficient ignition process. In order to achieve some reproducibility in ignition characteristics, it was decided to examine composition SR44 as an alternative to SR371C. An Igniter Development Program was devised to compare the ignition performance of silk bags and manilla-board cartons containing SR371C with manilla-board cartons containing SR44.

A total of fifty-seven test firings were called for in the Igniter Development Program and this document reports their conduct and results.

2. COMPOSITIONS SR371C AND SR44

Compositions SR371C and SR44 consist of the following ingredients:

SR371C	Parts by weight
Magnesium (Grade III)	32
Magnesium (Grade V)	10
Potassium Nitrate	50
Acaroid Resin	8
	100

SR44	
Boron (Amorphous)	30
Potassium Nitrate	70
	100

Manufacture of composition SR371C is described fully in reference 2. Briefly, the two grades of magnesium are tumble-mixed together and then added to the acaroid resin (dissolved in methylated spirits) which coats the magnesium. This mixture is dried, the potassium nitrate added and the new mixture is tumbled again. Details for the manufacture of composition SR44 are contained in reference 3. Again the process basically consists of blending the two ingredients together and tumble-mixing.

Both compositions are sensitive to impact and friction and require special safety precautions during manufacture and handling. They absorb moisture readily but the degradation in burning performance is much greater with SR371C than SR44. Hence, both compositions should be manufactured and stored in an environment with a relative humidity below 50%.

3. TEST EQUIPMENT AND PROCEDURES

In order to conduct the required test firings, the ITE (Igniter TEst) vessel was developed. It consists of an insulated short section of mild steel tubing with a nozzle end closure from the rocket motor used for propellant testing. An alloy spacer is fixed into the head end of the tubing to give an internal configuration which represents the motor situation (see figure 1). A pressure tapping in the tubing allows pressure to be recorded during each test firing.

The ITE vessel is bolted, nozzle end up, to a firing pad and after each test the nozzle end plate is removed and loose debris cleared from the vessel. A new igniter is then fitted, the nozzle end plate replaced and the next test proceeds.

The chosen parameters of interest in the test firings were:

(a) Ignition Delay Time - time at which the pressure had risen to 10% of its maximum.

(b) Maximum Initial Pressure - maximum pressure occurring within the ignition phase.

(c) Rate of Pressure Increase - time rate of change of pressure from 10% to 90% of its maximum.

4. TESTS

The fifty-seven igniters which were test fired were manufactured according to Table 1. The following paragraphs explain the headings in the table:

(a) Container

The igniter container was one of two types, a silk bag or a cylindrical manilla-board carton. The silk bag igniters containing composition SR371C were made in accordance with reference 1, using a type 'E' fuzehead. Instructions for the manufacture of the cylindrical manilla-board carton igniters are contained in reference 4. The diameter of the cartons was fixed at 32 mm and the height was varied for the different masses of composition as follows:

Mass of Composition (g)	Height of Carton (mm)	
	SR371C	SR44
8	10	15
12	15	20
16	20	25

(b) Fuzehead location

In the silk bag igniters, the type 'E' fuzehead was located in the centre of the bag. During manufacture of the carton igniters it was possible to locate the fuzehead anywhere inside the carton, so it was decided to place some along the base and the remainder in the centre of the carton.

(c) Sealed vessel

As shown in figure 1, the nozzle throat of the ITE vessel is not sealed. In order to increase the rate of pressure increase, a 'Silastic E' plug was inserted into the nozzle throat after the igniter to seal the vessel. The plug was held in the nozzle throat by interference fit only and was ejected when sufficient pressure had built up in the vessel.

TABLE 1. IGNITER CONFIGURATIONS AND TEST RESULTS

ITE No.	Number of igniters	Composition	Mass (g)	Container	Fuzehead location	Sealed vessel	Propellant present	Ignition delay Mean (ms)	Ignition delay Std.dev. (ms)	Maximum pressure Mean (MPa)	Maximum pressure Std.dev. (MPa)	Rate of pressure increase Mean (MPa/ms x 1000)	Rate of pressure increase Std.dev. (MPa/ms x 1000)
1	3	SR371C	8	Silk bag	Centre	No	No	32.7	2.5	2.93	0.16	87.3	7.8
	3	SR371C	12	Silk bag	Centre	No	No	34.3	5.9	3.02	0.61	94.3	44.0
	3	SR371C	16	Silk bag	Centre	No	No	32.0	2.6	3.92	0.45	122.7	52.0
2	3	SR371C	8	Carton	Base	No	No	33.7	2.9	3.07	0.23	136.3	7.4
	3	SR371C	12	Carton	Base	No	No	44.3	5.7	3.36	1.12	104.3	110.6
	3	SR371C	16	Carton	Base	No	No	40.7	3.5	4.16	0.74	70.7	18.6
3	3	SR44	8	Carton	Base	No	No	13.3	3.2	2.14	0.25	130.0	19.5
	3	SR44	12	Carton	Base	No	No	12.0	1.0	2.35	0.36	99.0	44.0
	3	SR44	16	Carton	Base	No	No	17.3	3.5	2.45	0.23	70.0	10.6
4	3	SR44	8	Carton	Centre	No	No	8.7	3.1	2.00	0.97	106.7	92.7
	3	SR44	12	Carton	Centre	No	No	5.7	0.6	2.48	0.46	74.0	7.2
	3	SR44	16	Carton	Centre	No	No	7.3	0.6	3.29	0.26	103.3	8.3
5	3	SR44	8	Carton	Base	Yes	No	8.3	2.1	3.36	0.09	103.7	36.7
	3	SR44	12	Carton	Base	Yes	No	6.7	1.2	4.16	0.24	125.7	34.5
	3	SR44	16	Carton	Base	Yes	No	8.0	0.0	5.76	0.95	109.0	6.9
6	3	SR44	8	Carton	Base	Yes	Yes	10.0	3.5	9.82	0.38	254.0	39.1
	3	SR44	12	Carton	Base	Yes	Yes	17.0	3.5	11.85	0.51	296.3	19.7
	3	SR44	16	Carton	Base	Yes	Yes	15.3	0.6	11.58	0.77	218.3	107.6
7	3	SR371C	16	Silk bag	Centre	Yes	Yes	51.	3.5	14.23	0.71	285.0	85.3

(d) Propellant present

It is possible in the ITE vessel to test the performance of the igniter alone or to include a sample of rocket motor propellant to be ignited. This was done in ITE Nos 6 and 7 firings by sectioning two cast composite charges (Cast Numbers CPE 3758B and 3769A) into 20 mm slabs. The alloy spacer in the ITE vessel was shortened by 20 mm and the propellant slabs were attached to it using a generous quantity of Epophen Resin, thus ensuring that the propellant face was completely inhibited. The cast composite propellant consisted essentially of approximately 17% HTPB (Hydroxyl Terminated Poly Butadiene) as fuel and 83% Ammonium Perchlorate as oxidiser.

5. RESULTS AND DISCUSSION

The fifty-seven igniters were test fired in the ITE vessel. The measured values of ignition delay time and maximum initial pressure and the calculated rates of pressure increase are presented in Table 1. Values reported are the mean of three samples and the sample standard deviation about the mean.

The results of ITE No 1 firings, that is silk bags containing composition SR371C, show ignition delay times of 30 to 35 ms, independent of the mass of composition. Both the maximum pressure and rate of change of pressure increase with increasing mass.

The ignition delay times for ITE No 2 igniters (composition SR371C contained in cartons) range from 30 to 45 ms with 12 g cartons being slowest and 8 g fastest. Maximum pressures again increase with increasing mass and are consistently higher than ITE No 1 results, while the rates of change of pressure decrease as composition mass increases.

Typical results from ITE Nos 1 and 2 are illustrated in figures 2 and 3. Figure 2 shows pressure vs time traces for three igniters from ITE No 1. These igniters contain 8, 12 and 16 g of SR371C respectively. As the mass of composition increases, a second pressure maximum is seen developing, after the initial pressure peak. Also as the mass of composition increases, the rise to maximum pressure occurs much faster. Figure 3 shows the corresponding pressure vs time traces for ITE No 2. As composition mass increases, a second pressure maximum again becomes evident, however it now occurs before the maximum ignition pressure and hence the delay to 90% of maximum pressure increases. This is reflected in the decreasing rates of change of pressure. The cause of this second maximum is unknown.

In the case of ITE No 3, the ignition delay times are seen to be less than one half of those recorded for ITE No 2. The maximum pressures are less than those for ITE Nos 1 or 2 and range only from 2.14 to 2.45 MPa. The rate of change of pressure decreases as composition mass increases, however unlike ITE No 2, this is not attributable to a second pressure maximum. All pressure vs time traces for ITE No 3 show a smooth rise to a single pressure peak followed by a steady decay.

ITE No 4 is a repeat of ITE No 3, with the fuzehead located in the centre of the manilla-board carton. This modification is seen to réduce ignition delay times down to the range 5 to 10 ms, compared with 10 to 20 ms for ITE No 3. Maximum pressures are generally above ITE No 3, while the calculated rates of pressure increase are inconclusive.

Figure 4 shows the pressure vs time traces for the three 8 g igniters of ITE No 5. In these test firings, the ITE vessel was sealed by inserting a 'Silastic E' plug into the nozzle throat, after the igniter. It is clear that for the first firing, the nozzle plug remained in the nozzle throat until approximately 0.23 s after ignition. In the two other cases shown and for all the 12 g and 16 g igniters, the nozzle plug was ejected during the pressure rise and a sharp maximum was recorded. The presence of the plug during pressurisation succeeded in reducing ignition delays from 10 to 20 ms in ITE No 3, to 5 to 10 ms in ITE No 5. Maximum pressures increase as the composition mass increases and the rates of change of pressure are all high as was expected.

For the firings of ITE No 6, slabs of propellant from the two cast composite charges were ignited in the ITE vessel using cartons of SR44. The recorded values of delay time, maximum initial pressure and rate of pressure increase are hence not comparable with the results discussed to date. However, comparison with ITE No 7, consisting of 16 g silk bags of SR371C igniting propellant slabs, can be made and shows a marked reduction in ignition delay times from 52 ms to 10 to 20 ms. Maximum pressures obtained for ITE No 7 are higher, while the rates of change of pressure are comparable. Figure 5 shows the pressure vs time traces for two 16 g igniters, one each from ITE No 6 and ITE No 7. In both cases the vessel is 'over-ignited', that is, the maximum ignition pressure exceeds the propellant operating pressure. This is not the case for the 8 g igniters of ITE No 6 where the maximum ignition pressure closely matches that of the propellant as it burns. The difference in ignition delay times between ITE Nos 6 and 7 is also evident in Figure 5, even though the timescales for the two pressure vs time traces are different.

6. SUMMARY AND CONCLUSIONS

The following summary is prepared from the results of the igniter test firings.

6.1 Ignition delay times

(a) are shorter for SR371C silk bags than for SR371C cartons, by 0 to 15 ms

(b) are shorter for SR44 cartons than for either SR371C configuration, by 10 to 35 ms

(c) are reduced by placing the fuzehead in the centre of the carton, as opposed to along the base, by 1 to 15 ms

(d) are reduced by sealing the vessel, by 2 to 15 ms

(e) for SR44 cartons are less than one half those of SR371C silk bags when igniting the given cast composite propellant in a sealed vessel.

6.2 Maximum pressures

(a) are greater for SR371C than for SR44

(b) are increased slightly by placing the fuzehead in the centre of an SR44 carton

(c) are significantly increased by sealing the vessel during ignition

6.3 Rates of increase in pressure

(a) show little difference between cartons of SR371C and SR44

(b) are only slightly improved by sealing the vessel.

It is concluded that a more reproducible ignition system for the test rocket motor could be achieved by using composition SR44 in a manilla-board carton and by sealing the vessel during ignition. Further work should continue to evaluate the mass of igniter composition required to provide optimum ignition characteristics. It has already been seen that 12 g and 16 g igniters 'over-ignite' the propellant slabs in the vessel, and tests involving masses of 10 g or less are recommended.

7. ACKNOWLEDGEMENTS

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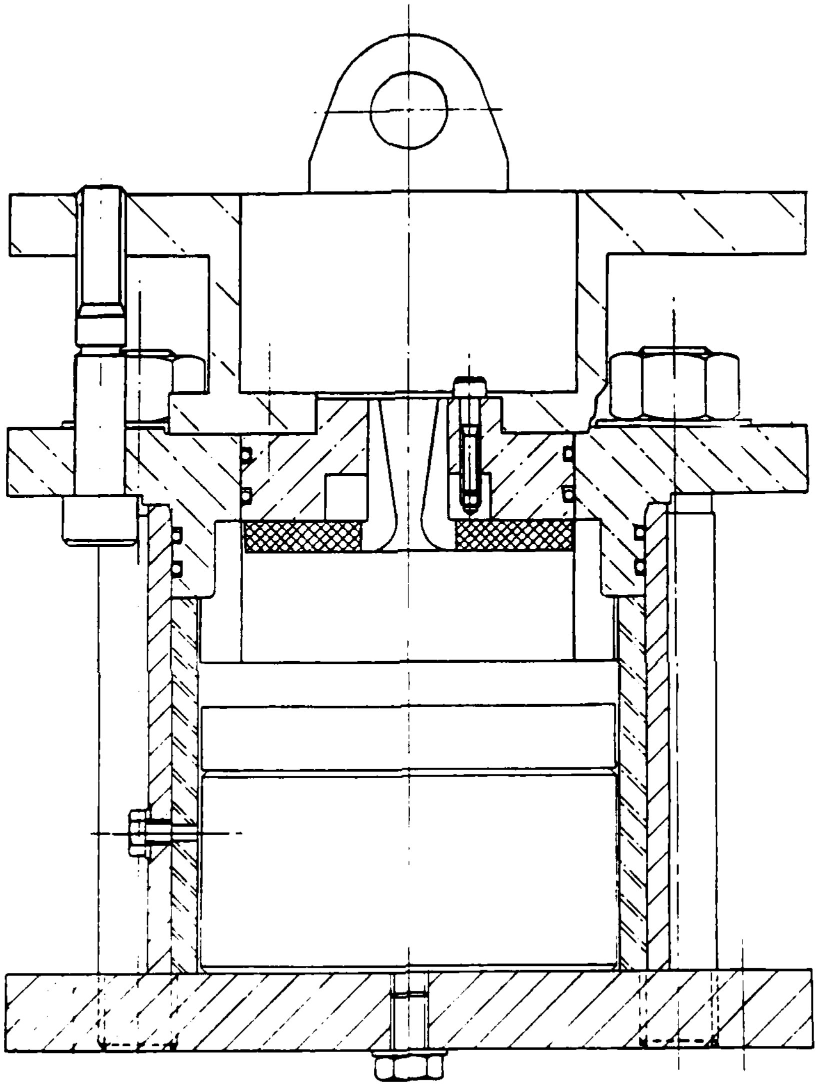

Figure 1. The ITE vessel

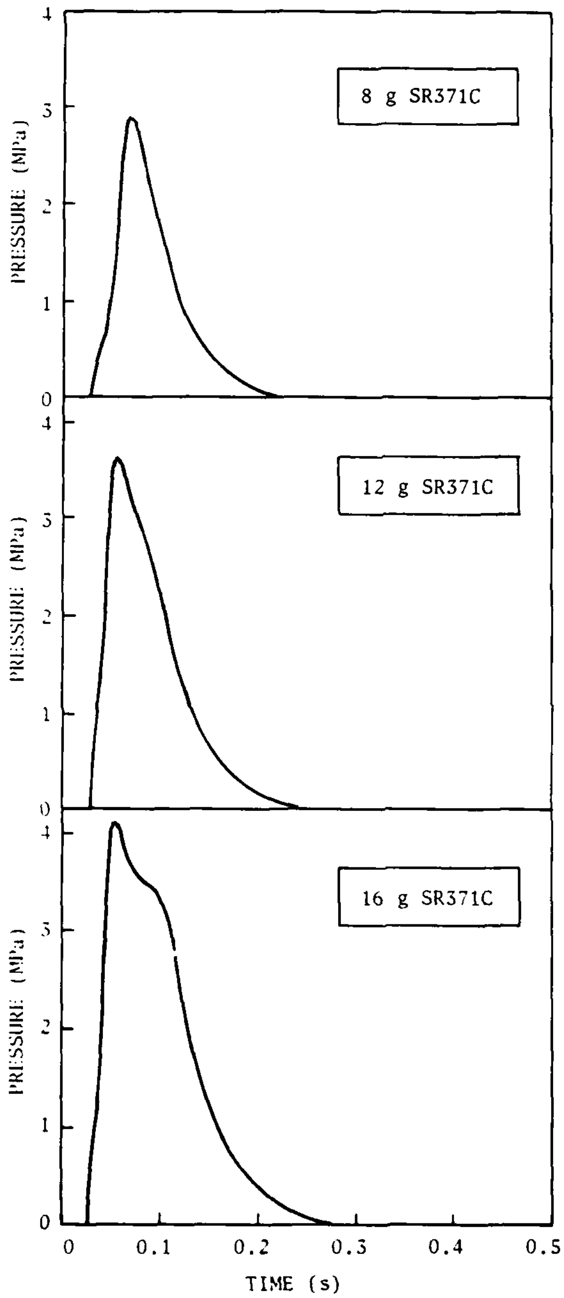

Figure 2. Pressure vs time traces for silk bag igniters containing composition SR371C - ITE No 1

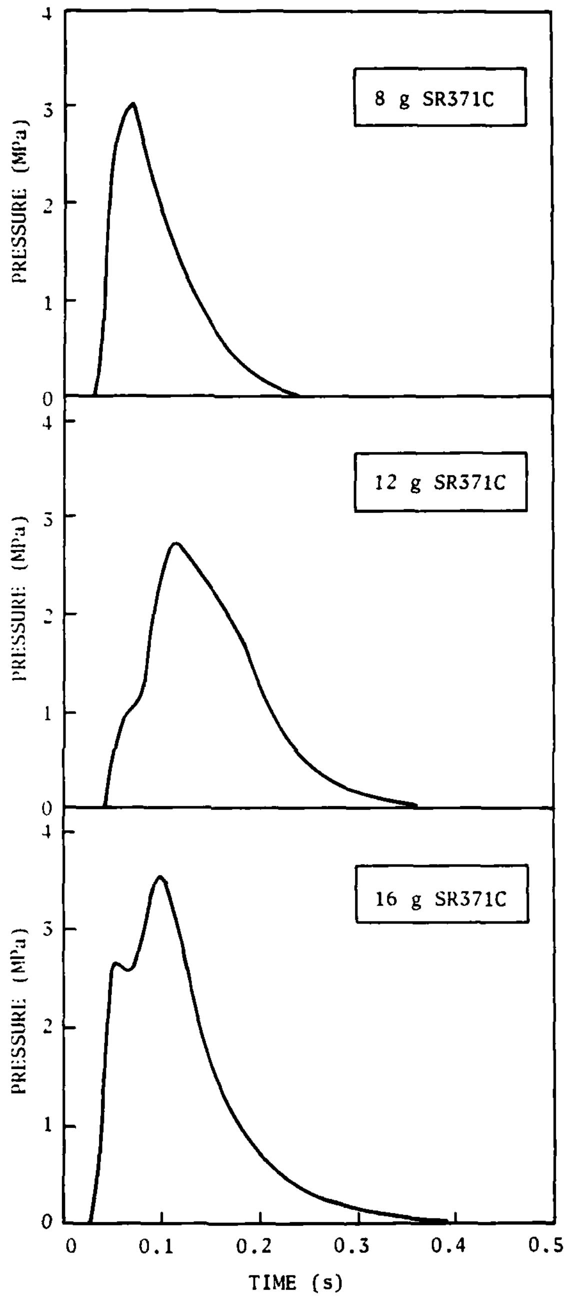

Figure 3. Pressure vs time traces for carton igniters containing composition SR371C - ITE No 2

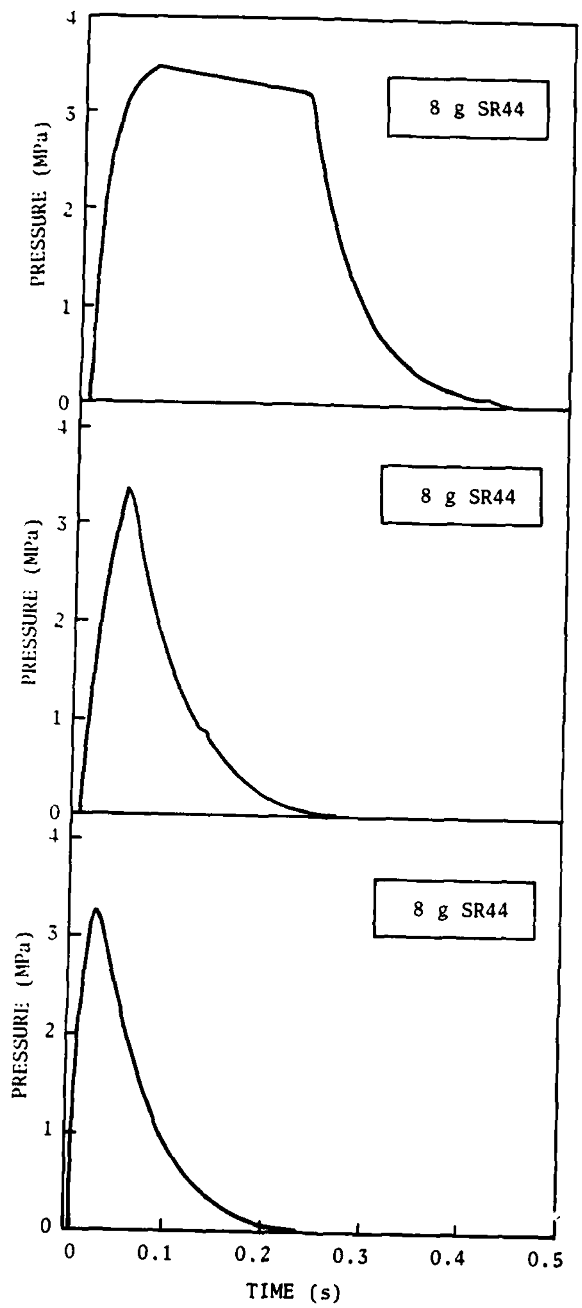

Figure 4. Pressure vs time traces for carton igniters containing composition SR44 - ITE No 5

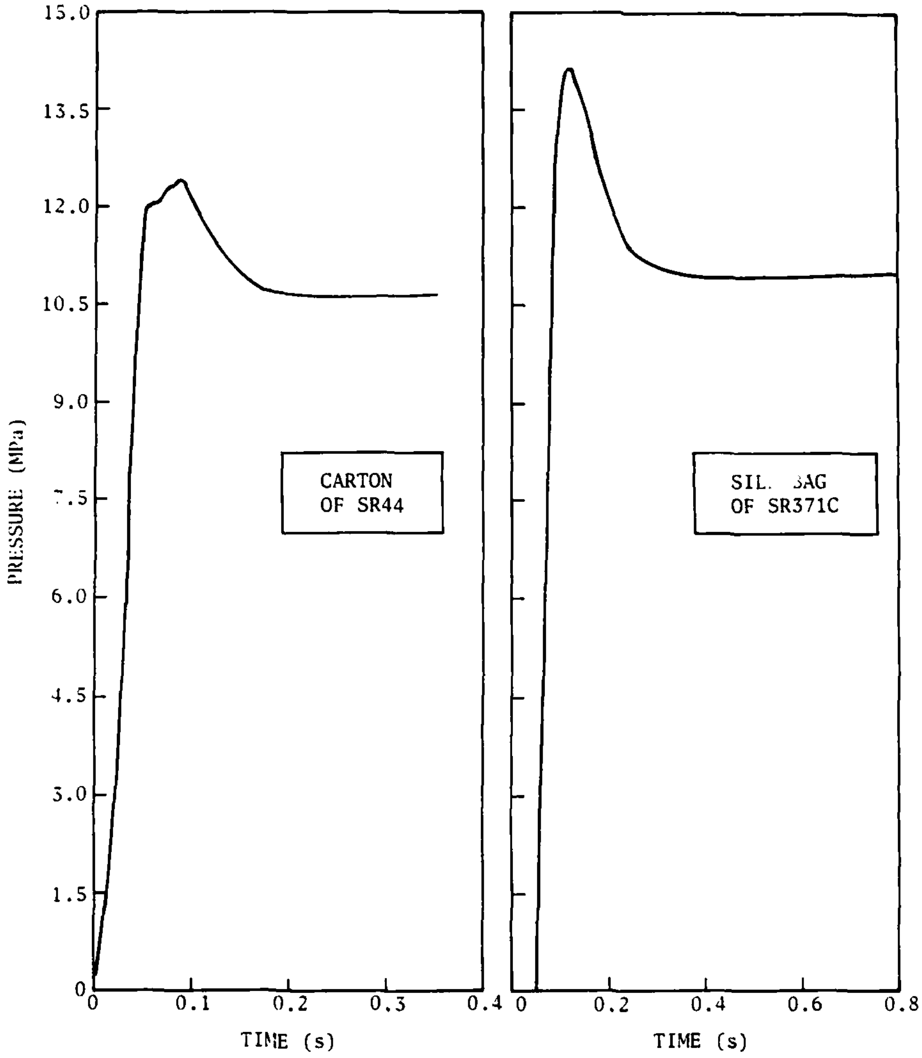

Figure 5. **Pressure vs time traces for igniters containing 16 g of composition in a sealed vessel with propellant present - ITE Nos 6 and 7**

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