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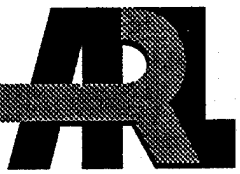

# Electrothermal-Chemical (ETC) Temperature Sensitivity of JA2 7 Perf Propellant

M. Del Guercio
I. Stobie
W. Oberle

ARL-TN-67 June 1996

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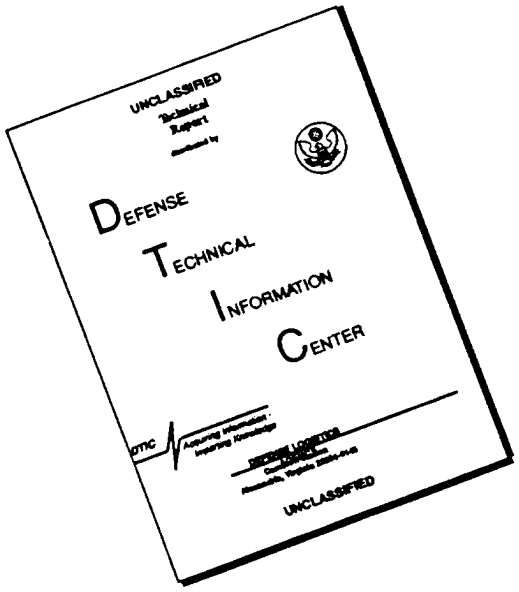


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**13. ABSTRACT** *(Maximum 200 words)*

The temperature sensitivity of JA2 7 perf propellant was studied by conditioning it to 21.1° C, 48.9° C, and -31.7° C. The firings were conducted in a 120-cc closed chamber, conventionally and with plasma injection (ETC), using a 1.2-ms pulse width provided by four banks of a 400 kJ PFN (Pulse Forming Network). The study showed a decrease in the burn rate between the ETC firings at 21.1° C and the conventional at the same temperature, but it showed an increase in the burn rate for the 48.9° C and -31.7° C cases, respectively.

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## 1. BACKGROUND

Electrothermal and Chemical (ETC) closed chamber firings in support of the US Army's ETC propulsion technology program using JA2, 7 perf propellant (RAD-PE-792-71), were conducted in April 1995. These firings used a 400 kJ upgraded pulse forming network (Del Guercio et al. 1995) to determine the temperature sensitivity of the propellant. A modified configuration consisting of four banks was used instead of the full eight banks (eight capacitors and eight inductors), with the purpose of using a shorter 1.2 ms pulse length instead of the full 2.4 ms. To obtain an energy output in the range of 20 kJ, a charging voltage of 4 kV was selected (Del Guercio et al. 1996).

## 2. EXPERIMENTAL FIRINGS

Nine firings were conducted in this series. The first six consisted of three pairs of ETC firings done at three different temperature ranges; 21.10° C, 48.9° C, and -31.7° C. They will be referred to as "ambient" plasma, "hot" plasma and "cold" plasma firings. The last series of three firings consisted of the baselines for the previous six, and were comprised of conventional firings (via electric match ignition and FFFG black powder pellets), fired at the same temperatures (i.e., 21.1° C, 48.9° C, and -31.7° C). The firing information sheets for these firings are included in Appendix C. Experimental pressure and PFN energy are shown in Appendix D, and the actual burn rate data are shown in Appendix E.

## 3. SUMMARY OF RESULTS

The three baseline tests obtained through conventional firings (non-ETC firings), idents 04255S7 at 21.1° C, 04265S8 at -31.7° C and 04275S9 at 48.9° C are shown in Figure 1. These plots indicate that for the conventional firing the burning rate of the propellant depends on its conditioning temperature, as the ambient locus is displayed between the hot and the cold.

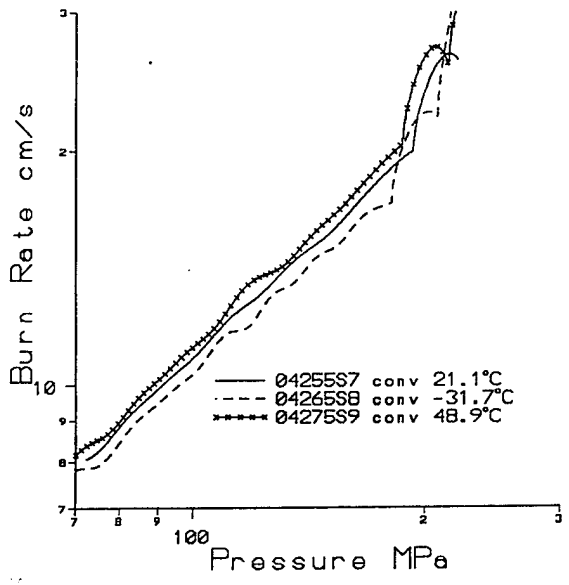


Figure 1. Conventional firings at 21.1° C, 48.9° C, and -31.7° C.

The plasma firings (ETC firings) done at "ambient" (21.1° C), hot (48.9° C) and cold (-31.7° C) temperatures, correspond to the idents 04115S1 and 04115S2 for ambient, 04125S3 and 04175S4 for hot, and 04205S5 and 04205S6 for cold, respectively.

Burn rates for the plasma firings performed at "ambient" temperature (21.1° C) are plotted vs. the conventional firing at the same temperature (Figure 2). The "ambient" plasma burn rates (idents 04115S1 and 04115S2) show a decrease with respect to the "conventional" burn rate baseline at 21.1° C (ident 04255S7).

Burn rates for the "hot" plasma firings performed at 48.9° C (idents 04125S3 and 04175S4) are plotted along with the "conventional" burn rate at the same temperature (ident 04275S9) on Figure 3. An enhancement of the burn rates for the plasma "hot" tests can be observed with respect to the "conventional" baseline at the same temperature.

Burn rates for the "cold" plasma (-31.7° C) firings are plotted (idents 04205S5 and 04205S6) vs. the "conventional" burn rate at the same temperature (ident 04265S8) in Figure 4. Also in

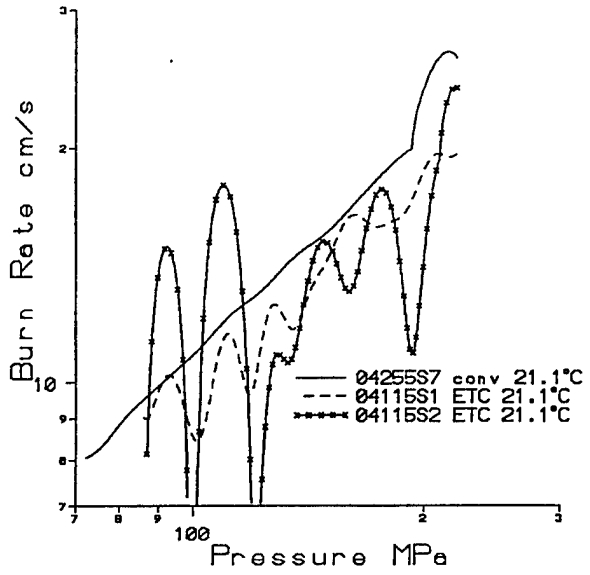


Figure 2. "Ambient" plasma burn rates vs. "ambient" conventional.

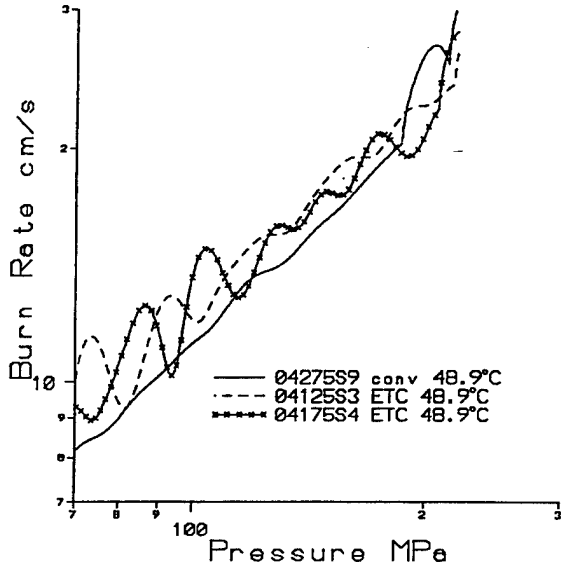


Figure 3. "Hot" plasma burn rates vs. "hot" conventional.

this case, an enhancement on the burn rates for the "cold" test can be observed with respect to the "conventional" burn rate baseline at the same temperature.

To compare the effects of plasma injection on the propellant conditioned at the three different temperatures, burn rate change vs. pressure is plotted as:

1) "Ambient" plasma(21.1° C) burn rate vs. "conventional" burn rate baselines at 21.1° C and 48.9° C (Figure 5).

2) "Hot" plasma (48.9° C) burn rate vs. "conventional" burn rate baselines at 21.1° C and 48.9° C (Figure 6).

3) "Cold" plasma (-31.7° C) burn rate vs. "conventional" burn rate baselines at 21.1° C and -31.7° C (Figure 7).

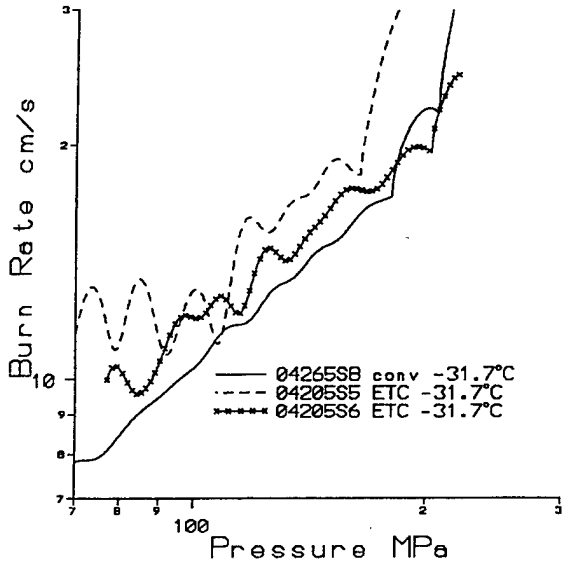


Figure 4. "Cold" plasma burn rates vs. "cold" conventional.

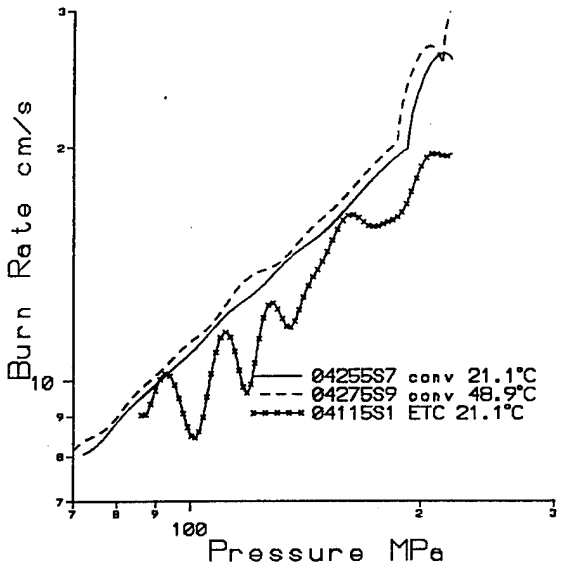


Figure 5. "Ambient" plasma vs. "conventional" at 21.1° C and 48.9° C.

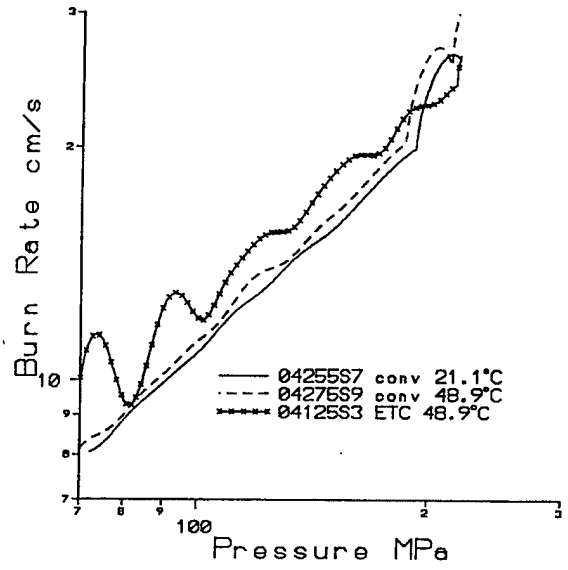


Figure 6. "Hot" plasma vs. "conventional" at 21.1° C and 48.9° C.

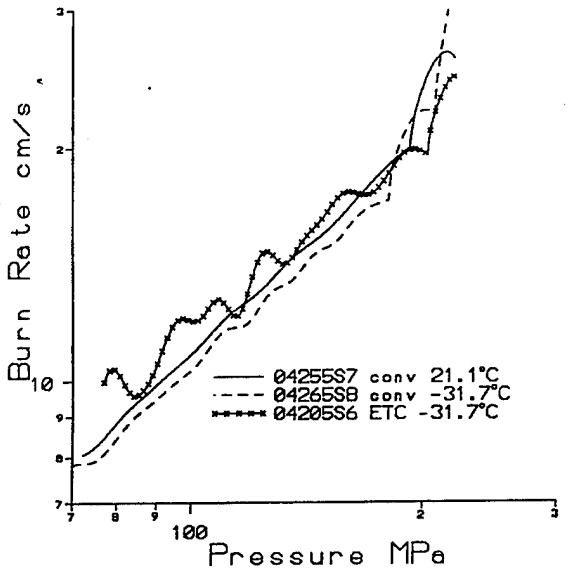


Figure 7. "Cold" plasma vs. "conventional" at 21.1° C and -31.7° C.

## 4. CONCLUSIONS

The burn rate percent differences between the "ambient" plasma (Figure 5) and the "ambient" conventional baseline is 14% (negative). The burn rate percent difference between the "hot" plasma (Figure 6) and the "hot" conventional baseline is 11.5%, while the burn rate percent difference between the "cold" plasma (Figure 7) and the "cold" conventional baseline is about 11.2%.

The injection of the "hot" plasma at 48.9° C (Figure 6) shows a more enhanced burn rate than the "cold" plasma firing at -31.7° C (Figure 7), while Figure 5 shows no enhancement at all for the "ambient" plasma injection.

The burn rate obtained for the "ambient" plasma injection agrees with previous data (Fortier et al. 1992) in which no noticeable effect has been observed for ETC firings at room temperature.

The increase on the burn rates for the "hot" plasma injection and the "hot" conventional cases, could be explained as related to the added energy used to condition the propellant up to 48.9° C.

One possible scenario for the behavior of the "cold" plasma (-31.7° C) firing, could be the fragmentation of the cold conditioned propellant as is impacted by the pressure waves and the initial plasma jet. This fragmentation would cause an increase in the propellant surface area which will then cause an increase in the apparent burning rate. Further tests will determine the repeatability of the "cold" conventional below the "ambient" conventional baseline.

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## 5. REFERENCES

Del Guercio, M., H. Burden, I. Stobie, and K. White. "A Pulse-Forming Network Design for Electrothermal-Chemical (ETC) Combustion Characterization of Solid Propellants." ARL-MR-261, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, September 1995.

Del Guercio, M., I. Stobie, and W. Oberle. "JA2 Firings With Modified 400 kJ Pulser." ARL-TN-66, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, May 1996.

Fortier, S., K. White, A. Juhasz, M. Del Guercio, and G. Katulka. "Combustion Characterization of Plasma-Augmented ETC Solid Propellants." 29th JANNAF Combustion Subcommittee Meeting, Hampton, VA, October 1992.

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# APPENDIX A:

# CONVENTIONAL AND ETC SETUP

# FOR 120 $CM^3$ CLOSED CHAMBER

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The pulse forming network (PFN) configuration used for the closed chamber plasma injection uses only four banks (four capacitor-inductor sets) of the eight available. The pulse obtained is close to the 1.2-ms width desired. Figure A-1 schematic shows two of the banks and the PFN and closed vessel layout. Instrumentation for the conventional firing is shown in Figure A-2, where electric match ignition is obtained through an "impulse" firing box and data is recorded on the oscilloscopes through fiber optic links. Plasma injection (ETC) is obtained by discharge of the energy stored in the PFN as its closing switch (ignitron) is activated by a trigger signal. The configuration for ETC data acquisition is shown in Figure A-3.

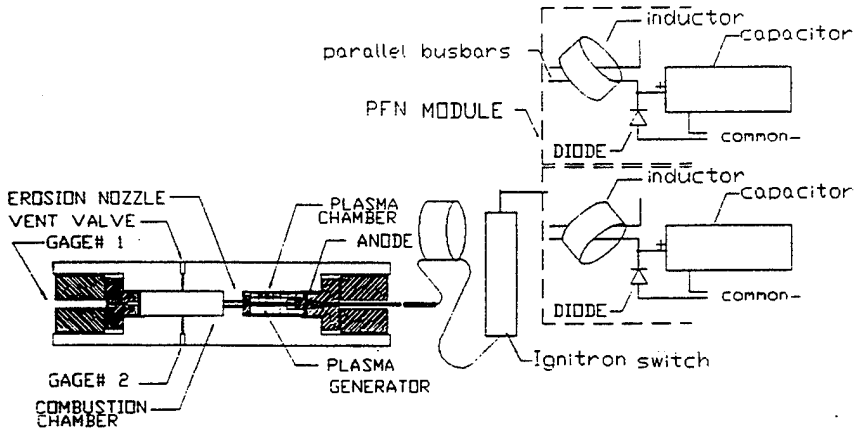


Figure A-1. ETC closed vessel and PFN layout.

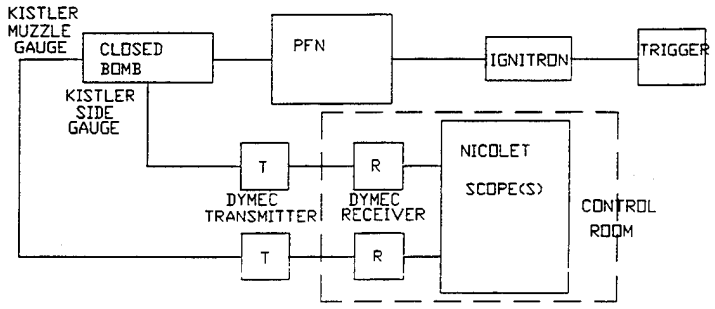


Figure A-2. Conventional mode data acquisition layout.

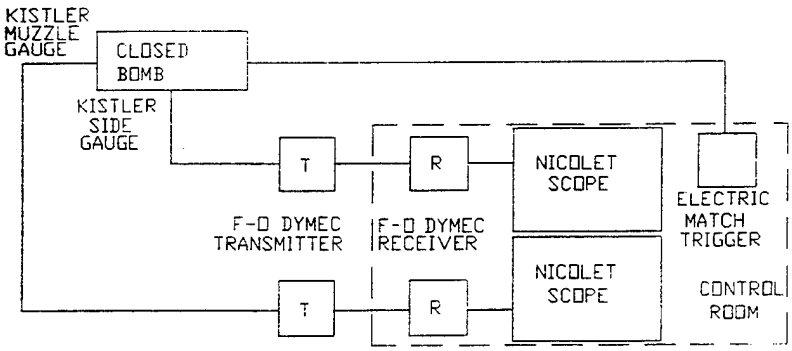


Figure A-3. ETC mode data acquisition layout.

# APPENDIX B:

# TEST FIRING MATRIX

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Table B-1 below, shows the sequence of the firings according to the order they were conducted. The conventional firings show zero electrical energy (kJ), zero electrical energy density (kJ/g), and zero pulse forming network (PFN) charging voltage (kV).

Table B-1. JA2 7 Perf Temperature sensitivity firings

| ID No. | Loading Density ($g/cm^3$) | Temp (C°) | Energy (kJ) | Electrical Energy Density (kJ/g) | PFN Charging Voltage (kV) |
|---|---|---|---|---|---|
| 04115S1 | 0.22 | 21.1 | 21 | 0.78 | 4 |
| 04115S2 | 0.22 | 21.1 | 21 | 0.78 | 4 |
| 04125S3 | 0.22 | 48.9 | 22 | 0.82 | 4 |
| 04175S4 | 0.22 | 48.9 | 21 | 0.78 | 4 |
| 04205S5 | 0.22 | -31.7 | 24 | 0.89 | 4 |
| 04205S6 | 0.22 | -31.7 | 23 | 0.86 | 4 |
| 04255S7 | 0.23 | 21.1 | 0 | 0 | 0 |
| 04265S8 | 0.22 | -31.7 | 0 | 0 | 0 |
| 04275S9 | 0.22 | 48.9 | 0 | 0 | 0 |

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# APPENDIX C:

# FIRING INFORMATION DATA SHEETS

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ETCTEML1 INFORMATION SHEET FOR ETC CLOSED CHAMBER FIRING
DATE:04/11/95 SERIES RUN=: 1 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT =:RAD-PE-792-71 SAMPLE TREATMENT: 70F
SAMPLE WEIGHT:26.934g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 290MPa WINDOW: 20ms

PFNPULSE LENGTH:1.2ms PFN SCHEMATIC=:4caps@830uF ea.&4ind@ 30uHea
PFN Vin DC:4.0kV; EXPECTED ENERGY:18.4kJ@ 70%efficy;WINDOW :4ms
PEARSON'S CAL K:2630;
pfn's ROGOVSKI#2CAL K:82.45E-06;vessel's ROGOVSKI#1CAL K:80.49E+06

MUZZLE GAGE#1 SN(P1): C47189 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.76E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ETC#4_____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#4
TRACK ID:6

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.28V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.07 V

FIRING

***** SCOPE A*****
DISK ID:ETC#4
TRACK ID:2
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 1B: P2 | 20ms | 5usxpnt |
| 2A:di/dt | 4ms | 1usxpnt |
| 2B: V | 4ms | 1usxpnt |

ROGOVSKY#1 (m.A/V.s):1

PRESSURE MAX(MPa):150
SCOPE ID:B
GAGE ID: #1

*****SCOPE B*****
DISK ID:120cc#4
TRACK ID:7
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 8.0ms | 2usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 2A: NA | | |
| 1B: ROGOSVKY#2 | | |

ROGOSVSKY#2 (m.A/V.s):2

PRESSURE MAX(MPa):280
SCOPE ID:B
GAGE ID:#2

NOTES:
1 wrap of cellophane tape
27.346g total weigth

opaque grease in both gage ports

ETCTEML1 INFORMATION SHEET FOR ETC CLOSED CHAMBER FIRING
DATE:04/11/95 SERIES RUN=: 1 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT =:RAD-PE-792-71 SAMPLE TREATMENT: 70F
SAMPLE WEIGHT:26.889g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 290MPa WINDOW: 20ms

PFNPULSE LENGTH:1.2ms PFN SCHEMATIC=:4caps@830uF ea.&4ind@ 30uHea
PFN Vin DC:4.0kV; EXPECTED ENERGY:18.4kJ@ 70%efficy;WINDOW :4ms
PEARSON'S CAL K:2630;
pfn's ROGOVSKI#2CAL K:82.45E+06;vessel's ROGOVSKI#1CAL K:82.56E+06

MUZZLE GAGE#1 SN(P1): C47189 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.76E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ETC#4_____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#4
TRACK ID:8

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.235V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.03 V

FIRING

***** SCOPE A*****
DISK ID:ETC#4
TRACK ID:3
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 1B: P2 | 20ms | 5usxpnt |
| 2A:di/dt | 4ms | 1usxpnt |
| 2B: V | 4ms | 1usxpnt |

ROGOVSKY#1 (m.A/V.s)

PRESSURE MAX(MPa):260
SCOPE ID:B
GAGE ID:#1

*****SCOPE B*****
DISK ID:120cc#4
TRACK ID:9
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 8.0ms | 2usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 2A: NA | | |
| 1B: ROGOSVKY#2 | | |

ROGOSVSKY#2 (m.A/V.s)

PRESSURE MAX(MPa):270
SCOPE ID:B
GAGE ID:#2

NOTES: Sample weight : 26.889g
1 wrap of cellophane tape
27.311g total weigth

opaque grease in both gage ports

ETCTEML1 INFORMATION SHEET FOR ETC CLOSED CHAMBER FIRING
DATE:04/11/95 SERIES RUN#:3 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT #:RAD-PE-792-71 SAMPLE TREATMENT:120F
SAMPLE WEIGHT:26.946g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 290MPa WINDOW: 20ms

PFNPULSE LENGTH:1.2ms PFN SCHEMATIC#:4caps@830uF ea.&4ind@ 30uHea
PFN Vin DC:4.0kV; EXPECTED ENERGY:18.4kJ@ 70%efficy;WINDOW :4ms
PEARSON'S CAL K:2630;
vessel's ROGOVSKI#1CAL K:82.45E+06;pfn's ROGOVSKI#2CAL K:82.56E+06

MUZZLE GAGE#1 SN(P1): C47189 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.76E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ETC#4_____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#4
TRACK ID:10

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.26V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.065 V

FIRING

***** SCOPE A*****
DISK ID:ETC#4
TRACK ID:4
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 1B: P2 | 20ms | 5usxpnt |
| 2A:di/dt | 4ms | 1usxpnt |
| 2B: V | 4ms | 1usxpnt |

ROGOVSKY#1 (m.A/V.s)

PRESSURE MAX(MPa):260
SCOPE ID:B
GAGE ID:#1

*****SCOPE B*****
DISK ID:120cc#4
TRACK ID:11
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 8.0ms | 2usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 2A: NA | | |
| 1B: ROGOSVKY#2 | | 2usxpnt |

ROGOSVSKY#2 (m.A/V.s)

PRESSURE MAX(MPa):270
SCOPE ID:B
GAGE ID:#2

NOTES: DATE : 04/12/95
1 wrap cellophane 27.329g total weigth
opaque grease in both gage ports

Previous firing got Rogosvky#1 replaced
At this firing Rogovsky #2 broke

ETCTEML1 INFORMATION SHEET FOR ETC CLOSED CHAMBER FIRING
DATE:04/11/95 SERIES RUN#:4 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT #:RAD-PE-792-71 SAMPLE TREATMENT:120F
SAMPLE WEIGHT:26.901g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 290MPa WINDOW: 20ms

PFNPULSE LENGTH:1.2ms PFN SCHEMATIC#:4caps@830uF ea.&4ind@ 30uHea
PFN Vin DC:4.0kV; EXPECTED ENERGY:18.4kJ@ 70%efficy;WINDOW :4ms
PEARSON'S CAL K:2630;
vessel's ROGOVSKI#1CAL K:82.34E+06;pfn's ROGOVSKI#2CAL K:82.56E+06

MUZZLE GAGE#1 SN(P1): C47189 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.76E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ETC#4_____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#4
TRACK ID:13

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.230V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.025 V

FIRING

***** SCOPE A*****
DISK ID:ETC#4
TRACK ID:5
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 1B: P2 | 20ms | 5usxpnt |
| 2A:di/dt | 4ms | 1usxpnt |
| 2B: V | 4ms | 1usxpnt |

ROGOVSKY#1 (m.A/V.s)

PRESSURE MAX(MPa):250
SCOPE ID:B
GAGE ID:#1

*****SCOPE B*****
DISK ID:120cc#4
TRACK ID:12
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20.0ms | 5usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 2A: NA | | |
| 1B: ROGOSVKY#2 | | 5usxpnt |

ROGOSVSKY#2 (m.A/V.s)

PRESSURE MAX(MPa):260
SCOPE ID:B
GAGE ID:#2

NOTES: DATE : 04/17/95
1 wrap cellophane 27.273g total weigth

vessel's side Rogovsky#1 defective

ETCTEML1 INFORMATION SHEET FOR ETC CLOSED CHAMBER FIRING
DATE:04/20/95 SERIES RUN#:5 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT #:RAD-PE-792-71 SAMPLE TREATMENT:-25F
SAMPLE WEIGHT:26.803g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 290MPa WINDOW: 20ms

PFNPULSE LENGTH:1.2ms PFN SCHEMATIC#:4caps@830uF ea.&4ind@ 30uHea
PFN Vin DC:4.0kV; EXPECTED ENERGY:18.4kJ@ 70%efficy;WINDOW :4ms
PEARSON'S CAL K:2630;
vessel's ROGOVSKI#1CAL K:80.79E+06;pfn's ROGOVSKI#2CAL K:82.56E+06

MUZZLE GAGE#1 SN(P1): C47189 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.76E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

| *****SCOPE A***** | *****SCOPE B***** |
|---|---|
| CAL (DC)VOLTAGE IN :NA | CAL (DC)VOLTAGE IN:8.0 V |
| DISK ID:___ETC#4_____ | DISK D: 120cc#4 |
| TRACKID:_____ | TRACK ID:14 |
| CAL#1(gage#1)/CHAN 1A: NA | CAL#1(gage#1)/CHAN 1A:8.0 V |
| VCAL VOLTAGE OUT:_____ | CAL VOLTAGE OUT: 9.295V |
| CAL#2(gage#2)/CHAN 1B:NA | CAL#2(gage#2)/CHAN 2A:8.0 V |
| CAL VOLTAGE OUT:_____ | CAL VOLTAGE OUT: 9.015 V |

FIRING

| ***** SCOPE A***** | *****SCOPE B***** |
|---|---|
| DISK ID:ETC#4 | DISK ID:120cc#4 |
| TRACK ID:6 | TRACK ID:15 |
| SENSITIVITY: MIN | SENSITIVITY:MIN |

| CHANNEL | WINDOW | S.RATE | CHANNEL | WINDOW | S.RATE |
|---|---|---|---|---|---|
| 1A: P1 | 20ms | 5usxpnt | 1A: P1 | 20.0ms | 5usxpnt |
| 1B: P2 | 20ms | 5usxpnt | 2A: P2 | 20ms | 5usxpnt |
| 2A:di/dt | 4ms | 1usxpnt | 2A: NA | | |
| 2B: V | 4ms | 1usxpnt | 1B: ROGOSVKY#2 | | |
| ROGOVSKY#1 (m.A/V.s) | | | ROGOSVSKY#2 (m.A/V.s) | | |

| | |
|---|---|
| PRESSURE MAX(MPa):too low(190) | PRESSURE MAX(MPa):270 |
| SCOPE ID:B | SCOPE ID:B |
| GAGE ID:#1 | GAGE ID:#2 |

NOTES:
sample wrapped in cellophane,27.185g total weigth

new vessel's side Rogovsky#1 installed

ETCTEML1 INFORMATION SHEET FOR ETC CLOSED CHAMBER FIRING
DATE:04/20/95 SERIES RUN#:6 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT #:RAD-PE-792-71 SAMPLE TREATMENT:-25F
SAMPLE WEIGHT:26.812g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 290MPa WINDOW: 20ms

PFNPULSE LENGTH:1.2ms PFN SCHEMATIC#:4caps@830uF ea.&4ind@ 30uHea
PFN Vin DC:4.0kV; EXPECTED ENERGY:18.4kJ@ 70%efficy;WINDOW :4ms
PEARSON'S CAL K:2630;
vessel's ROGOVSKI#1CAL K:80.79E+06;pfn's ROGOVSKI#2CAL K:82.56E+06

MUZZLE GAGE#1 SN(P1): C47189 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.76E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

| *****SCOPE A***** | *****SCOPE B***** |
|---|---|
| CAL (DC)VOLTAGE IN :NA | CAL (DC)VOLTAGE IN:8.0 V |
| DISK ID:___ETC#4_____ | DISK D: 120cc#4 |
| TRACKID:_____ | TRACK ID:16 |
| CAL#1(gage#1)/CHAN 1A: NA | CAL#1(gage#1)/CHAN 1A:8.0 V |
| VCAL VOLTAGE OUT:_____ | CAL VOLTAGE OUT: 9.310V |
| CAL#2(gage#2)/CHAN 1B:NA | CAL#2(gage#2)/CHAN 2A:8.0 V |
| CAL VOLTAGE OUT:_____ | CAL VOLTAGE OUT: 9.025 V |

FIRING

| ***** SCOPE A***** | *****SCOPE B***** |
|---|---|
| DISK ID:ETC#4 | DISK ID:120cc#4 |
| TRACK ID:7 | TRACK ID:17 |
| SENSITIVITY: MIN | SENSITIVITY:MIN |

| CHANNEL | WINDOW | S.RATE | CHANNEL | WINDOW | S.RATE |
|---|---|---|---|---|---|
| 1A: P1 | 20ms | 5usxpnt | 1A: P1 | 20.0ms | 5usxpnt |
| 1B: P2 | 20ms | 5usxpnt | 2A: P2 | 20ms | 5usxpnt |
| 2A:di/dt | 4ms | 1usxpnt | 2A: NA | | |
| 2B: V | 4ms | 1usxpnt | 1B: ROGOSVKY#2 , 5usxpnt | | |
| ROGOVSKY#1 (m.A/V.s) | | | ROGOSVSKY#2 (m.A/V.s) | | |

| | |
|---|---|
| PRESSURE MAX(MPa): | PRESSURE MAX(MPa):270 |
| SCOPE ID:B | SCOPE ID:B |
| GAGE ID:#1 | GAGE ID:#2 |

NOTES:
sample wrapped in cellophane,27.145g total weigth

new vessel's side Rogovsky#1 worked fine.
gage #1 did not record

CONTML1 INFORMATION SHEET FOR CLOSED CHAMBER FIRING
DATE:04/25/95 SERIES RUN#:7 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT #:RAD-PE-792-71 SAMPLE TREATMENT:70F
SAMPLE WEIGHT:27.182g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 270MPa WINDOW: 20ms

MUZZLE GAGE#1 SN(P1): C20303 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.24E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ NA _____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#4
TRACK ID:18

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.390V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.13 V

FIRING

***** SCOPE A*****
DISK ID: NA
TRACK ID:
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: | | |
| 1B: | | |
| 2A: | | |
| 2B: | | |

PRESSURE MAX(MPa):250
SCOPE ID:B
GAGE ID:#1

*****SCOPE B*****
DISK ID:120cc#4
TRACK ID:19
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 1B: NA | | |
| 2B: NA | | |

PRESSURE MAX(MPa):250
SCOPE ID:B
GAGE ID:#2

NOTES:
sample wrapped in cellophane,27.959g total weigth
0.575g FFFG, electric match

CONTML1 INFORMATION SHEET FOR CLOSED CHAMBER FIRING
DATE:04/26/95 SERIES RUN#:8 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf;LOT #:RAD-PE-792-71 SAMPLE TREATMENT:-25F
SAMPLE WEIGHT:27.182g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 270MPa WINDOW: 20ms

MUZZLE GAGE#1 SN(P1): C20303 SIDE GAGE#2 SN(P2): C19928
gage#1:1rstdegfit coeff:5.24E-02;gage#2:1rstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ NA _____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#5
TRACK ID:#1

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.385V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.15 V

FIRING

***** SCOPE A*****
DISK ID: NA
TRACK ID:
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: | | |
| 1B: | | |
| 2A: | | |
| 2B: | | |

PRESSURE MAX(MPa):
SCOPE ID:B

*****SCOPE B*****
DISK ID:120cc#5
TRACK ID:#2
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 1B: NA | | |
| 2B: NA | | |

PRESSURE MAX(MPa):230
SCOPE ID:B
GAGE ID:#1
GAGE ID:#2

NOTES:
sample wrapped in cellophane,27.593g total weigth
0.541g FFFG, electric match

CONTML1 INFORMATION SHEET FOR CLOSED CHAMBER FIRING
DATE:04/27/95 SERIES RUN#:9 PROJECT: 129.0 CLOSED CHAMBER
PROPELLANT TYPE:JA2;7perf:LOT #:RAD-PE-792-71 SAMPLE TREATMENT:120F
SAMPLE WEIGHT:27.060g GRAIN DIMENSION:0.6"L, 0.3"D; 0.03 WEB
CHAMBERVOL:129.4cc CALCMAX PRESSURE: 270MPa WINDOW: 20ms

MUZZLE GAGE#1 SN(P1): C20303 SIDE GAGE#2 SN(P2): C19928
gage#1:lrstdegfit coeff:5.24E-02;gage#2:lrstdegfit coeff:5.21E-02

CALIBRATION

*****SCOPE A*****
CAL (DC)VOLTAGE IN :NA
DISK ID:___ NA _____
TRACKID:_____

CAL#1(gage#1)/CHAN 1A: NA
VCAL VOLTAGE OUT:_____

CAL#2(gage#2)/CHAN 1B:NA
CAL VOLTAGE OUT:_____

*****SCOPE B*****
CAL (DC)VOLTAGE IN:8.0 V
DISK D: 120cc#5
TRACK ID:#3

CAL#1(gage#1)/CHAN 1A:8.0 V
CAL VOLTAGE OUT: 9.375V

CAL#2(gage#2)/CHAN 2A:8.0 V
CAL VOLTAGE OUT: 9.165 V

FIRING

***** SCOPE A*****
DISK ID: NA
TRACK ID:
SENSITIVITY: MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: | | |
| 1B: | | |
| 2A: | | |
| 2B: | | |

PRESSURE MAX(MPa):
SCOPE ID:B

*****SCOPE B*****
DISK ID:120cc#5
TRACK ID:#4
SENSITIVITY:MIN

| CHANNEL | WINDOW | S.RATE |
|---|---|---|
| 1A: P1 | 20ms | 5usxpnt |
| 2A: P2 | 20ms | 5usxpnt |
| 1B: NA | | |
| 2B: NA | | |

PRESSURE MAX(MPa):
SCOPE ID:B
GAGE ID:#1
GAGE ID:#2

NOTES:
sample wrapped in cellophane,27.866g total weigth
0.563g FFFG, electric match

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# APPENDIX D:

# EXPERIMENTAL PRESSURE AND PULSE FORMING NETWORK ENERGY OUTPUT

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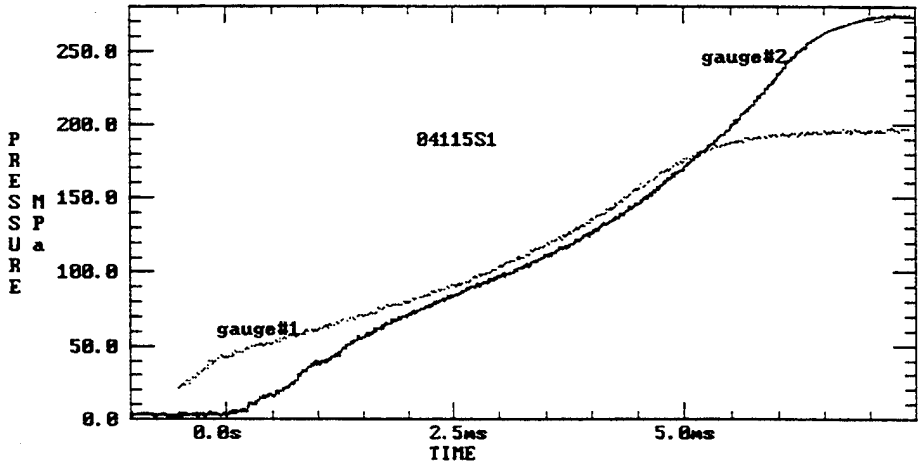


Figure D-1. Ident 4115S1 (ETC), pressure vs. time.

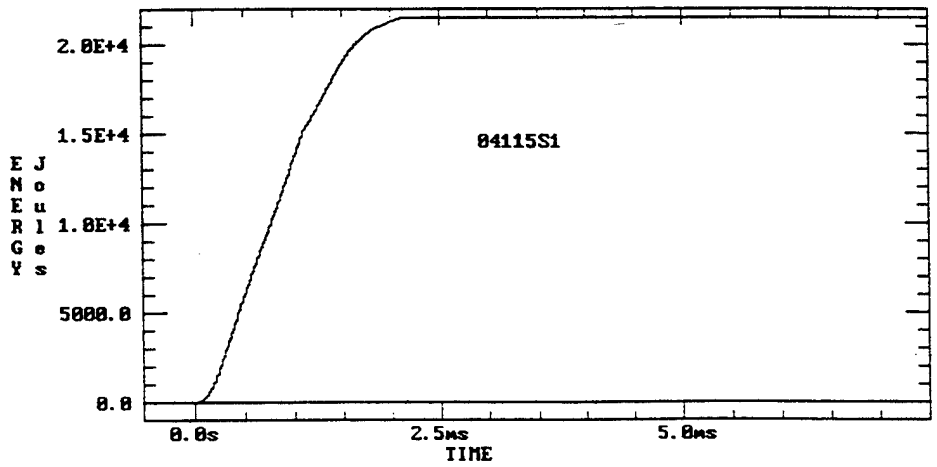


Figure D-2. Ident 4115S1 (ETC), energy vs. time.

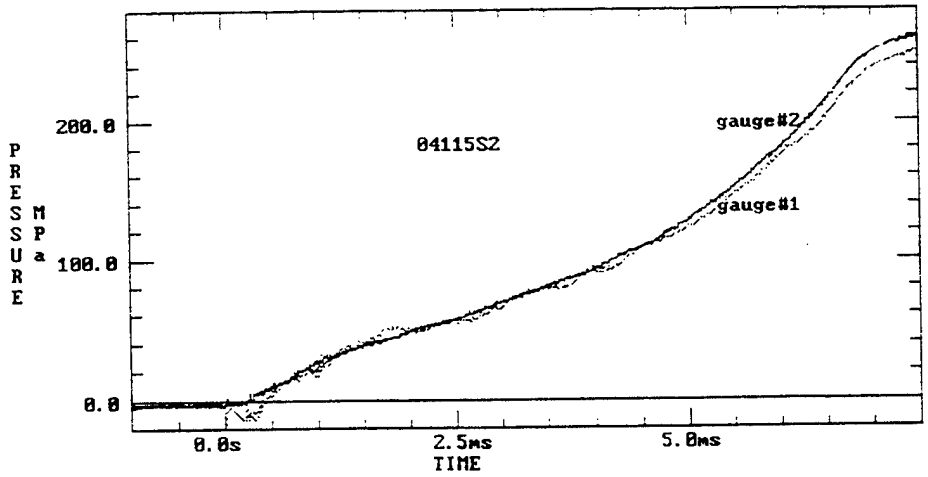


Figure D-3. Ident 4115S2 (ETC), pressure vs. time.

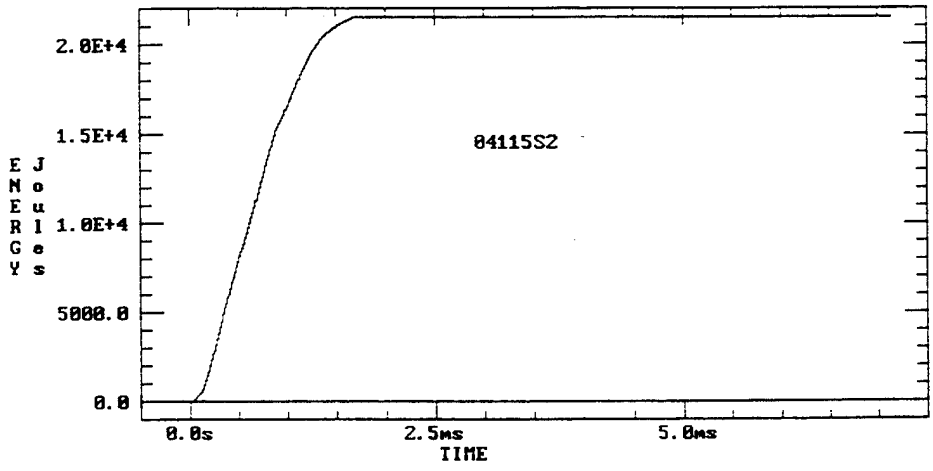


Figure D-4. Ident 4115S2 (ETC), energy vs. time.

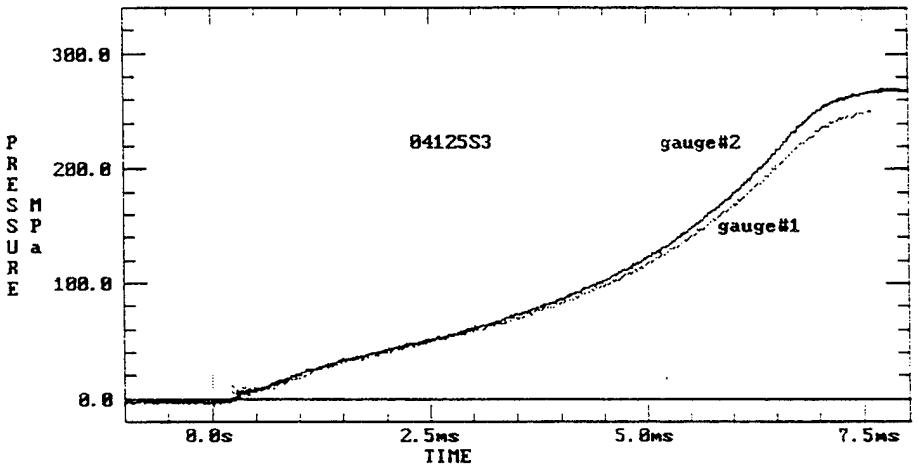


Figure D-5. Ident 4125S3(ETC), pressure vs. time.

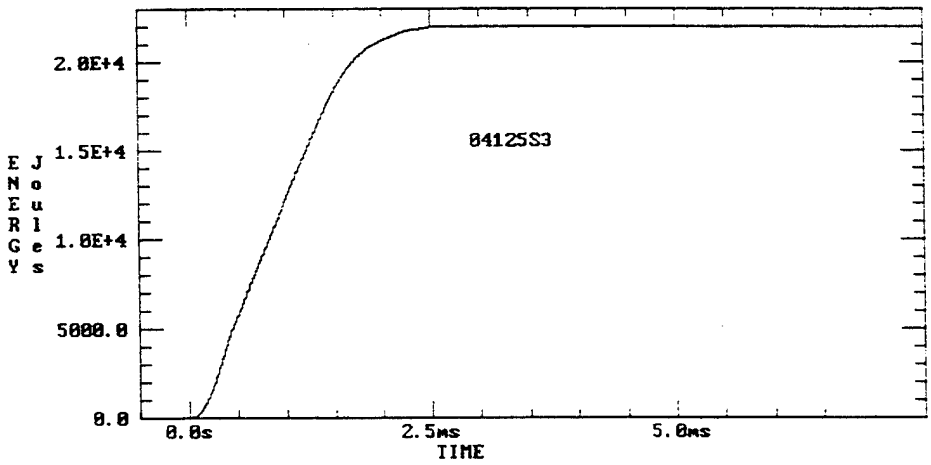


Figure D-6. Ident 4125S3 (ETC), energy vs. time.

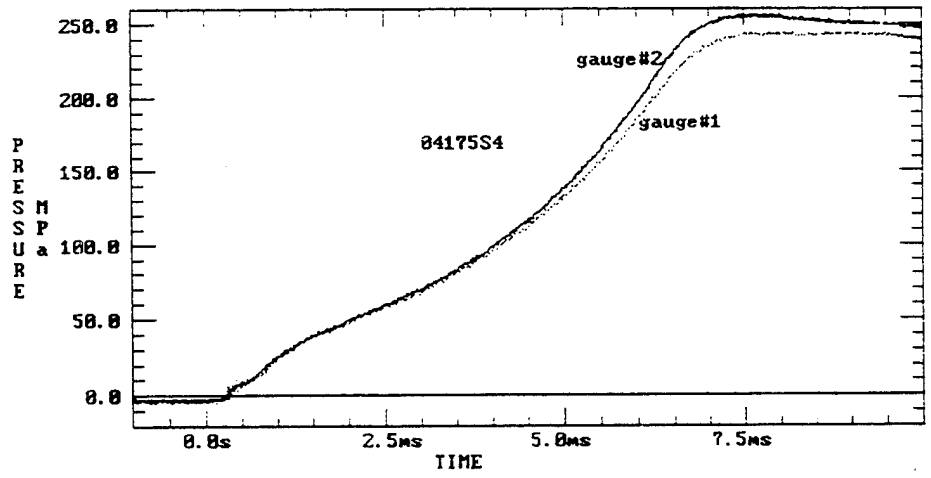


Figure D-7. Ident 4175S4 (ETC), pressure vs. time.

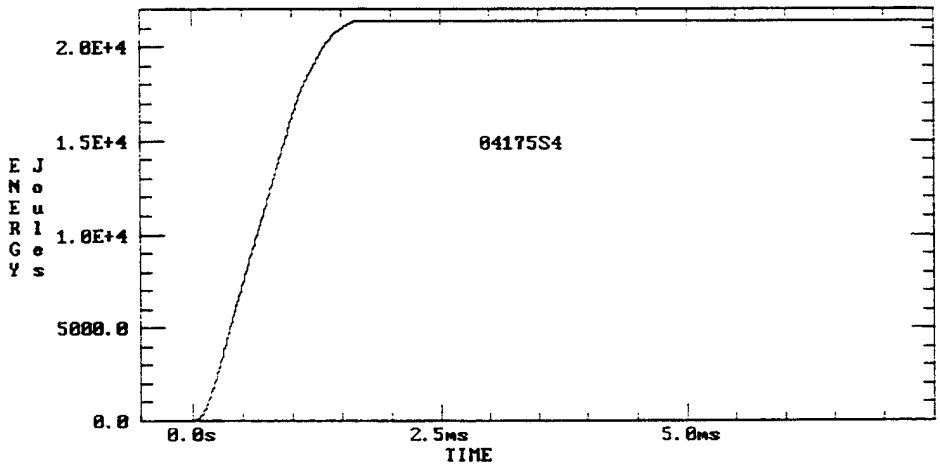


Figure D-8. Ident 4175S4 (ETC), energy vs. time.

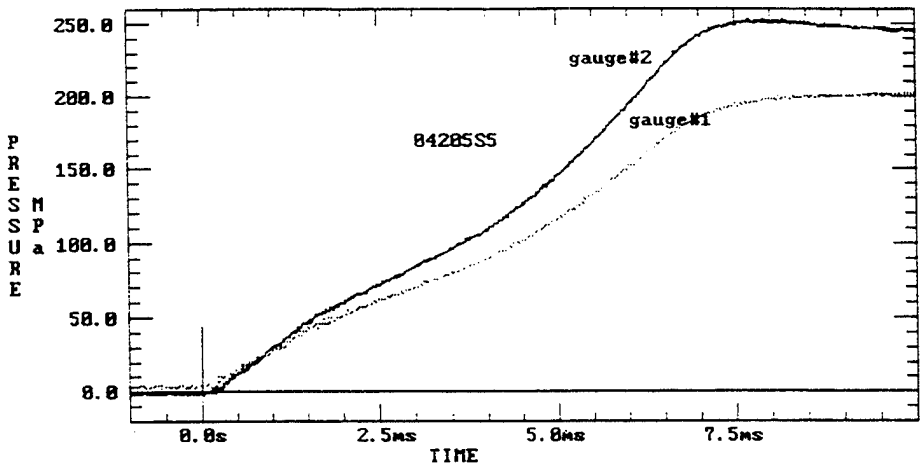


Figure D-9. Ident 4205S5 (ETC), pressure vs. time.

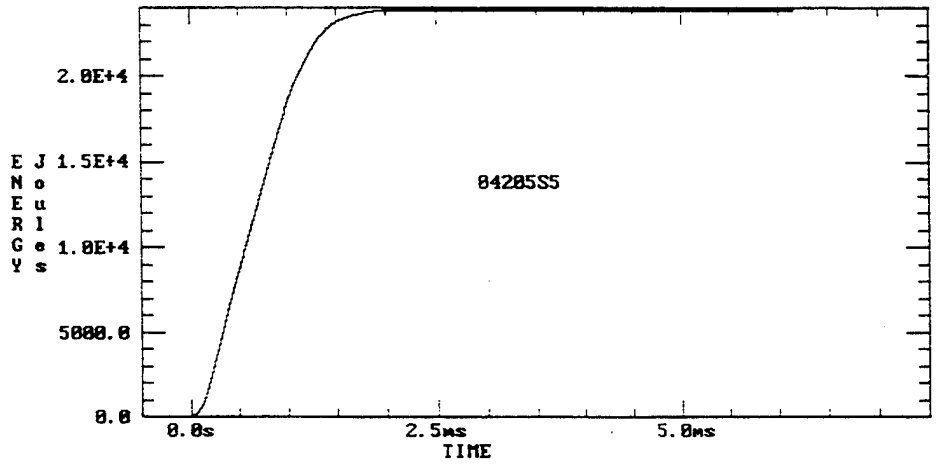


Figure D-10. Ident 4205S5 (ETC), energy vs. time.

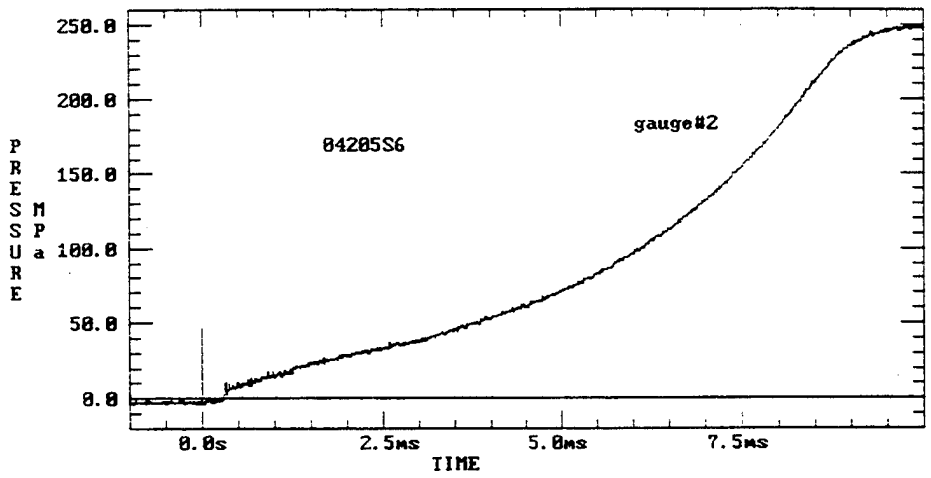


Figure D-11. Ident 4205S6 (ETC), pressure vs. time.

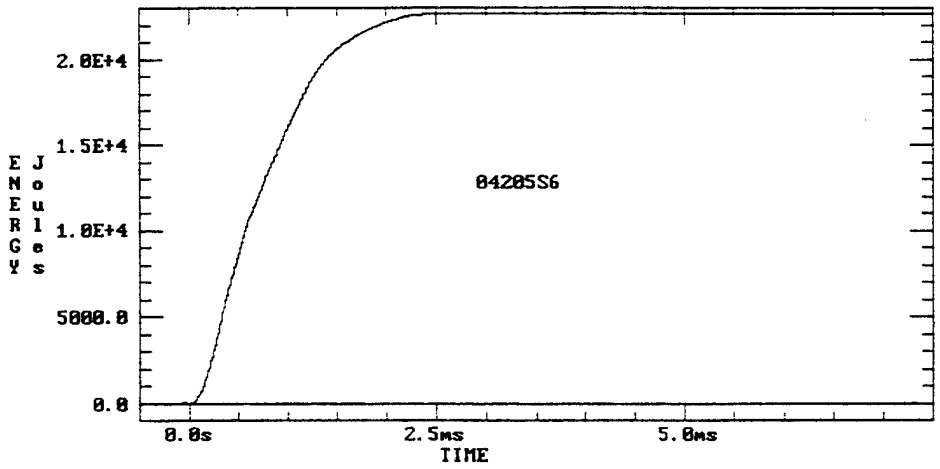


Figure D-12. Ident 4205S6 (ETC), energy vs. time.

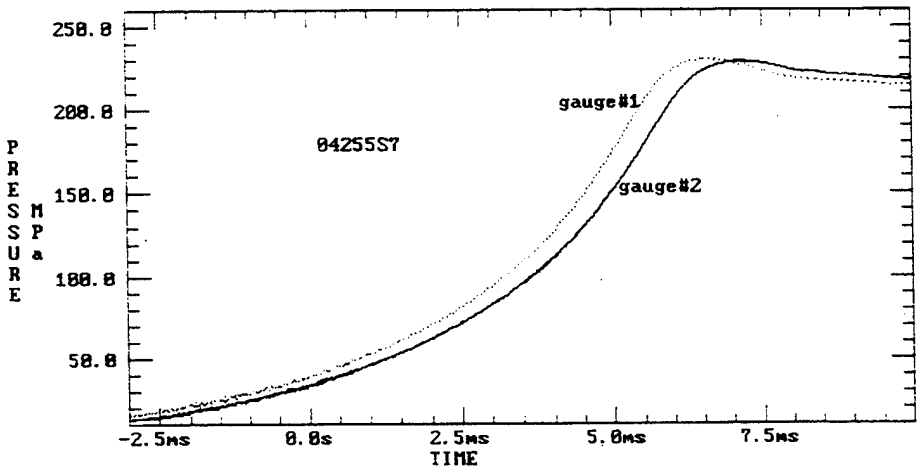


Figure D-13. Ident 4255S7 (conventional), pressure vs. time.

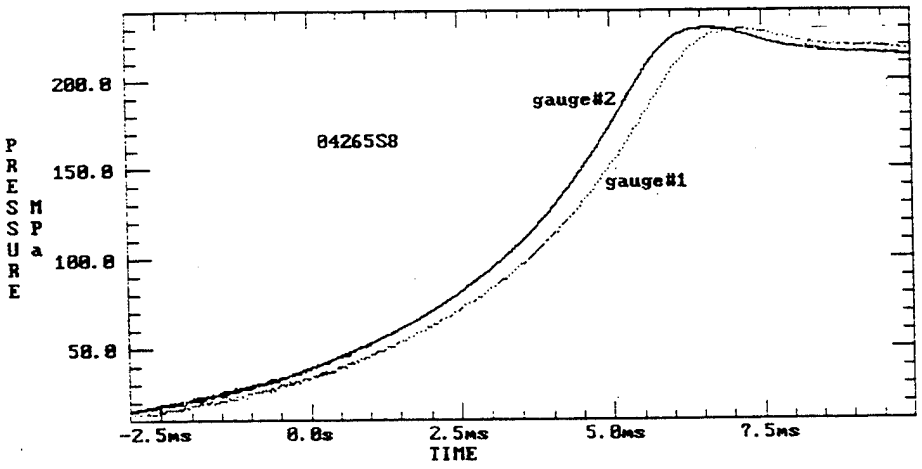


Figure D-14. Ident 4265S8 (conventional), pressure vs. time.

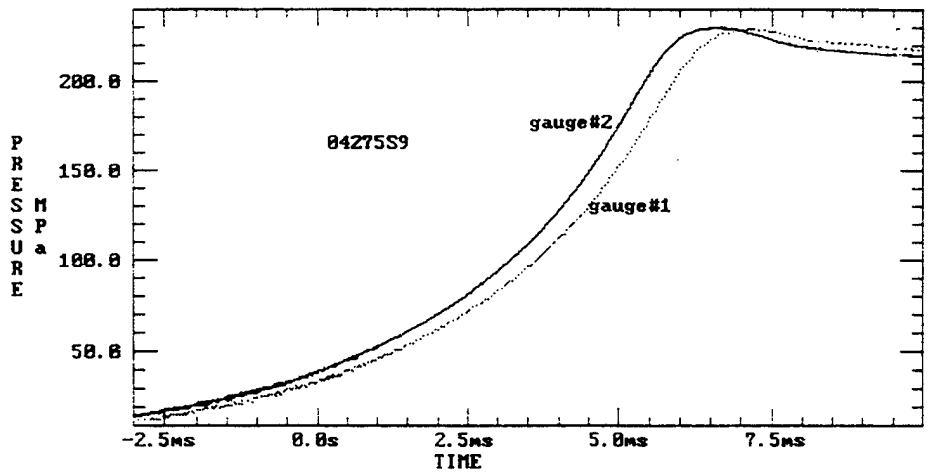


Figure D-15. Ident 4275S9 (conventional), pressure vs. time.

# APPENDIX E:

# BURN RATES

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The BRLCB[1] code was used to obtain the ETC as well as the conventional burn rate analysis. The first six plots of burn rate vs. pressure correspond to the ETC firings, and the last three correspond to the conventional firings. Plots show burn rate vs. pressure on log-log axis.

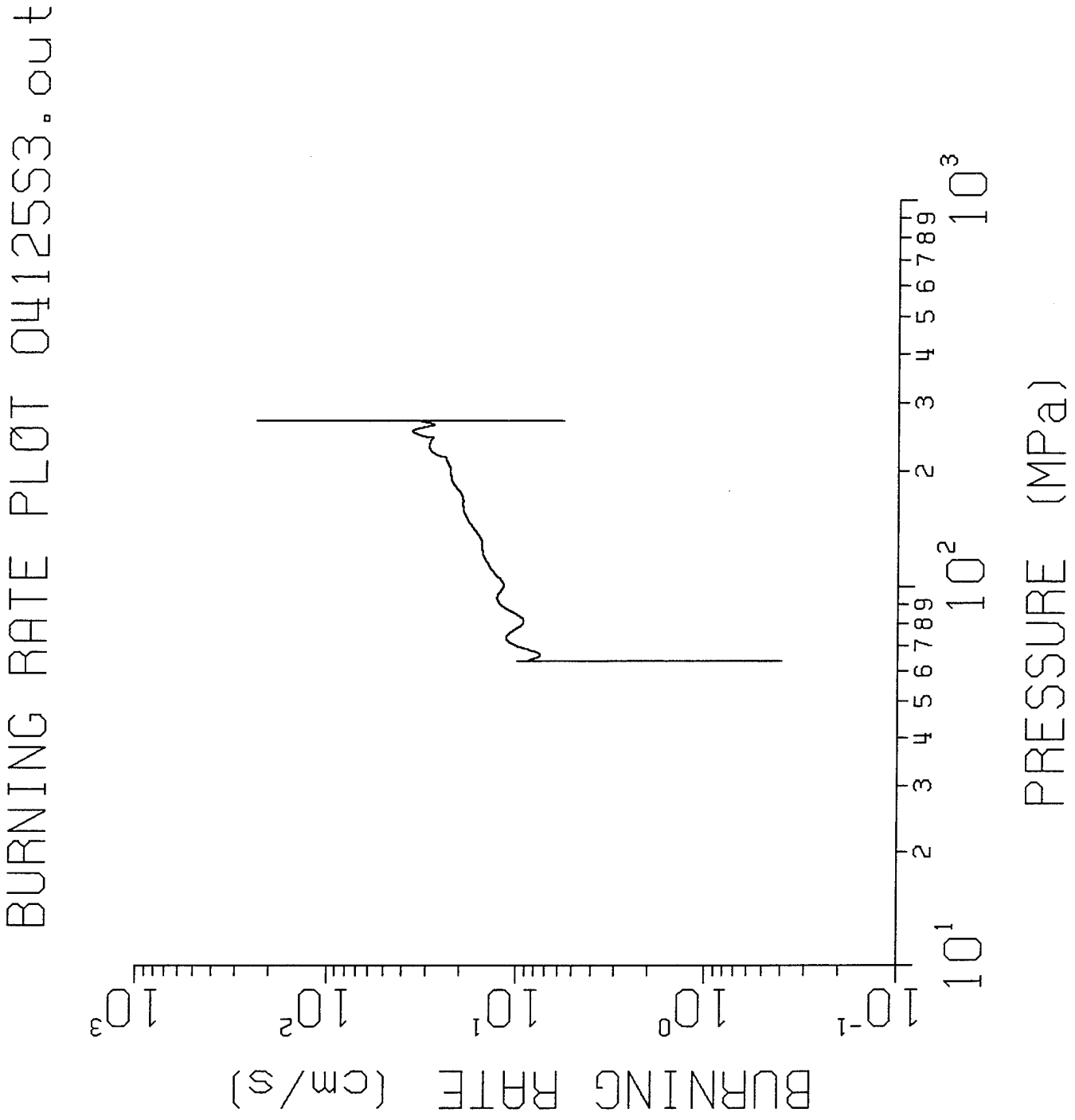
[1] Oberle, W., and D. Kooker. "BRLCB: A Closed-Chamber Data Analysis Program." ARL-TR-36, U.S Army Research Laboratory, Aberdeen Proving Ground, MD, January 1993.

BURNING RATE PLOT 041155S1.out
BURNING RATE (cm/s)
PRESSURE (MPa)
10^-1
10^0
10^1
10^2
10^3
2 3 4 5 6 7 8 9

```
                              ETC BURN RATE ANALYSIS
                                   BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04115S1.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04115S1.pvt           Calculation Output File: 04115S1.out
Smoothed: 04115S1.pdt           Graphics File          : 04115S1.dat
EE  File: A:04115S1E.AD
Fired on: 04/11/95
FIRING REMARKS:
TEMPERATURE SENSITIVITY JA27PERF @ 70F
USED GAGE#2 AND 04115S2E.AD AS DI/DT DUE YO
FAULTY ROVGOSKY

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                      PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information               Gage Information
-------------------------------------------------
Bomb Type    :Closed Chamber        Gage I.D.    : C19928
Bomb Vol (cc):     129.4            Input Voltage:  8.0000
                                    Constants For Fit: A+Bx+C^2
                                    A:   .21637E+00
                                    B:   .54171E-01
                                    C:  -.31853E-06

       Temperature and Charge Mass Information
-------------------------------------------------
Propellant Mass (g)   :  26.9340      Igniter Mass (g):    .0000
Initial Temp. Prop.(K):  294.         Igniter Temp.(K):  294.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    25.49


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04115S1.OP7
 ********************************************************************************

 ********************************************************************************

     Total # Layers =    1

     Chamber Volume (cm3) =   129.400

     Heat-Loss-Fraction (n-d) =      .000
```

BURNING RATE PLOT 041152.out
BURNING RATE (cm/s)
PRESSURE (MPa)

```
                              ETC BURN RATE ANALYSIS
                                   BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04115S2.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04115S2.pvt           Calculation Output File: 04115S2.out
Smoothed: 04115S2.pdt           Graphics File          : 04115S2.dat
EE  File: A:04115S2E.AD
Fired on: 04/11/95
FIRING REMARKS:
TEMPERATURE SENSIVITY JA27PERF @ 70F
USED GAGE # 1 FOR REDUCTION

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                     PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information               Gage Information
-------------------------------------------------
Bomb Type    :Closed Chamber        Gage I.D.     : C47189
Bomb Vol (cc):     129.4            Input Voltage:  8.0000
                                    Constants For Fit: A+Bx+C^2
                                    A:   .66081E+00
                                    B:   .61167E-01
                                    C:  -.39696E-06

       Temperature and Charge Mass Information
-------------------------------------------------
Propellant Mass (g)   :  26.8890      Igniter Mass (g):    .0000
Initial Temp. Prop.(K):  294.         Igniter Temp.(K):  294.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    25.44


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04115S2.OP7
 ********************************************************************************

 ********************************************************************************

     Total # Layers =    1

     Chamber Volume (cm3) =   129.400

     Heat-Loss-Fraction (n-d) =      .000
```


BURNING RATE PLOT 041253.out
BURNING RATE (cm/s)
PRESSURE (MPa)

ETC BURN RATE ANALYSIS
BRLCB V3.0
ADVANCED BALLISTIC CONCEPTS BRANCH - BRL

Project : 120CC CLOSED BOMB  Requested by : DEL GUERCIO
Inf File: 04125S3.inf  Created From .MAS File : JA27PERF.MAS
P/T File: 04125S3.pvt  Calculation Output File: 04125S3.out
Smoothed: 04125S3.pdt  Graphics File : 04125S3.dat
EE File: A:04125S3E.AD
Fired on: 04/12/95
FIRING REMARKS:
TEMPERATURE SENSITIVITY JA27PERF @ 120F
gage#2 used as gag2#1 was low

IGNITER INFORMATION
The Igntier Used Is : Black Powder  Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g) : 290.0 Molecular Weight : 66.37000
Flame Temperature (K): 2188.0 Covolume (cc/g) : .78500
Density (g/cc) : 1.75000 Gamma : 1.21840

PROPELLANT INFORMATION
The Propellant Used Is : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

Propellant Thermochemical Properties: Following
Sheets of Output

PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
Length --- (cm.): 1.529080
Outer Diam.(cm.): .762000
Perf Diam. (cm.): .066040
Inner Web (cm.): .130810
Outer Web (cm.): .151130

| Bomb Information | | Gage Information | |
|---|---|---|---|
| Bomb Type | :Closed Chamber | Gage I.D. | : C19928 |
| Bomb Vol (cc): | 129.4 | Input Voltage: | 8.0000 |
| | | Constants For Fit: | A+Bx+C^2 |
| | | A: | .21637E+00 |
| | | B: | .54171E-01 |
| | | C: | -.31853E-06 |

Temperature and Charge Mass Information

| | | | |
|---|---|---|---|
| Propellant Mass (g) : | 26.9460 | Igniter Mass (g): | .0000 |
| Initial Temp. Prop.(K): | 322. | Igniter Temp.(K): | 322. |
| Initial Bomb Temp. (K): | 294. | | |
| Number of Propellant Grains: | 25.50 | | |

Number of Wildpoint Passes: 1 Wildpoint Tolerance: 5.000
Number of Smoothing Passes: 1 Smoothing Option: 1
Bridge Length: 15
1 OUTPUT FILE: 04125s3.op7

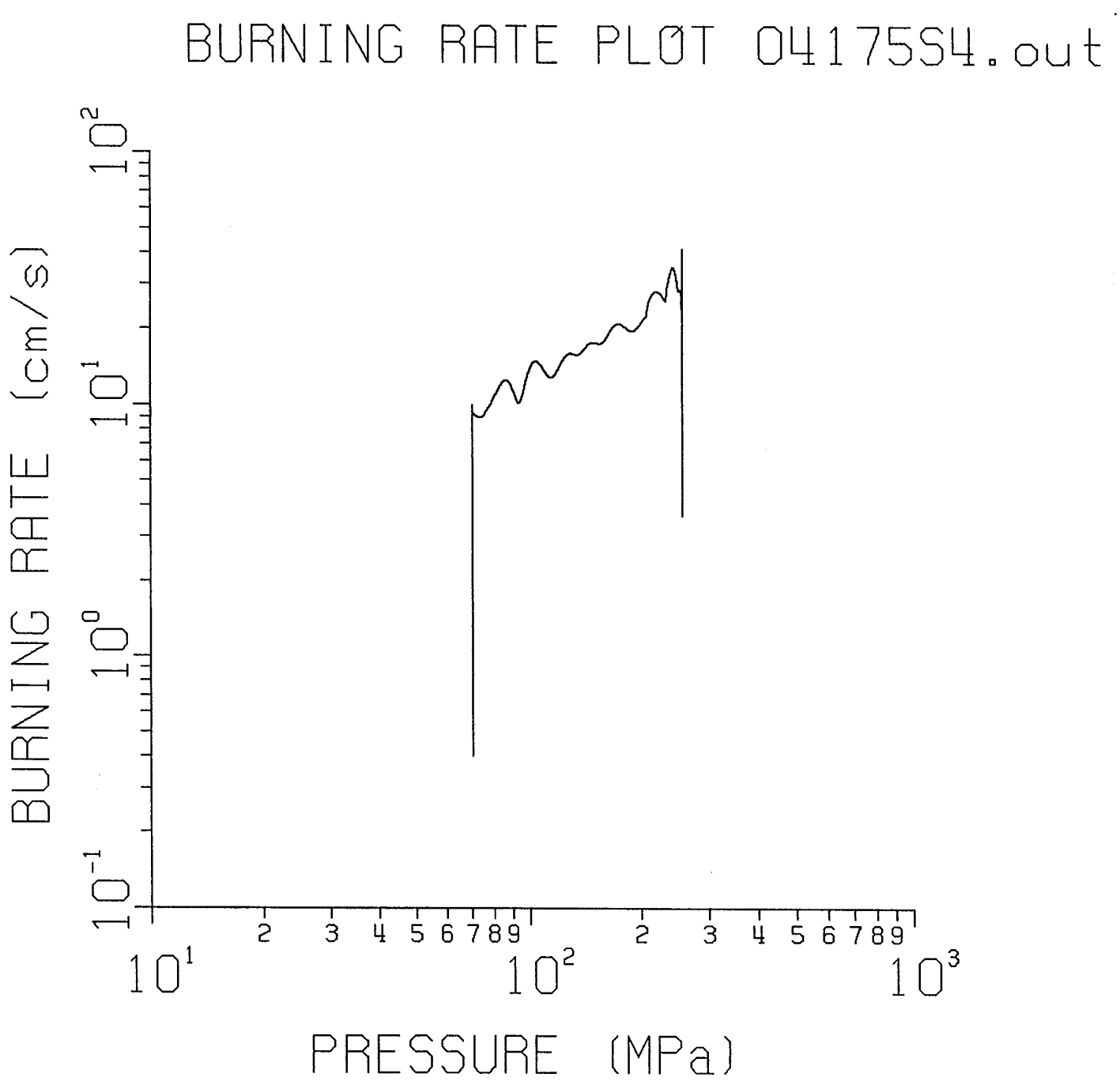
**********

**********

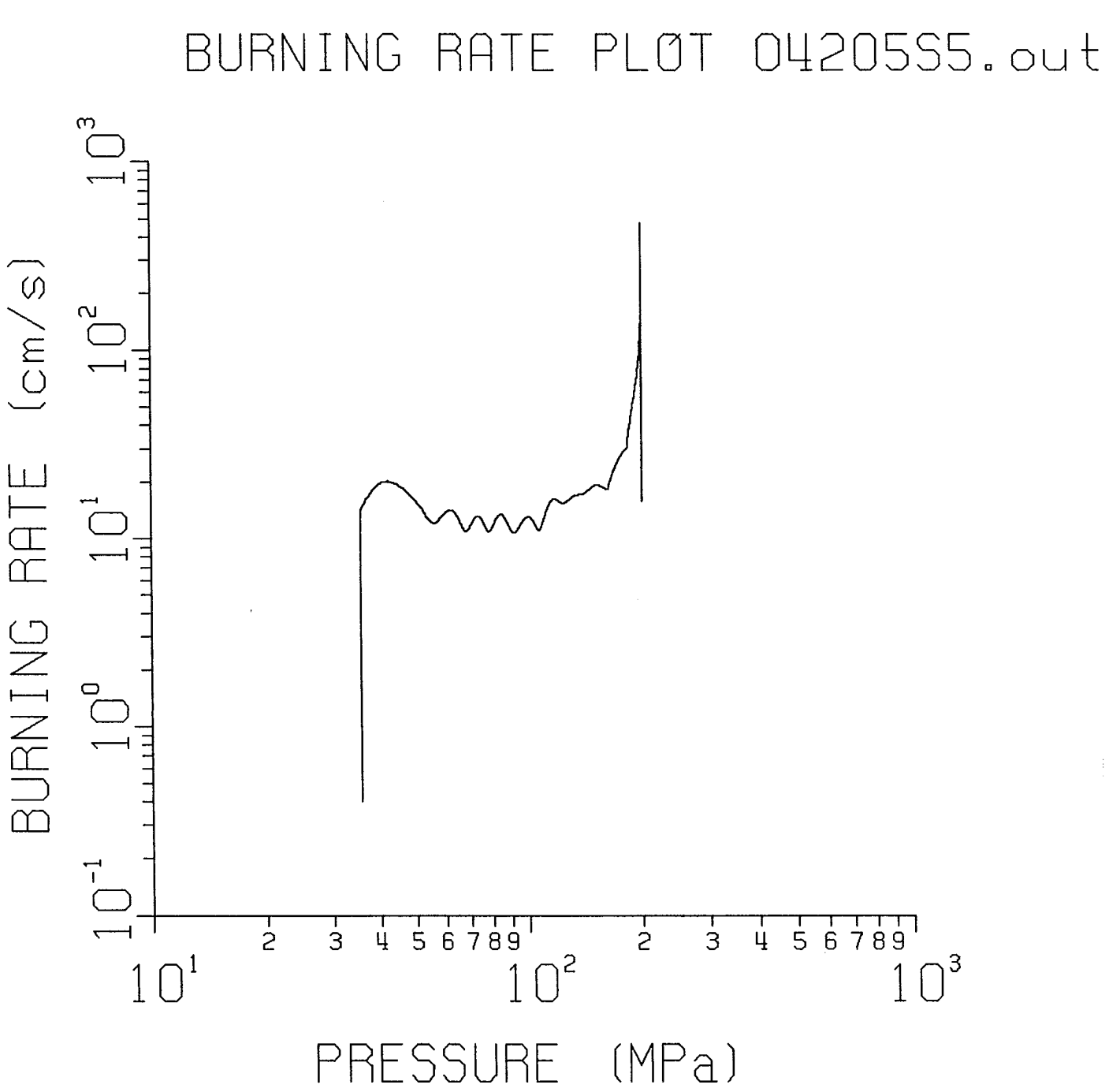
Total # Layers = 1

Chamber Volume (cm3) = 129.400

Heat-Loss-Fraction (n-d) = .000


BURNING RATE PLØT 04175S4.out
BURNING RATE (cm/s)
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
2 3 4 5 6 7 8 9
$10^{1}$
$10^{2}$
$10^{3}$
PRESSURE (MPa)

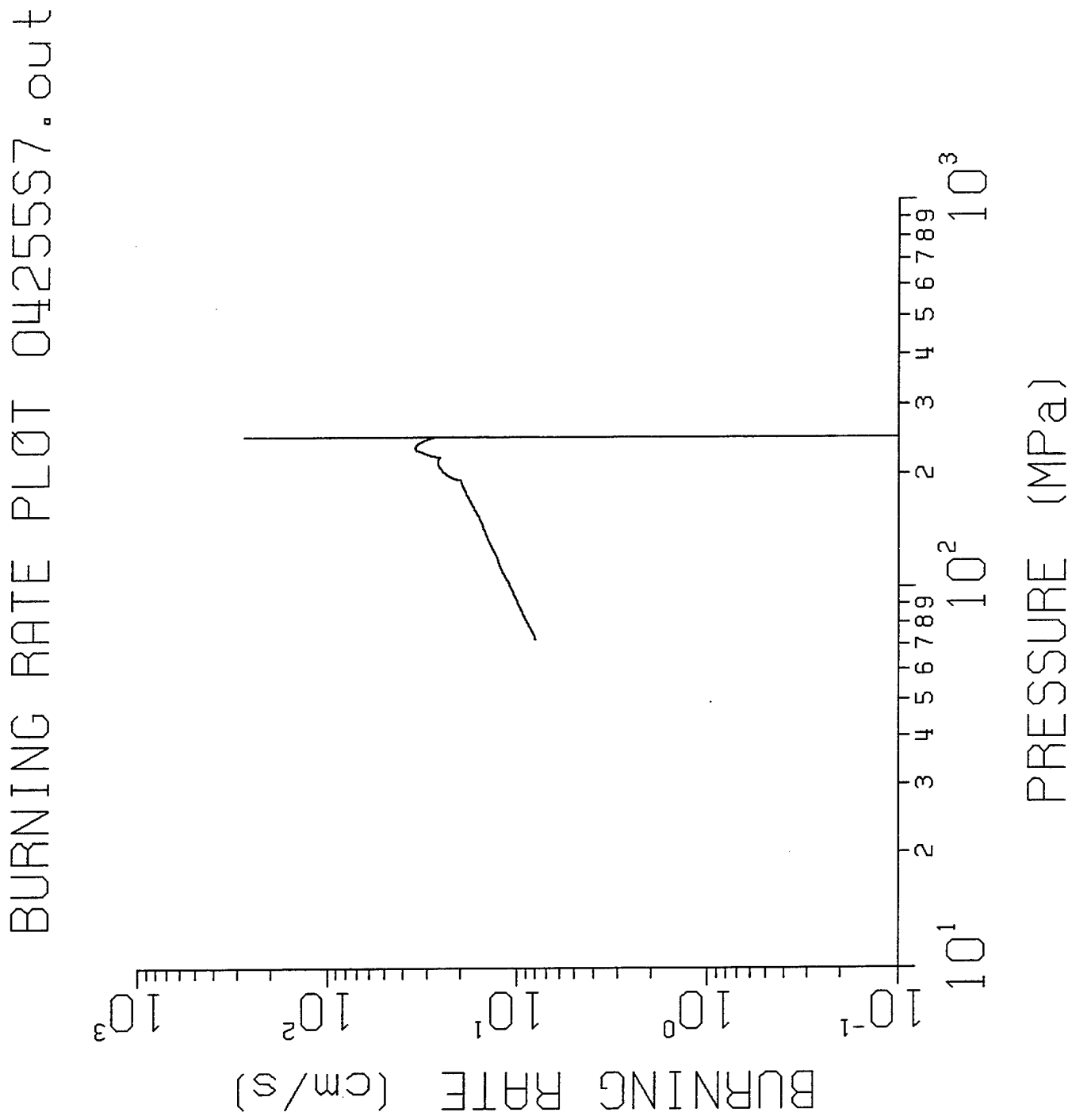
```
                              ETC BURN RATE ANALYSIS
                                    BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04175S4.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04175S4.pvt           Calculation Output File: 04175S4.out
Smoothed: 04175S4.pdt           Graphics File          : 04175S4.dat
EE  File: A:04175S4E.AD
Fired on: 04/17/95
FIRING REMARKS:
TEMPERATURE SENSITIVITY JA27PERF @ 120F
USED GAGE#2 FOR REDUCTION

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                     PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information               Gage Information
-------------------------------------------------
Bomb Type    :Closed Chamber        Gage I.D.    : C19928
Bomb Vol (cc):     129.4            Input Voltage:  8.0000
                                    Constants For Fit: A+Bx+C^2
                                    A:   .21637E+00
                                    B:   .54171E-01
                                    C:  -.31853E-06

       Temperature and Charge Mass Information
-------------------------------------------------
Propellant Mass (g)   :  26.9010      Igniter Mass (g):    .0000
Initial Temp. Prop.(K):  322.         Igniter Temp.(K):  322.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    25.46


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04175S4.OP7
 ********************************************************************************

 ********************************************************************************

     Total # Layers =    1

     Chamber Volume (cm3) =   129.400

     Heat-Loss-Fraction (n-d) =      .000
```


BURNING RATE PLØT 042055S5.out
BURNING RATE (cm/s)
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
$10^{3}$
2 3 4 5 6 7 8 9
$10^{1}$
$10^{2}$
$10^{3}$
PRESSURE (MPa)

```
                              ETC BURN RATE ANALYSIS
                                    BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04205S5.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04205S5.pvt           Calculation Output File: 04205S5.out
Smoothed: 04205S5.pdt           Graphics File          : 04205S5.dat
EE  File: A:04205S5E.AD
Fired on: 04/20/95
FIRING REMARKS:
TEMPERATURE SENSITIVITY JA27PERF @ -25F
USED GAGE#2 FOR REDUCTION

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                      PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information                Gage Information
-----------------------------------------------------
Bomb Type     :Closed Chamber       Gage I.D.     : C19928
Bomb Vol (cc):     129.4            Input Voltage:  8.0000
                                    Constants For Fit: A+Bx+C^2
                                    A:   .21637E+00
                                    B:   .54171E-01
                                    C:  -.31853E-06

        Temperature and Charge Mass Information
-----------------------------------------------------
Propellant Mass (g)   :  26.8030      Igniter Mass (g):    .0000
Initial Temp. Prop.(K):  241.         Igniter Temp.(K):  241.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    25.36


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04205S5.OP7
 ********************************************************************************

 ********************************************************************************

     Total # Layers =    1

     Chamber Volume (cm3) =   129.400

     Heat-Loss-Fraction (n-d) =      .000
```

BURNING RATE PLOT 042056S6.out
BURNING RATE (cm/s)
PRESSURE (MPa)
10^-1
10^0
10^1
10^2
10^3
2 3 4 5 6 7 8 9

```
                              ETC BURN RATE ANALYSIS
                                    BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04205S6.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04205S6.pvt           Calculation Output File: 04205S6.out
Smoothed: 04205S6.pdt           Graphics File          : 04205S6.dat
EE  File: A:04205S6.EGY
Fired on: 04/20/95
FIRING REMARKS:
TEMPERATURE SENSITIVITY JA27PERF @ -25F
USED GAGE#2 FOR REDUCTION

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                      PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information               Gage Information
-----------------------------------------------------
Bomb Type    :Closed Chamber        Gage I.D.     : C19928
Bomb Vol (cc):     129.4            Input Voltage:  8.0000
                                    Constants For Fit: A+Bx+C^2
                                    A:   .21637E+00
                                    B:   .54171E-01
                                    C:  -.31853E-06

       Temperature and Charge Mass Information
-----------------------------------------------------
Propellant Mass (g)   :  26.8120      Igniter Mass (g):    .0000
Initial Temp. Prop.(K):  241.         Igniter Temp.(K):  294.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    25.37


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04205S6.OP7
 ********************************************************************************************

 ********************************************************************************************

     Total # Layers =    1

     Chamber Volume (cm3) =   129.400

     Heat-Loss-Fraction (n-d) =      .000
```


BURNING RATE PLOT 042555S7.out
BURNING RATE (cm/s)
PRESSURE (MPa)
10^-1
10^0
10^1
10^2
10^3
10^1
2 3 4 5 6 7 8 9
10^2
2 3 4 5 6 7 8 9
10^3

```
                                BURNING RATE ANALYSIS
                                  BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04255S7.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04255S7.pvt           Calculation Output File: 04255S7.out
Smoothed: 04255S7.pdt           Graphics File         : 04255S7.dat
Fired on:

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                     PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information              Gage Information
-------------------------------------------------
Bomb Type    :Closed Chamber       Gage I.D.    : C20303
Bomb Vol (cc):     129.4           Input Voltage:  8.0000
                                   Constants For Fit: A+Bx+C^2
                                   A:  -.44711E+00
                                   B:   .54134E-01
                                   C:  -.17743E-06

        Temperature and Charge Mass Information
-------------------------------------------------
Propellant Mass (g)   :  27.9590      Igniter Mass (g):    .5750
Initial Temp. Prop.(K):  294.         Igniter Temp.(K):  294.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    26.46


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04255S7.OP7
 ********************************************************************************************

 ********************************************************************************************

     Total # Layers =    1

     Chamber Volume (cm3) =   129.400

     Heat-Loss-Fraction (n-d) =      .000

     Time Step (mil-sec) =   .10000000E-01     Max Time Steps =    1200

     Convergence Criterion =    .10000000E-04
```

BURNING RATE PLOT 042658.out
BURNING RATE (cm/s)
PRESSURE (MPa)

```
                              BURNING RATE ANALYSIS
                                    BRLCB V3.0
                          ADVANCED BALLISTIC CONCEPTS BRANCH - BRL


Project : 120CC CLOSED BOMB     Requested by          : DEL GUERCIO
Inf File: 04265S8.inf           Created From .MAS File : JA27PERF.MAS
P/T File: 04265S8.pvt           Calculation Output File: 04265S8.out
Smoothed: 04265S8.pdt           Graphics File         : 04265S8.dat
Fired on: 04/26/95
FIRING REMARKS:
TEMPERATURE SENSITIVITY CONV. FIRING
JA27PERF @ -25F, used gage#1

                        IGNITER INFORMATION
The Igntier Used Is          : Black Powder         Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

     IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g)        :     290.0 Molecular Weight  :  66.37000
Flame Temperature (K):    2188.0 Covolume (cc/g)   :    .78500
Density (g/cc)       :   1.75000 Gamma             :   1.21840

                      PROPELLANT INFORMATION
The Propellant Used Is          : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

 Propellant Thermochemical Properties: Following
 Sheets of Output

                      PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
          Length --- (cm.):  1.529080
          Outer Diam.(cm.):   .762000
          Perf Diam. (cm.):   .066040
          Inner Web  (cm.):   .130810
          Outer Web  (cm.):   .151130

     Bomb Information               Gage Information
-------------------------------------------------------
Bomb Type     :Closed Chamber       Gage I.D.     : C20303
Bomb Vol (cc):     129.4            Input Voltage:  8.0000
                                    Constants For Fit: A+Bx+C^2
                                    A:  -.44711E+00
                                    B:   .54134E-01
                                    C:  -.17743E-06

        Temperature and Charge Mass Information
-------------------------------------------------------
Propellant Mass (g)   :  26.7890      Igniter Mass (g):    .5410
Initial Temp. Prop.(K):  241.         Igniter Temp.(K):  294.
Initial Bomb Temp. (K):  294.
Number of Propellant Grains:    25.35


Number of Wildpoint Passes:   1 Wildpoint Tolerance:  5.000
Number of Smoothing Passes:   1 Smoothing Option:  1
Bridge Length: 15
1 OUTPUT FILE: 04265s8.op7
 ********************************************************************************************


 ********************************************************************************************


     Total # Layers =    1
```

BURNING RATE PLOT 042755S9.out
BURNING RATE (cm/s)
PRESSURE (MPa)

BURNING RATE ANALYSIS
BRLCB V3.0
ADVANCED BALLISTIC CONCEPTS BRANCH - BRL

Project : 120CC CLOSED BOMB  Requested by : DEL GUERCIO
Inf File: 04275S9.inf  Created From .MAS File : JA27PERF.MAS
P/T File: 04275S9.pvt  Calculation Output File: 04275S9.out
Smoothed: 04275S9.pdt  Graphics File : 04275S9.dat
Fired on: 04/27/95
FIRING REMARKS:
TEMPERSTURE SENSITIVITY, CONV. FIRING
JA27PERF @ 120F, gage#1 used.

IGNITER INFORMATION
The Igntier Used Is : Black Powder  Lot: FFFG
The Source For The Igniter Is: Pellets, Milan Ord.

IGNITER THERMOCHEMICAL PROPERTIES:
Impetus (J/g) : 290.0 Molecular Weight : 66.37000
Flame Temperature (K): 2188.0 Covolume (cc/g) : .78500
Density (g/cc) : 1.75000 Gamma : 1.21840

PROPELLANT INFORMATION
The Propellant Used Is : JA-2 7-PERF GRANULAR Lot: RAD-PE-792-71
The Source For The Propellant Is: RADFORD ARMY AMMUNIT

Propellant Thermochemical Properties: Following
Sheets of Output

PROPELLANT GRAIN GEOMETRY

Grain Type:7-Perf. Cyl.
Length --- (cm.): 1.529080
Outer Diam.(cm.): .762000
Perf Diam. (cm.): .066040
Inner Web (cm.): .130810
Outer Web (cm.): .151130

| Bomb Information | | Gage Information | |
|---|---|---|---|
| Bomb Type | :Closed Chamber | Gage I.D. | : C20303 |
| Bomb Vol (cc): | 129.4 | Input Voltage: | 8.0000 |
| | | Constants For Fit: | A+Bx+C^2 |
| | | A: | -.44711E+00 |
| | | B: | .54134E-01 |
| | | C: | -.17743E-06 |

Temperature and Charge Mass Information

| | | | |
|---|---|---|---|
| Propellant Mass (g) : | 27.0600 | Igniter Mass (g): | .5630 |
| Initial Temp. Prop.(K): | 322. | Igniter Temp.(K): | 294. |
| Initial Bomb Temp. (K): | 294. | | |
| Number of Propellant Grains: | 25.61 | | |

Number of Wildpoint Passes: 1 Wildpoint Tolerance: 5.000
Number of Smoothing Passes: 1 Smoothing Option: 1
Bridge Length: 15
1 OUTPUT FILE: 04275s9.op7
**********

**********

Total # Layers = 1

Chamber Volume (cm3) = 129.400

INTENTIONALLY LEFT BLANK.

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| 3 | DIRECTOR<br>ATTN AMSRL OP SD TL<br>US ARMY RESEARCH LAB<br>2800 POWDER MILL RD<br>ADELPHI MD 20783-1145 |
| 1 | DIRECTOR<br>ATTN AMSRL OP SD TP<br>US ARMY RESEARCH LAB<br>2800 POWDER MILL RD<br>ADELPHI MD 20783-1145 |
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| 2 | DIR USARL<br>ATTN AMSRL OP AP L (305) |

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PO BOX 12211
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27709-2211

1 DIRECTOR
ARMY RESEARCH OFFICE
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PO BOX 12211
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27709-2211

ABERDEEN PROVING GROUND

126 DIR, USARL
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W. STUREK
AMSRL-SC-C, H. BREAUX
AMSRL-SC-CC,
J. GROSH
A. CELMINS
AMSRL-SC-S, A. MARK
AMSRL-SL-B, P. DEITZ (328)
AMSRL-SL-BA, J. MORRISSEY (433)
AMSRL-SL-BG, A. YOUNG (238)
AMSRL-SL-BL, M. RITONDO (328)
AMSRL-SL,BS, D. BELY (328)
AMSRL-SL-BV, R. SANDMEYER (247)
AMSRL-SL-I, M. STARKS (433)
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