FFI RAPPORT

TESTING OF PYROTECHNIC COMPOSITIONS IN CLOSED VESSEL

NEVSTAD Gunnar Ove

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Bjarne Haugstad
Director of Research

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c) Combustion	c) Forbrenning
d) Pressure-time curves	d) Trykk-tid kurver
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8) ABSTRACT

In MP (multipurpose) munitions the nose cap is filled with a pyrotechnic composition that, when it sees certain stimuli, ignite and start burning. This burning is important for how the munitions will function. Compositions based on aluminium, magnesium and aluminium /magnesium powders in combination with potassium perchlorate have been tested.

Compositions with a loading density of up to 0.6 g/cm^3 have been tested in a 150 cm^3 Closed Vessel, and pressure- time curves have been recorded. The tested compositions have different burn rates and ignitability. In addition to the experimentally measured the pressures, we have done some theoretical calculations of the expected pressures by use of the thermochemical code Cheetah.

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TESTING OF PYROTECHNIC COMPOSITIONS IN CLOSED VESSEL

1 INTRODUCTION

The nose cap of MP (multipurpose) munitions is filled with pyrotechnic powder that will ignite and burn when it is exposed to certain stimulus. This burning reaction is important for how and when the other energetic compositions in the projectile will react. To be able to regulate or control the properties of the pyrotechnic powder it's important to know how it reacts after it has been ignited. One way to study the burning properties is by testing the pyrotechnic powder under controlled conditions in a Closed Vessel (CV).

The pyrotechnics we have tested is RS-41 and combination of its main ingredients, magnesium, aluminium and potassium perchlorate. The tests have been carried out with different loading densities and combinations of ingredients. The problem with this kind of energetic materials when they burn is that they give very high temperatures compared to energetic materials based on the elements C, H, N and O. Another difference when they burn is that, instead of giving mainly gas products as does propellants and explosives, pyrotechnics based on metal powders give solid products.

The combination of very high temperature and pressure set strong restrictions on what we can manage to test with regard to loading densities of pyrotechnic compositions without damaging the test equipment. In addition to the experimental testing, we have carried out some theoretical calculations by use of the themochemical code Cheetah to determine what pressures we should expect to measure in the CV.

2 EXPERIMENTAL

2.1 Test performance and conditions

The different compositions have been tested in a 150 cm^3 Closed Vessel. We have used three different CV that should be equal. For some tests we used a steel tube inside the vessel so the vessel should be easier to clean. This tube, when it was new, had a mass of 284.73 g.

The pressure was measured with a Kistler 6211 cell. A blue/brown squib surrounded with 2 g Black Powder (BP) in a plastic bag was used to ignite the tested compositions. Figure 2.1 gives a picture of the used ignition device. In Figure 2.2 is given a picture of the CV just before it should be fired. The green cable is the registration of the pressure, and the grey is for ignition of the squib.

For the majority of experiments the tested powder has been in a plastic bag that surround the squib/BP. For the rest the powder was loosely filled in the vessel.

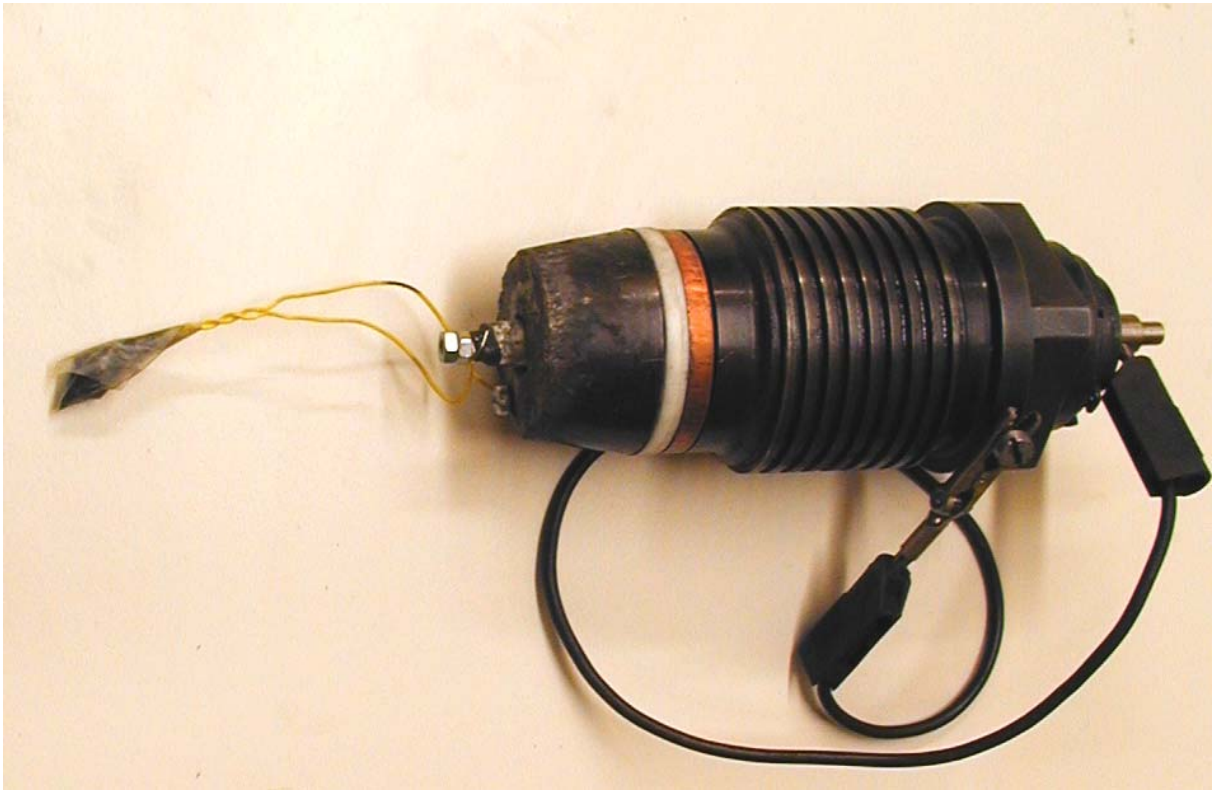

Figure 2.1 Ignition part of the CV, showing the squib surrounded by a plastic bag with the Black Powder.

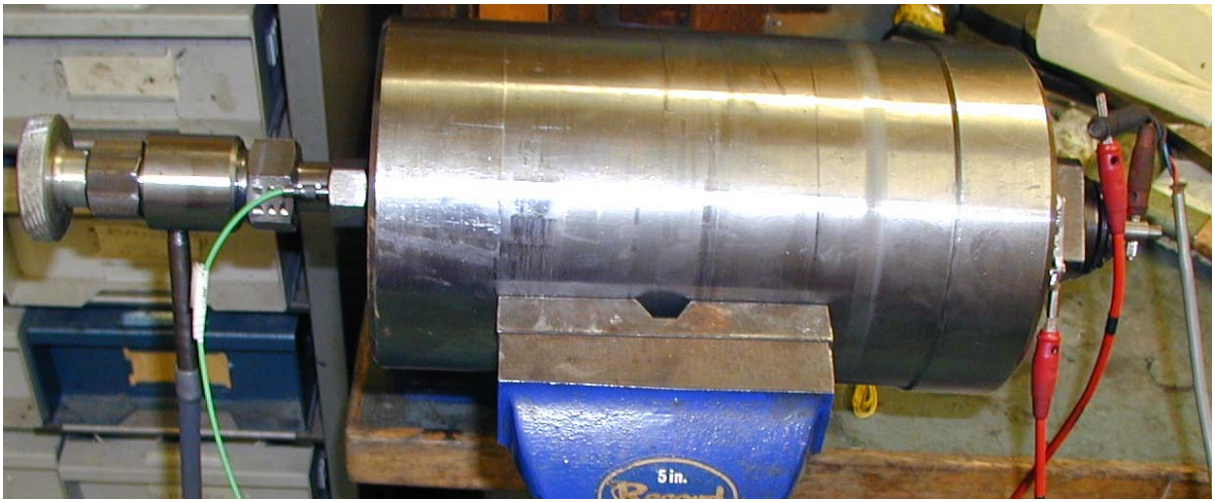

Figure 2.2 The CV ready for firing.

The pressure has been measured every 4 μs and the total number of points has been 65.536. Total sampling time 0.262 s.

2.2 Tested samples

Three composition types have been tested: RS-41, Mg + $KClO_4$ and Al + $KClO_4$. All compositions were received from Nammo Raufoss mixed ready for testing. In addition to the pyrotechnic powder was some M1-propellant fired to check the pressure cell.

The Table 2.1 gives a summary of test conditions and tested compositions.

Firing No	Date	Composition	Vessel	Condition	Weight (g)	Loading Density (g/cm^3)
CV-309	3/11-00	M1	With tube	Loosely powder	24.84	0.2181
CV-310	23/11-00	50/50 Mg-atomized 134648/$KClO_4$ 134302	With tube	Loosely powder	50.0156	0.4392
CV-311	23/11-00	M1-propellant	With tube	Loosely powder	25.09	0.2233
CV-312	23/11-00	P96-29-2 134685 Mg powder ≈ Mg/Al 134582 in particle size, 50 Mg/50 $KClO_4$	With tube	Loosely powder	13.69	0.1202
CV-313	24/11-00		With tube	Loosely powder	22.86	0.2008
CV-314	24/11-00		With tube	Loosely powder	45.56	0.4001
CV-315	5/12-00	P-96-28-2 133516 Al powder ≈ Mg/Al 134582 in particle size, 50 Al/50 $KClO_4$	With tube	Loosely powder	13.79	0.1211
CV-316	5/12-00		With tube	Loosely powder	22.80	0.2002
CV-317	5/12-00		With tube	Loosely powder	45.60	0.4005
CV-318	8/12-00	RS-41 “Skarp” delivered 30.4-98	I	Packed in bag	60.08	0.4005
CV-319	8/12-00		I	Packed in bag	18.03	0.1202
CV-320	8/12-00		I	Packed in bag	30.10	0.2007
CV-321	9/12-00		I	Packed in bag	30.00	0.2000
CV-322	9/12-00		I	Packed in bag	90.00	0.6000
CV-323	31/1-01	P-96-28-2 133516 Al powder ≈ Mg/Al 134582 in particle size, 50 Al/50 $KClO_4$	I	Packed in bag	30.00	0.2000
CV-324	31/1-01		I	Packed in bag	18.11	0.1207
CV-325	01/02-01	P-96-28-1 133516 Al powder ≈ Mg/Al 134582 in particle size, 49 Al/49 $KClO_4$/2 Res	II	Packed in bag	60.11	0.4007
CV-326	01/02-01		II	Packed in bag	18.11	0.1207
CV-327	01/02-01		II	Packed in bag	60.08	0.4005
CV-328	2/2-01	P96-29-1 134685 Mg powder ≈ Mg/Al 134582 in particle size, 49 Al/49 $KClO_4$/2 Res	III	Packed in bag	18.08	0.1205
CV-329	2/2-01		III	Packed in bag	30.15	0.2010
CV-330	2/2-01		III	Packed in bag	60.00	0.4000

‘Volume tube 36.0418 cm^3.

Table 2.0.1 Firing conditions for performed Closed Vessel firings.

3 RESULTS

3.1 Mg and $KClO_4$ mixtures

We have used three different mixtures of magnesium and potassium perchlorate. Test conditions is given in Table 2.1. The results from the firings are summarised in Table 3.1.

Firing No	Composition	Weight (g)	Load density (g/cm^3)	Reaction	Maximum Pressure (bars)
CV-310	50/50 Mg-atomised 134648/ $KClO_4$ 134302	50.0156	0.4392	Very fast	
CV-312	P96-29-2 134685 Mg powder ≈ Mg/Al 134582 in particle size, 50 Mg/50 $KClO_4$	13.69	0.1202	Normal	327
CV-313		22.86	0.2008	Normal	480.5
CV-314		45.56	0.4001	Normal	795
CV-328	P96-29-1 134685 Mg powder ≈ Mg/Al 134582 in particle size 49 Al/49 $KClO_4$/2 Ca-Resinate	18.08	0.1205	Normal	458.5
CV-329		30.15	0.2010	Normal	649
CV-330		60.00	0.4000	Fast	1264.5

Table 3.1 Properties of the firings containing Mg.

The first shot, having a loading density of 0.44 g/cm^3, did react very fast and the reaction is more like a deflagration than a burn, Figure 3.1. The pressure-time curves for all firings are given in Figure 3.1 to 3.7. For all firings with Mg-powder/$KClO_4$ the ignition of the mixture takes place instantaneous with no delay.

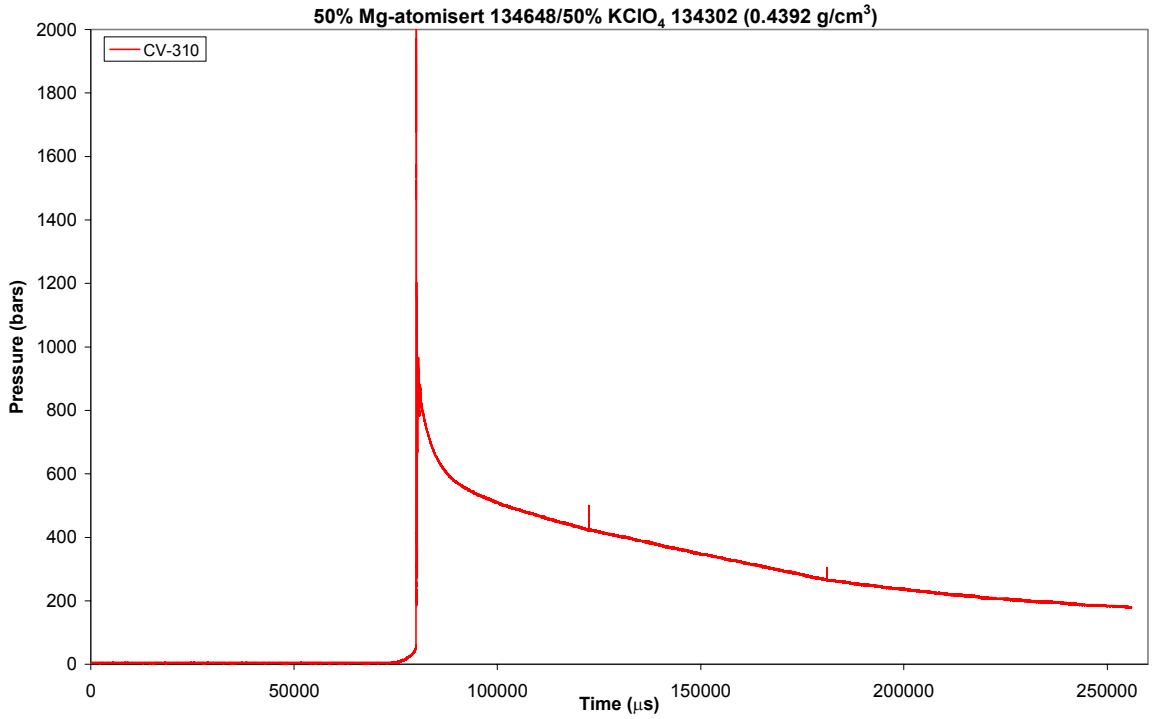

Figure 3.1 Pressure-time curve for firing CV-310, load density 0.4382 g/cm^3, 50/50 atomised Mg and $KClO_4$.

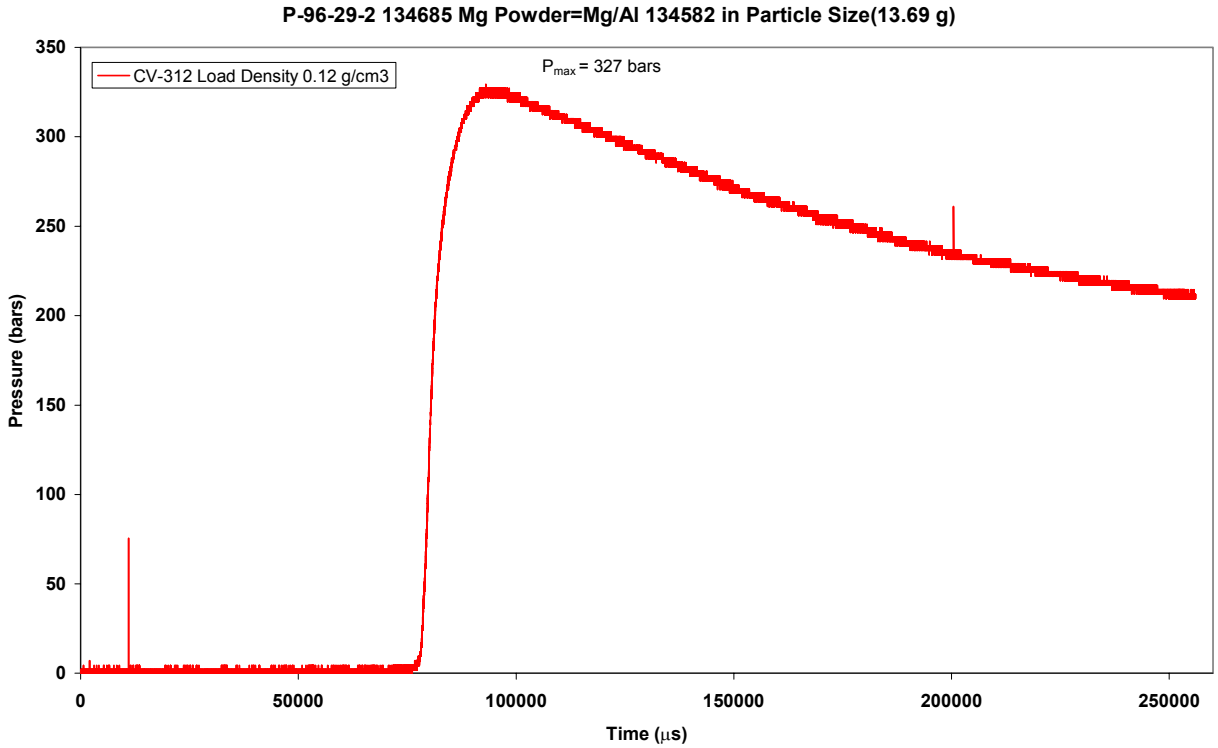

Figure 3.2 Pressure-time curve for firing CV-312, 50/50 Mg/$KClO_4$, load density 0.12 g/cm^3.

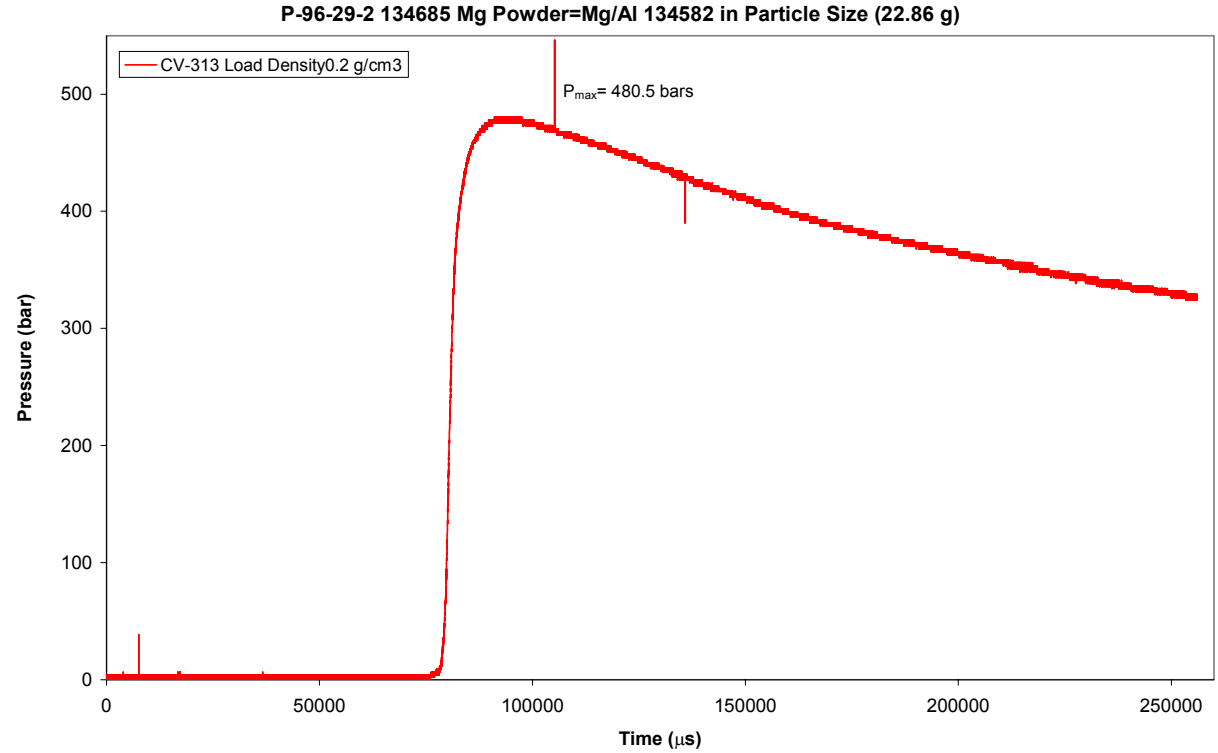

Figure 3.3 Pressure-time curve for firing CV-313, 50/50 Mg/$KClO_4$, load density 0.20 g/cm^3.

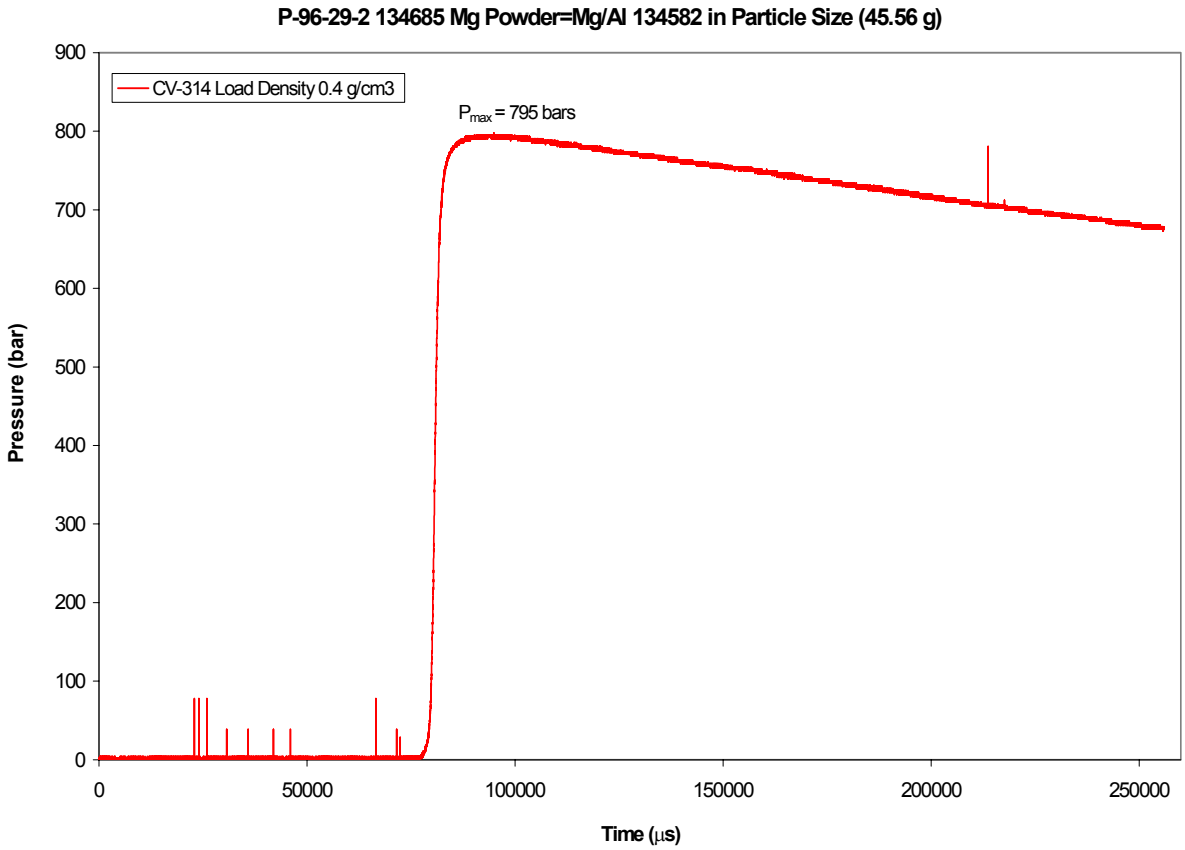

Figure 3.4 Pressure-time curve for firing CV-314, 50/50 Mg/$KClO_4$, load density 0.40 g/cm^3.

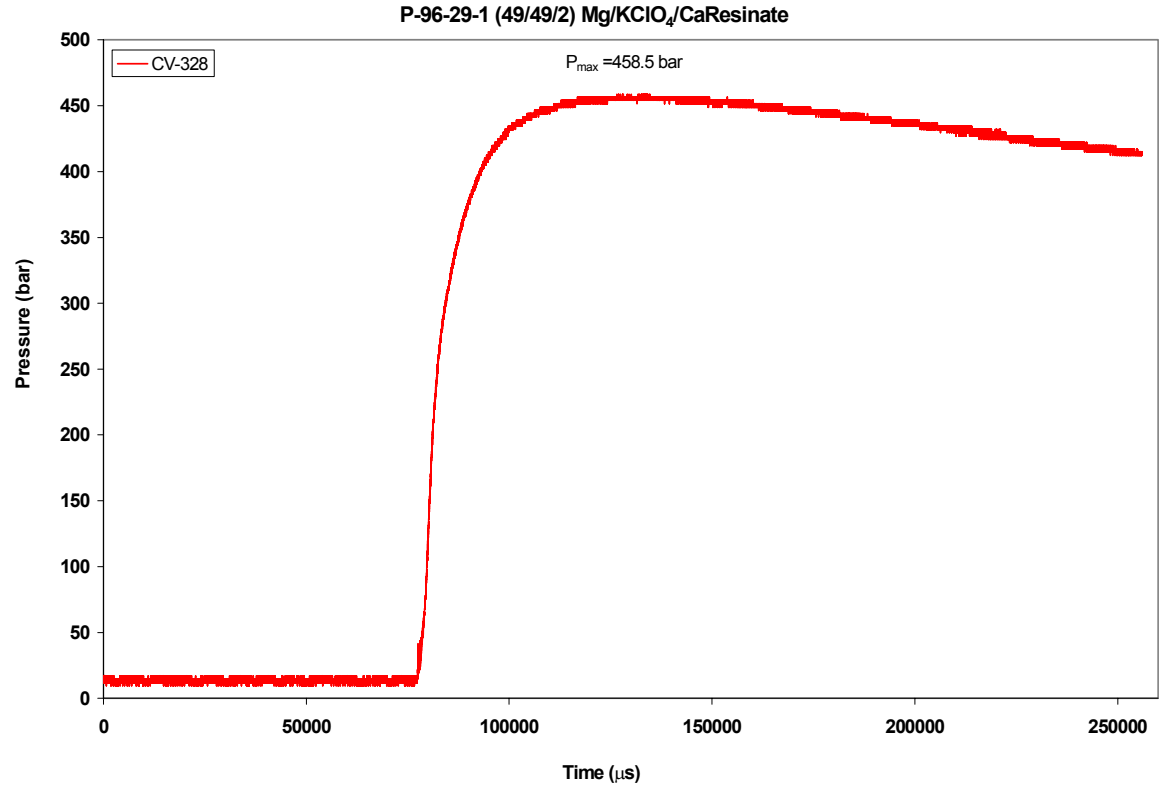

Figure 3.5 Pressure-time curve for firing CV-328, 49/49/2 Mg/$KClO_4$/Ca-res, load density 0.12 g/cm^3.

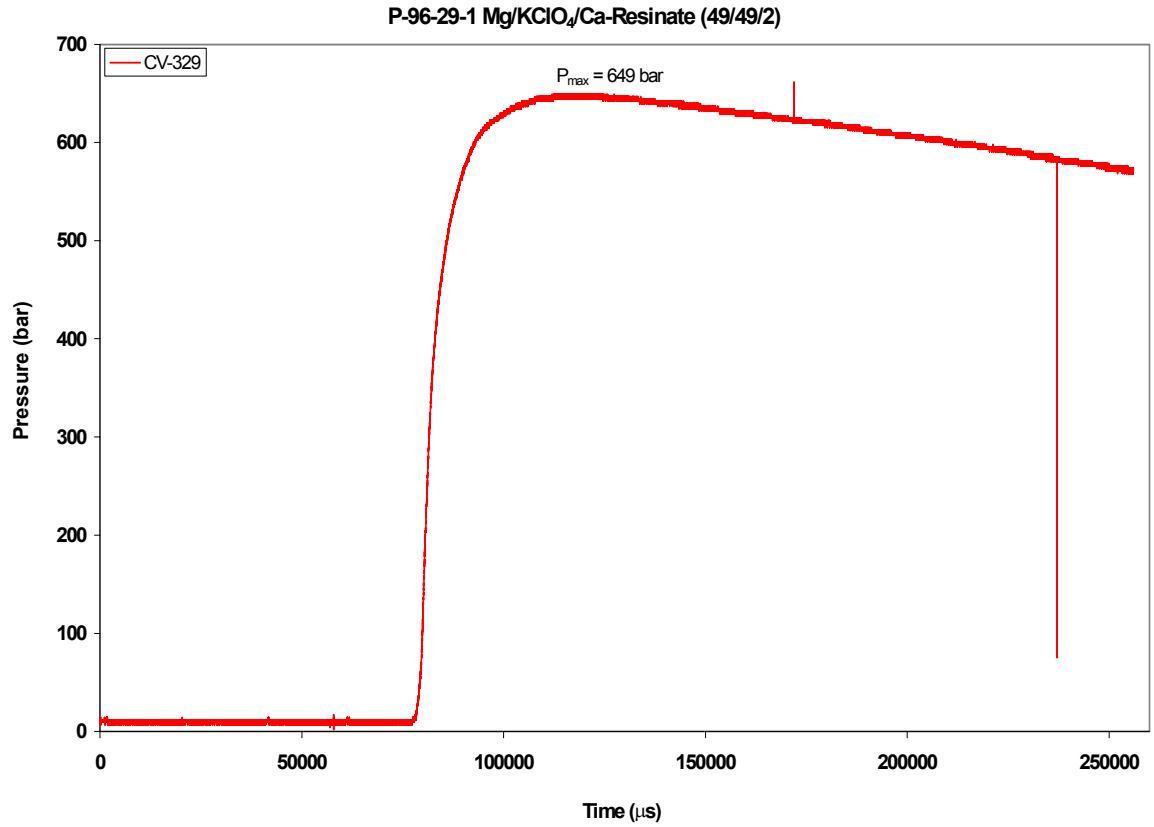

Figure 3.6 Pressure-time curve for firing CV-329, 49/49/2 Mg/$KClO_4$/Ca-res, load density 0.2 g/cm^3.

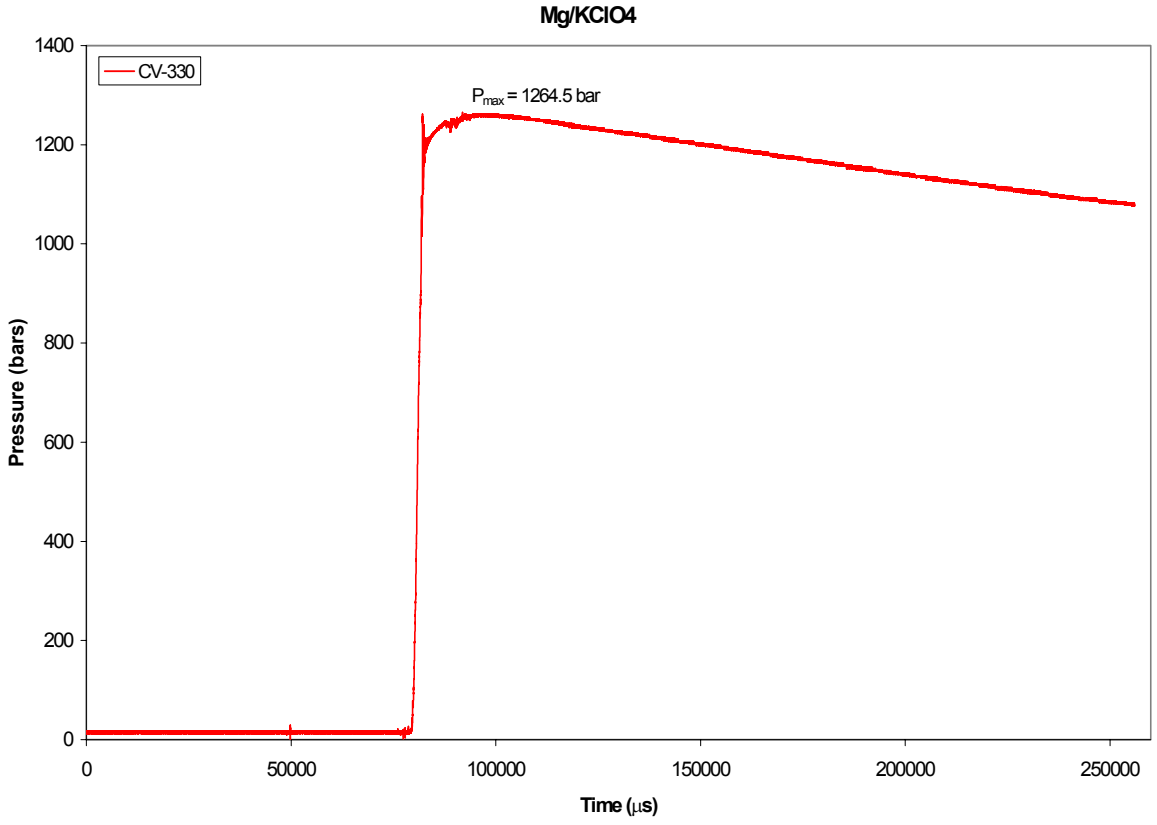

Figure 3.7 Pressure-time curve for firing CV-330, 49/49/2 Mg/$KClO_4$/Ca-res, load density 0.40 g/cm^3.

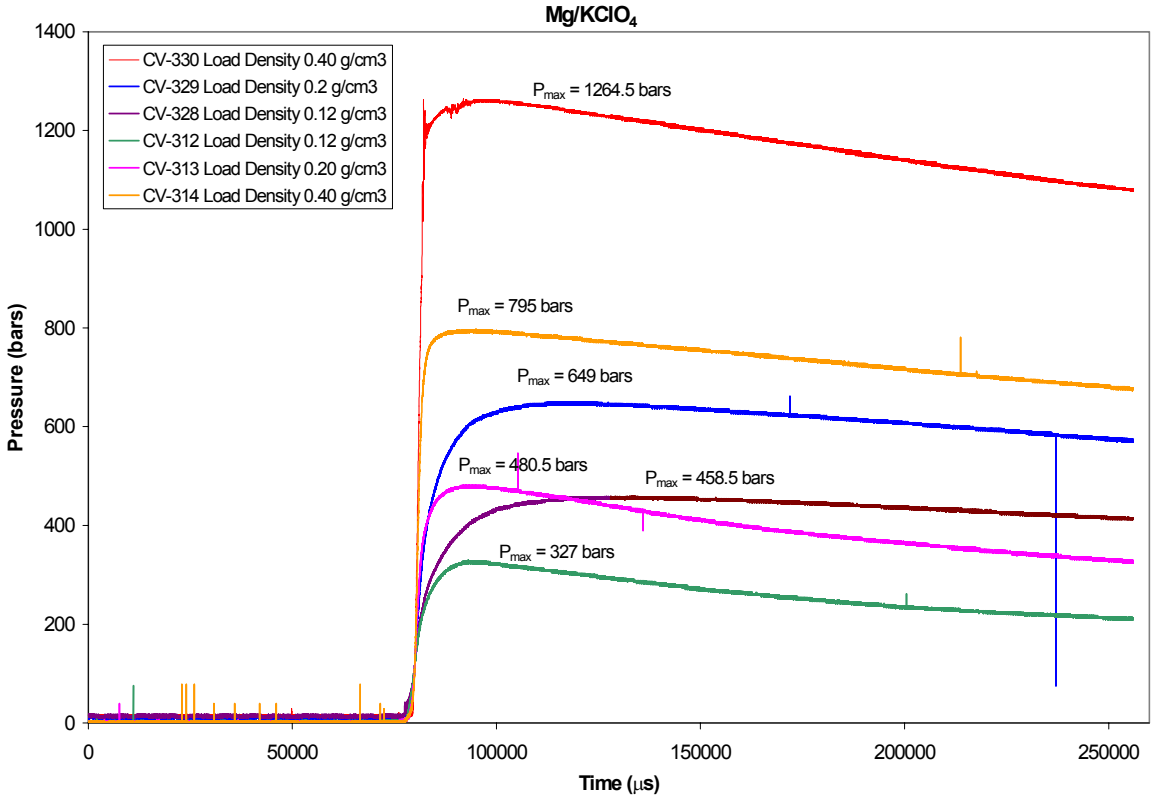

Figure 3.8 Pressure-time curves for all CV- firings containing Mg/KClO4.

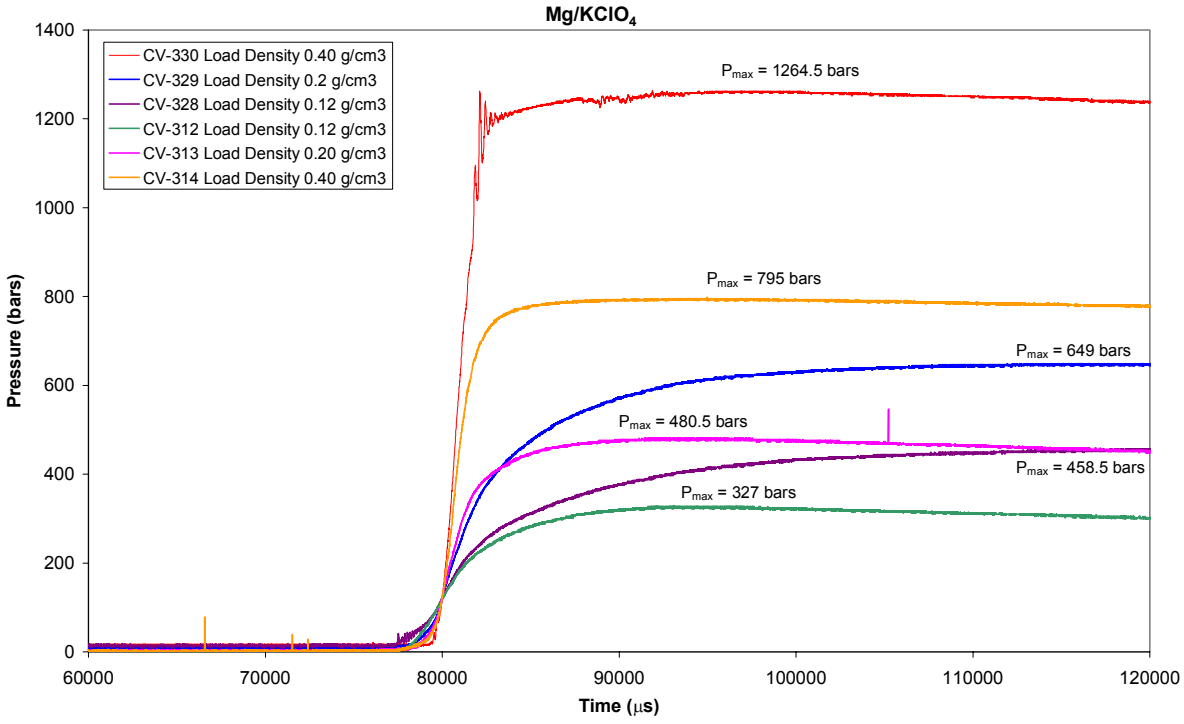

Figure 3.9 Parts of the pressure-time curves given in Figure 3.8.

For the firings (CV-312, CV-313, CV-314), where we use a steel tube inside the vessel to protect the vessel and facilitate the cleaning process, we have obtained lower maximum pressures than for the firings without the steel tube. Another difference between the results for these two series of firings is the form of the curves. The two firings with lowest loading densities have slower pressure rise with no steel tube in the vessel than the firings with steel

tube in the vessel. The exception is for the highest load density, firing CV-330, which for the first part of the reaction has a fast burning or a tendency towards a deflagration reaction, Figure 3.8. One difference between the powders used in these two series is that the one carried out with the steel tube in the vessel does not contain Ca-resinate. In Figure 3.10 we have

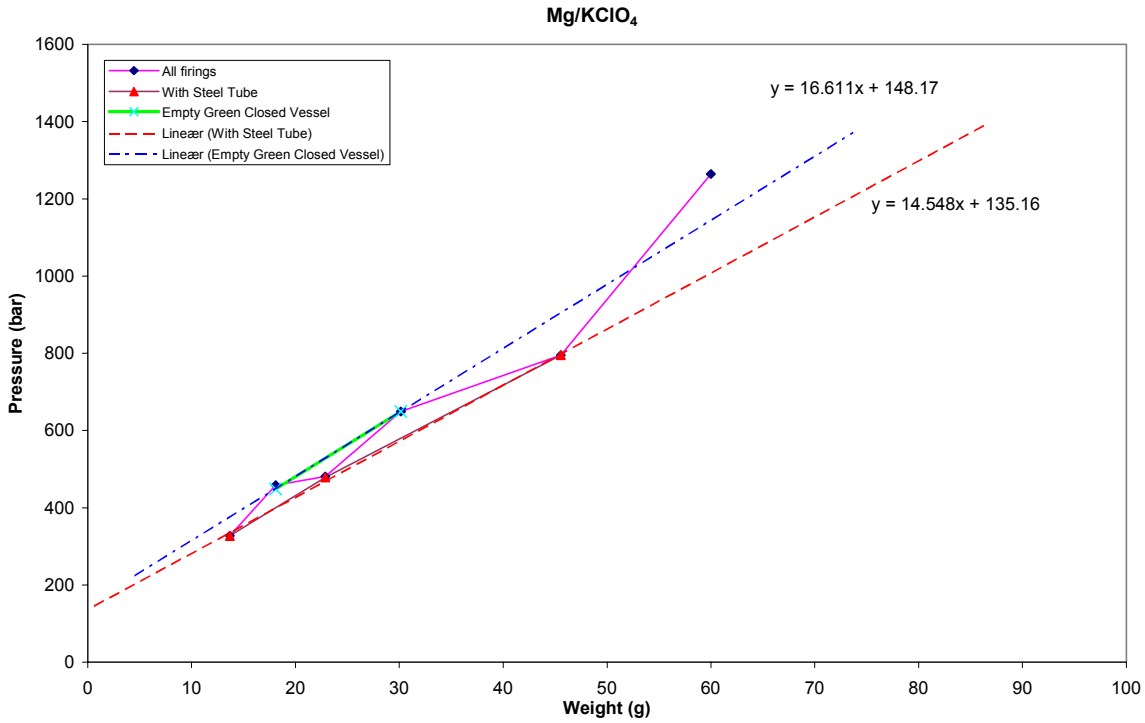

Figure 3.10 Maximum pressures as function of weights of magnesium compositions.

plotted maximum pressure as function of loaded amount of powder used in each firing. The pressures for the first series of firings (CV-312 – CV-314) lie on more or less a straight line. However, all points lie well below the second series of firings, especially if we take the chamber volume into consideration. The firings with the steel tube inside the CV have a much smaller volume available for the combustion products than the firings performed with a clean CV without the steel tube.

For the second series of firings the pressures do not lie on a straight line, the firing with load density 0.40 g/cm^3 (or 60 g) does deviate. This deviation can by looking on the pressure-time curves be explained by another reaction for CV-330 than for the other firings.

However, another strange observation for the firings of the Mg/$KClO_4$ compositions is, that the pressure does not increase exponentially with increasing loading density as it does for propellants and other CHNO-compositions.

3.2 Al and $KClO_4$ mixtures

For aluminium we have used two different mixtures, one with calcium resinate, and one mixture without Ca-resinate. Table 3.2 gives a summary of the measured pressures and other information about the firings. Figure 3.11 to 3.18 gives all pressure-time curves. Figure 3.19 and 3.20 give a summery of all curves. The trends for the firings with Al-powder are more or less the same as for the firings with Mg-powder. In general the firings with steel tube in the CV give significantly lower pressures than the firings without. Firings where the composition contains Ca-resinate, give slightly higher pressures.

Firing No	Composition	Weight (g)	Load density (g/cm^3)	Reaction	Maximum Pressure (bars)
CV-315	P-96-28-2 133516 Al powder ≈	13.79	0.1211	Normal	197.5
CV-316	Mg/Al 134582 in particle size	22.80	0.2002	Very fast	~480
CV-317	50 Al/50 $KClO_4$	45.60	0.4005	Normal	571
CV-323	P-96-28-2 133516 Al powder ≈	30.00	0.2000	Normal	463.5
CV-324	Mg/Al 134582 in particle size 50 Al/50 $KClO_4$	18.11	0.1207	Normal	319
CV-325	P-96-28-1 133516 Al powder ≈	60.11	0.4007	Normal	875
CV-326	Mg/Al 134582 in particle size	18.11	0.1207	Normal	356
CV-327	49 Al/49 $KClO_4$/2 Ca-Resinate	60.08	0.4005	Normal	937.5

Table 3.2 Properties of Closed Vessel firings of compositions containing aluminium.

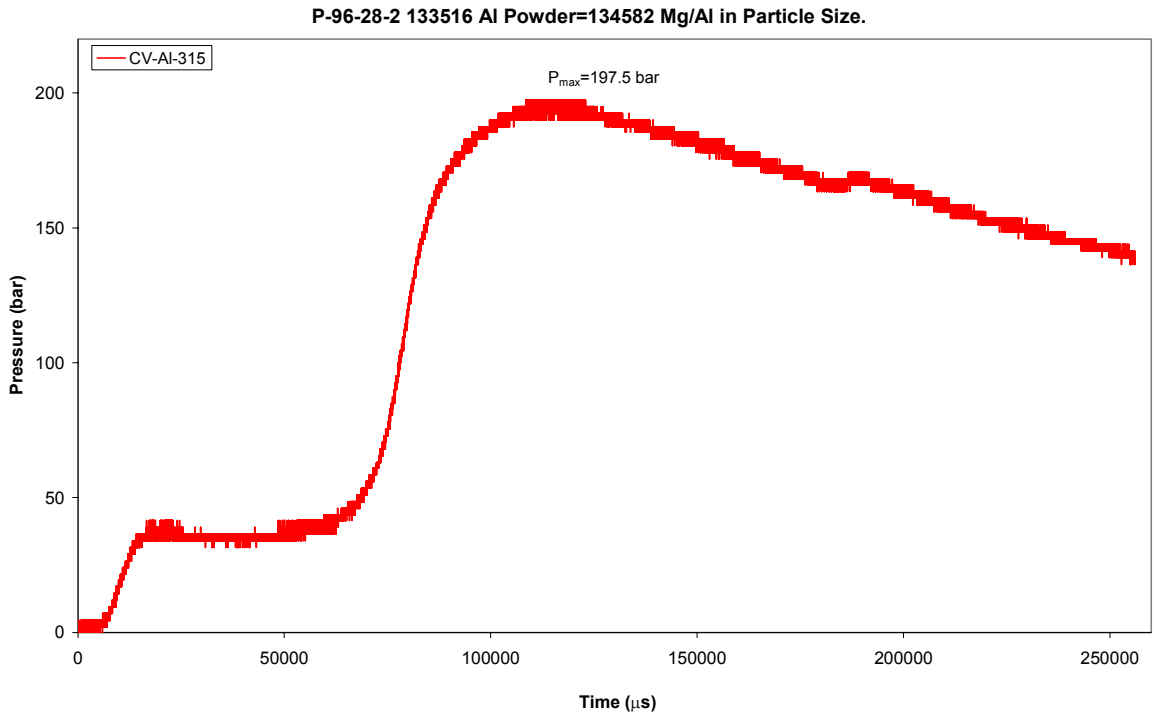

Figure 3.11 Pressure-time curve for firing CV-315, 50/50 Al/$KClO_4$, load density 0.12 g/cm^3.

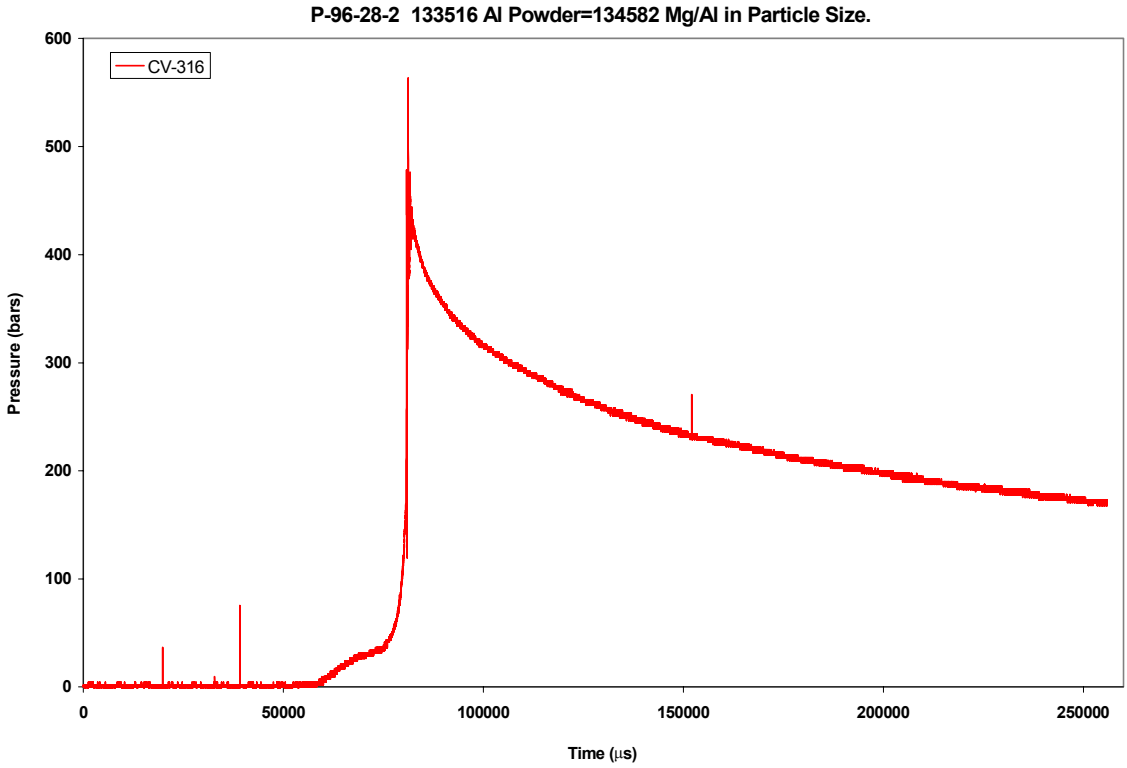

Figure 3.12 Pressure-time curve for firing CV-316, 50/50 Al/$KClO_4$, load density 0.20 g/cm^3.

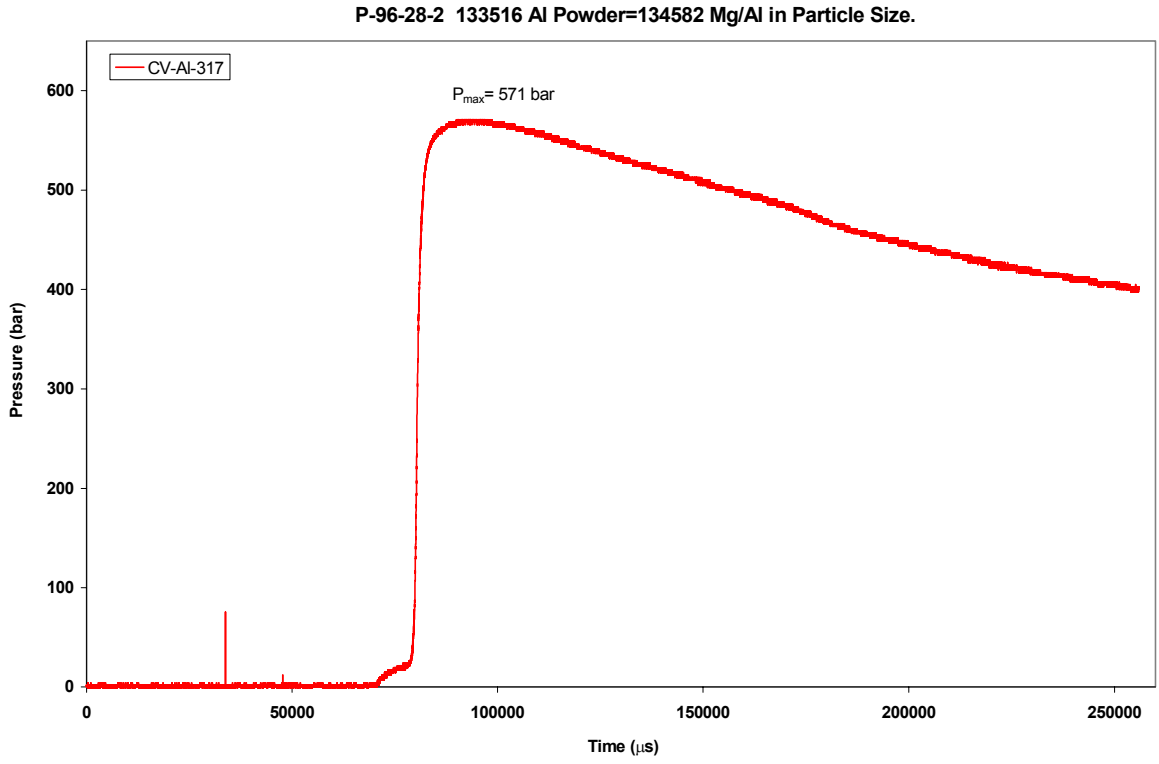

Figure 3.13 Pressure-time curve for firing CV-317, 50/50 Al/$KClO_4$, load density 0.40 g/cm^3.

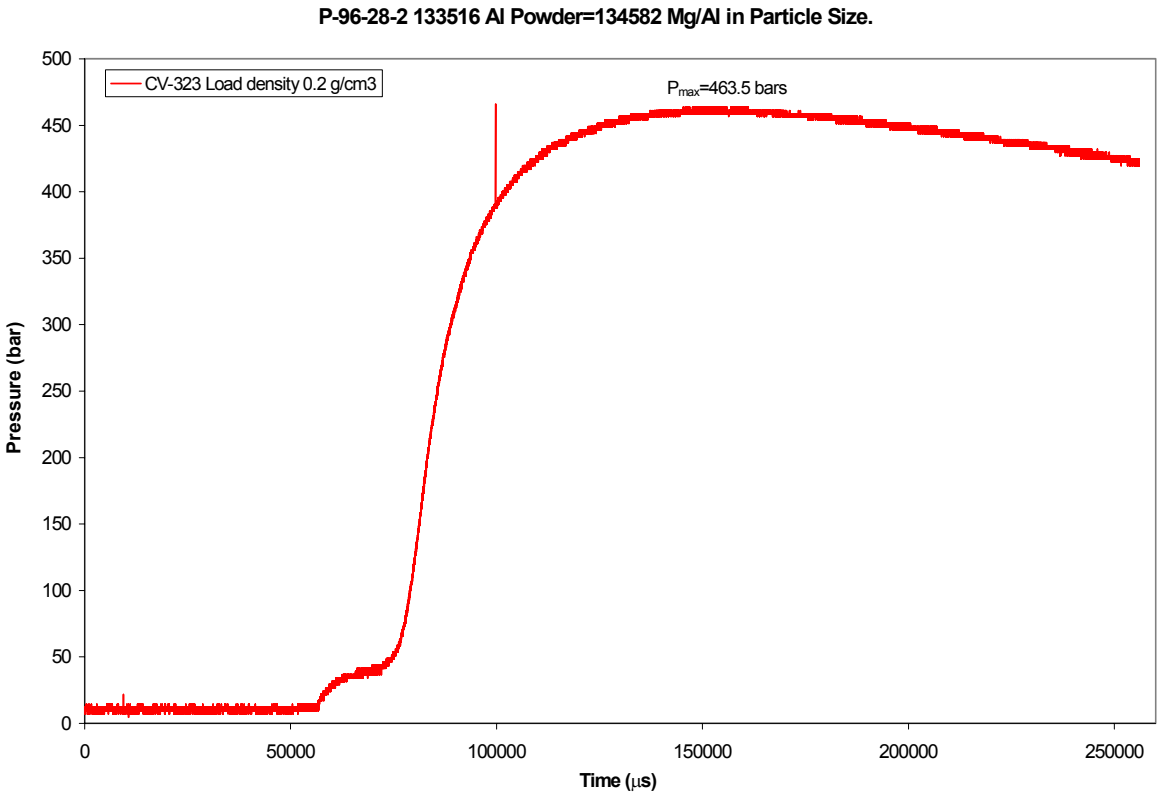

Figure 3.14 Pressure-time curve for firing CV-323, 50/50 Al/$KClO_4$, load density 0.20 g/cm^3.

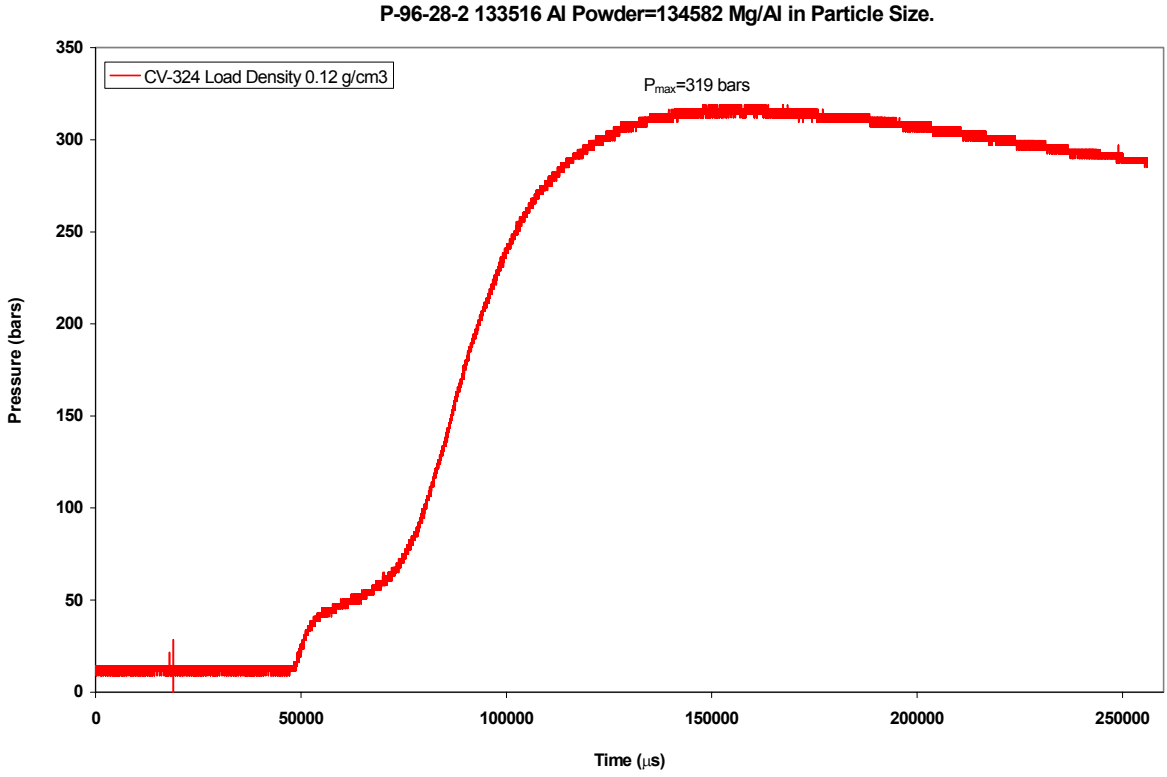

Figure 3.15 Pressure-time curve for firing CV-324, 50/50 Al/$KClO_4$, load density 0.12 g/cm^3.

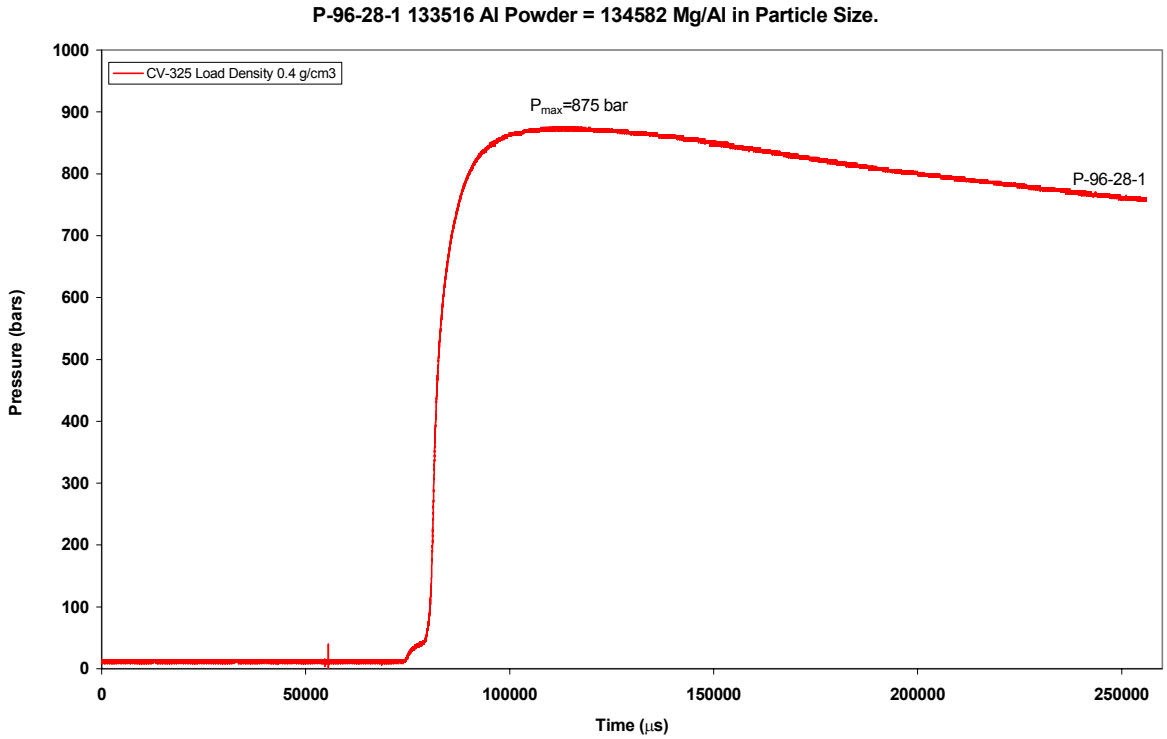

Figure 3.16 Pressure-time curve CV-325, 49/49/2 Al/$KClO_4$/Ca-res, load density 0.40 g/cm^3

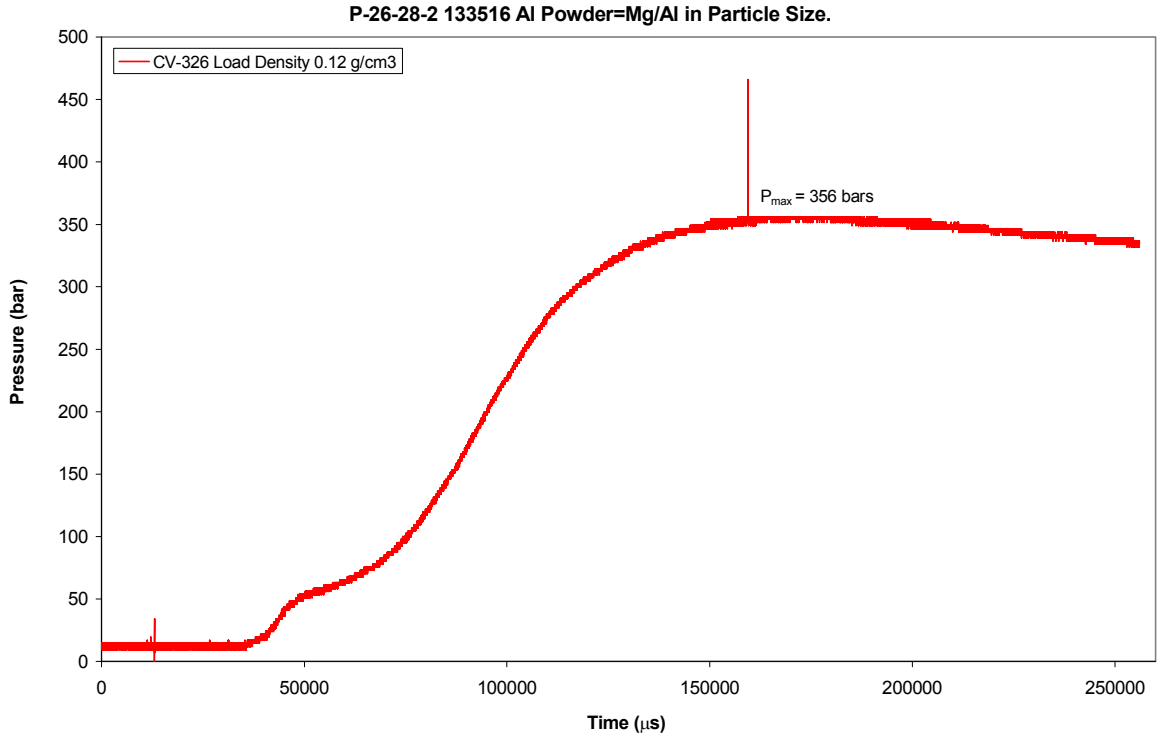

Figure 3.17 Pressure-time curve for firing CV-326, 49/49/2 Al/$KClO_4$/Ca-res, load density 0.12 g/cm^3

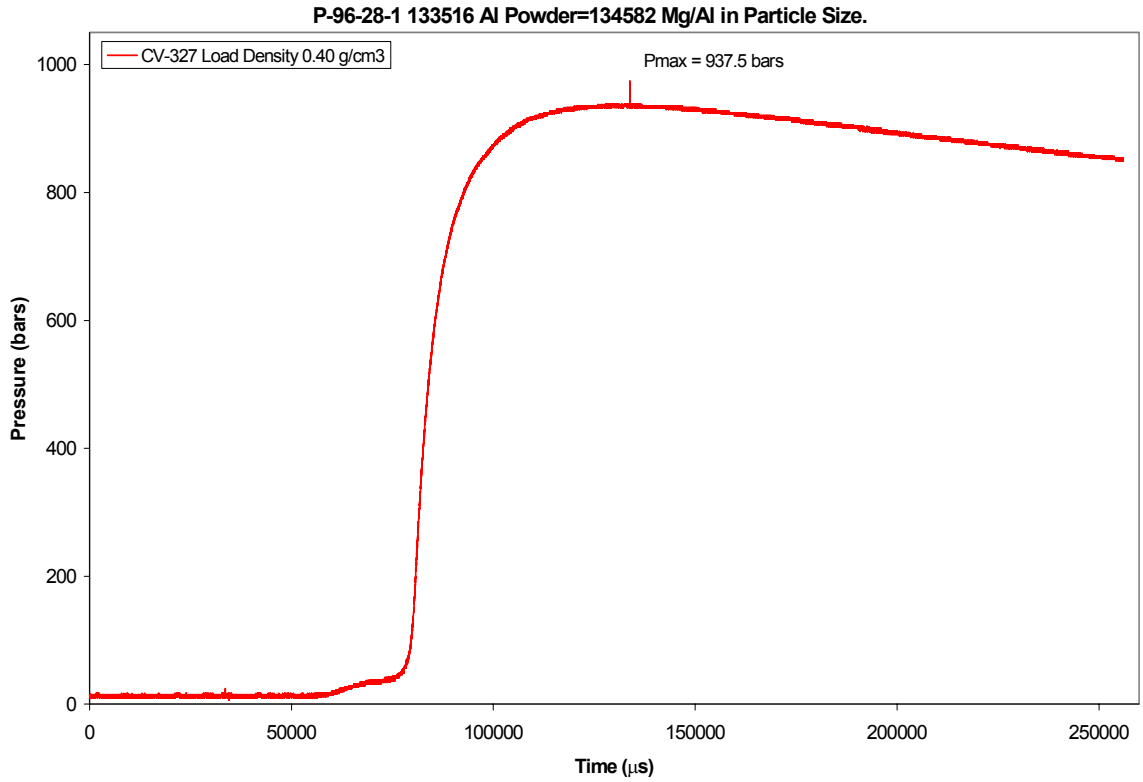

Figure 3.18 Pressure-time curve for firing CV-327, 49/49/2 Al/$KClO_4$/Ca-res, load density 0.40 g/cm^3.

As for the Mg-powder firings, gives one of the firing with Al-powder, firing CV-316, a reaction that is faster than normal burning. This firing was carried out with a steel tube inside the CV and loosely loaded powder.

One difference between the pressure-time curves for Mg and Al is that for the Al–curves the ignition is much slower than for Mg. After the BP has been ignited there is a delay in the ignition of the composition of up to 60.000 µs for CV-315, the firing that has the lowest amount of powder. For CV-315 the powder was loosely loaded. However, since the other two firings with loosely load powder, CV-316 and CV-317, are among the firings having fastest ignition, it may not explain the observed delay.

All firings with aluminium/potassium perchlorate give significantly lower maximum pressure, burn rate or reaction rate than similar compositions containing Mg instead of Al.

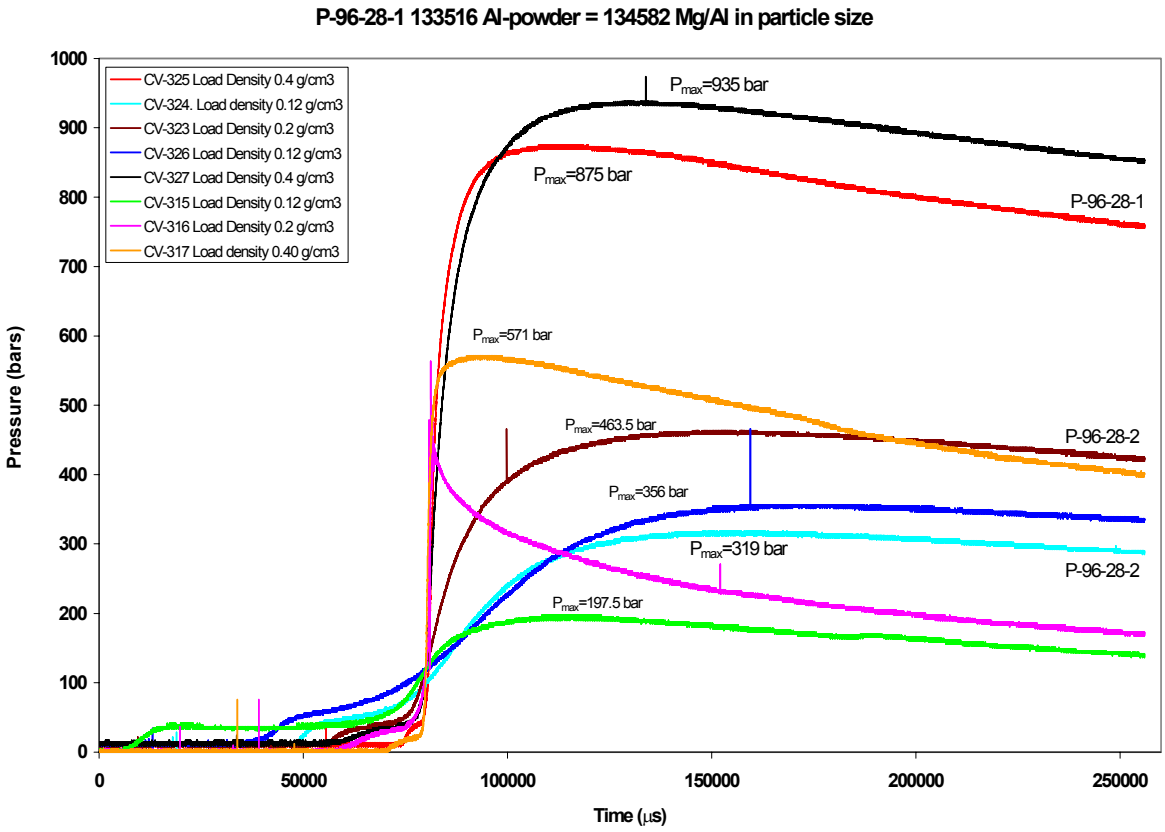

Figure 3.19 Pressure-time curves for all firings with aluminium.

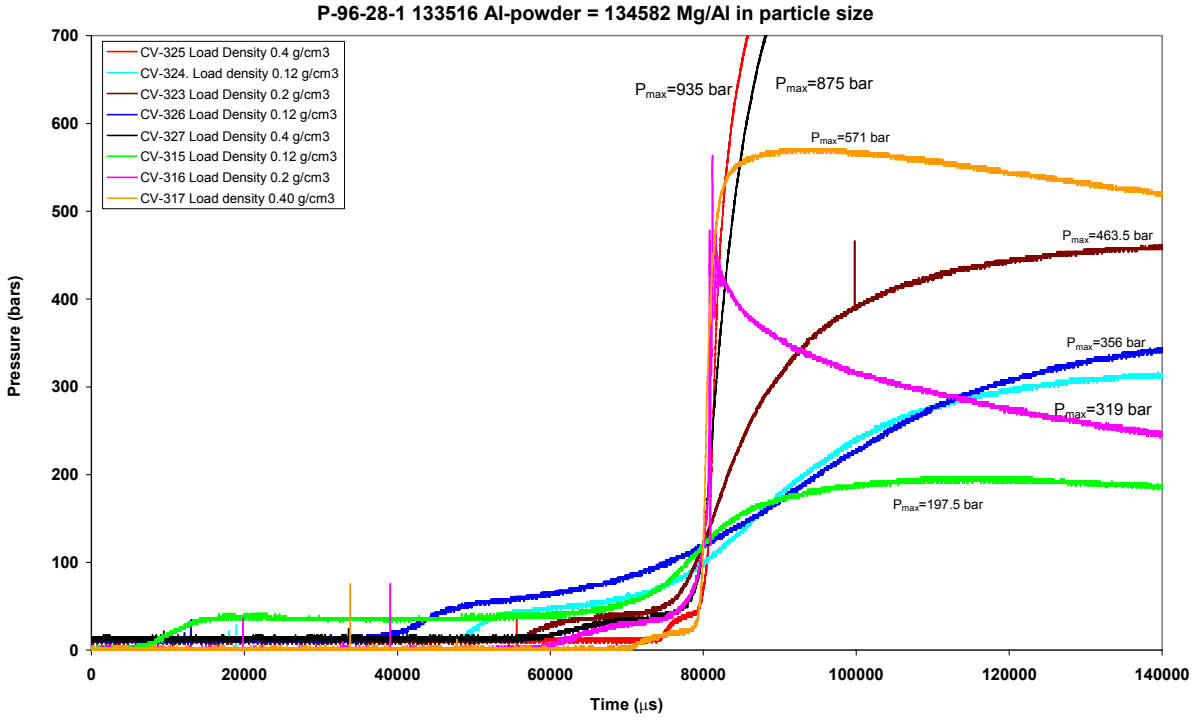

Figure 3.20 Parts of the pressure-time curves given in Figure 3.19 enlarged.

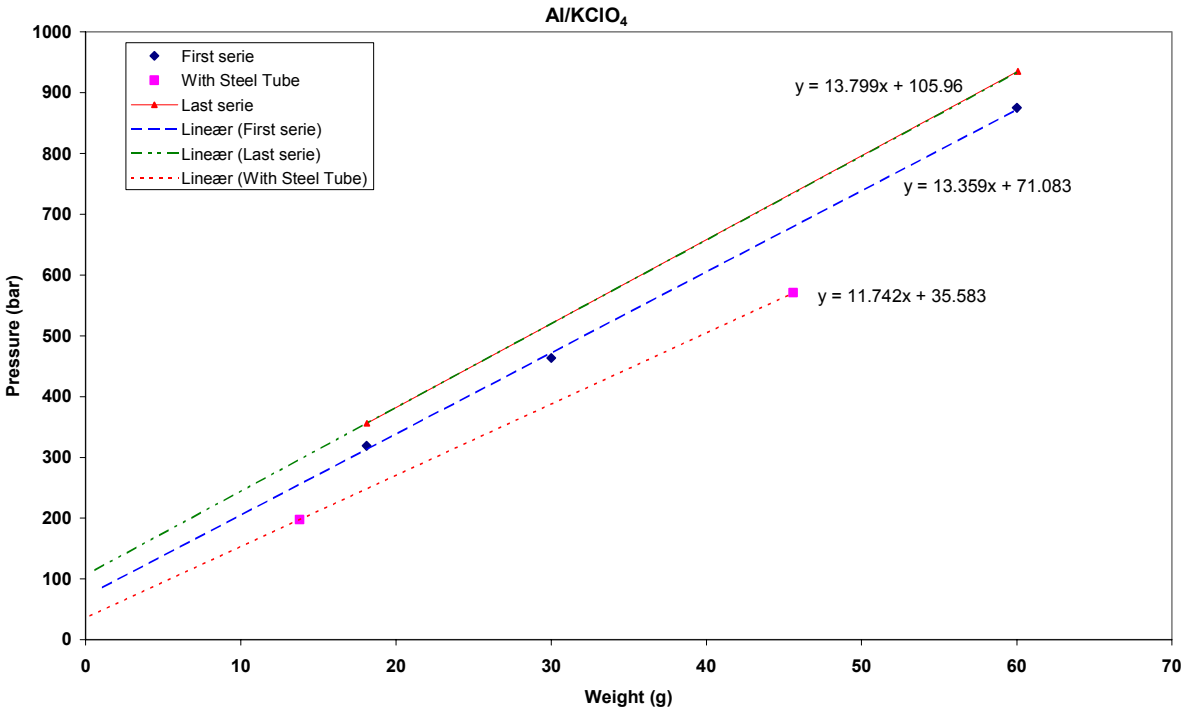

Figure 3.21 Maximum pressure as function of weight of aluminium powder for firings containing aluminium and potassium perchlorate (1/1).

In Figure 3.21 maximum pressure as function of the loaded amount of powder for most firings has been plotted. Firings under the same conditions can be connected with straight lines that are nearly parallel to each other. Why we obtain these lines is difficult to explain but one of the reasons may be that the consumption of material is not complete.

3.3 RS-41

For the composition RS-41 (24.5 wt.% Al/24.5 wt.% Mg/2 wt.% Resinate/49 wt.% $KClO_4$) all tests have been done in a clean vessel without any steel tube. We have performed 5 firings with RS-41. For firing CV-320 we got a leakage of the vessel. However, the part of the reaction we were able to register did follow the same pressure increase as for firing CV-321. CV-321 was a repetition of the CV-320 firing. For the other firings, CV-318 has an

Firing No	Composition	Weight (g)	Load density (g/cm^3)	Reaction	Maximum Pressure (bars)
CV-318	RS-41 "Skarp" delivered 30.4-98	60.08	0.4005	Fast	1186.5
CV-319		18.03	0.1202	Normal	317
CV-320		30.10	0.2007	Normal	444*
CV-321		30.00	0.2000	Normal	539.5
CV-322		90.00	0.6000	Normal	1604

*Leakage in the vessel

Table 3.3 Results and properties of CV-firings with RS-41 powder.

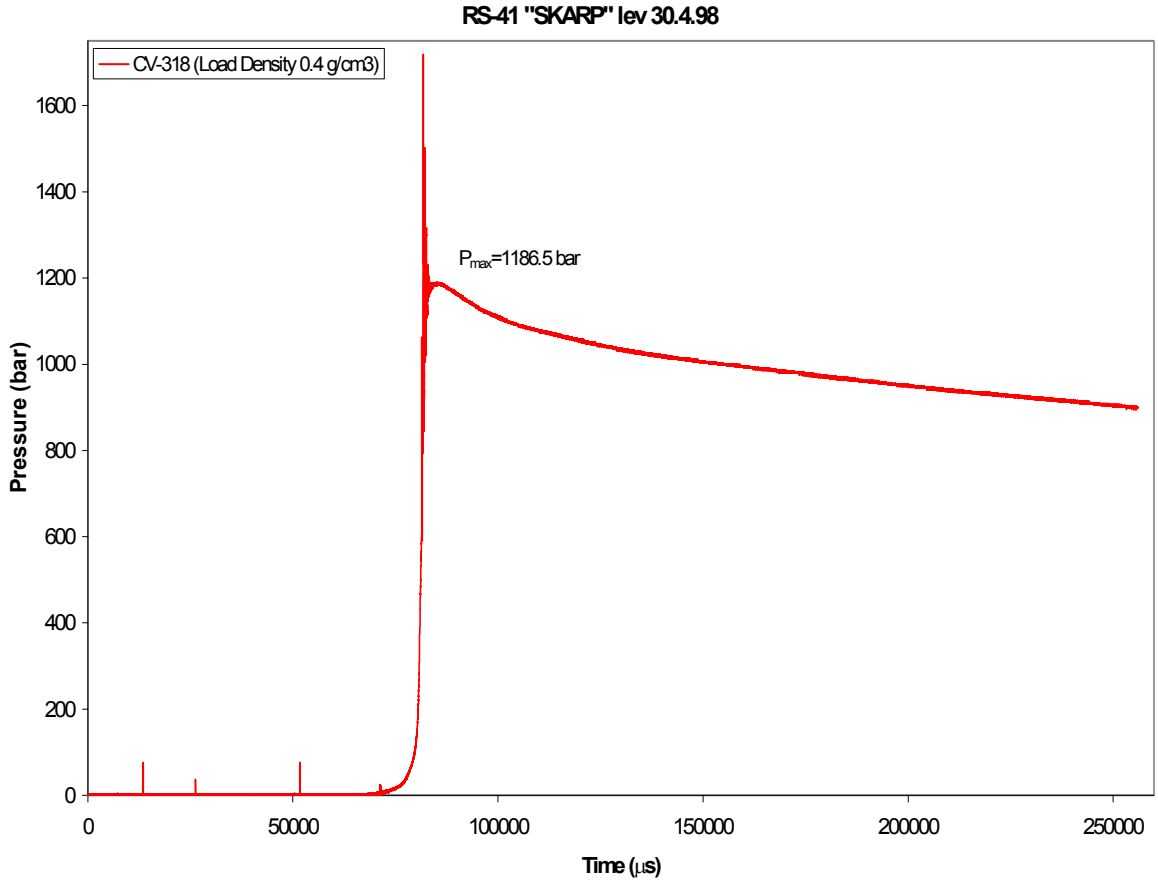

Figure 3.22 Pressure-time curve for firing CV-318, RS-41, load density 0.40 g/cm^3.

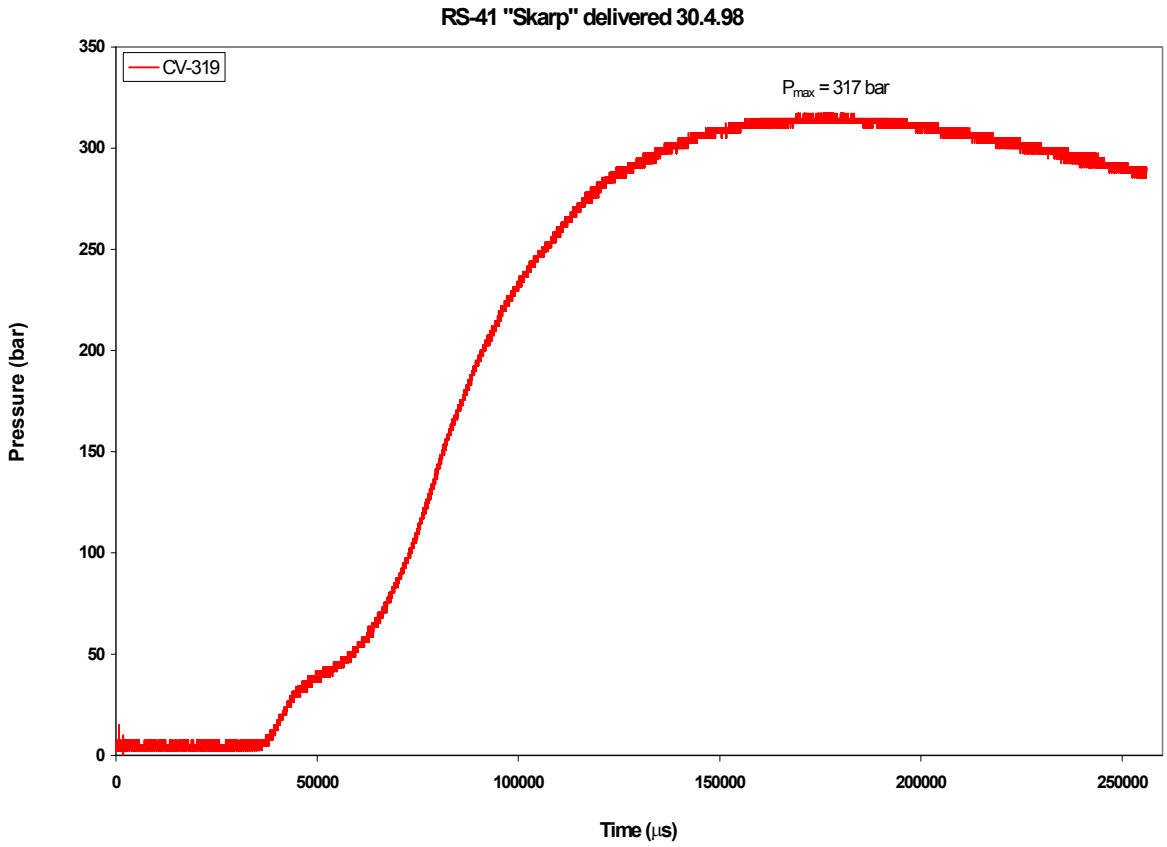

Figure 3.23 Pressure-time curve for firing CV-319, RS-41, load density 0.12 g/cm^3.

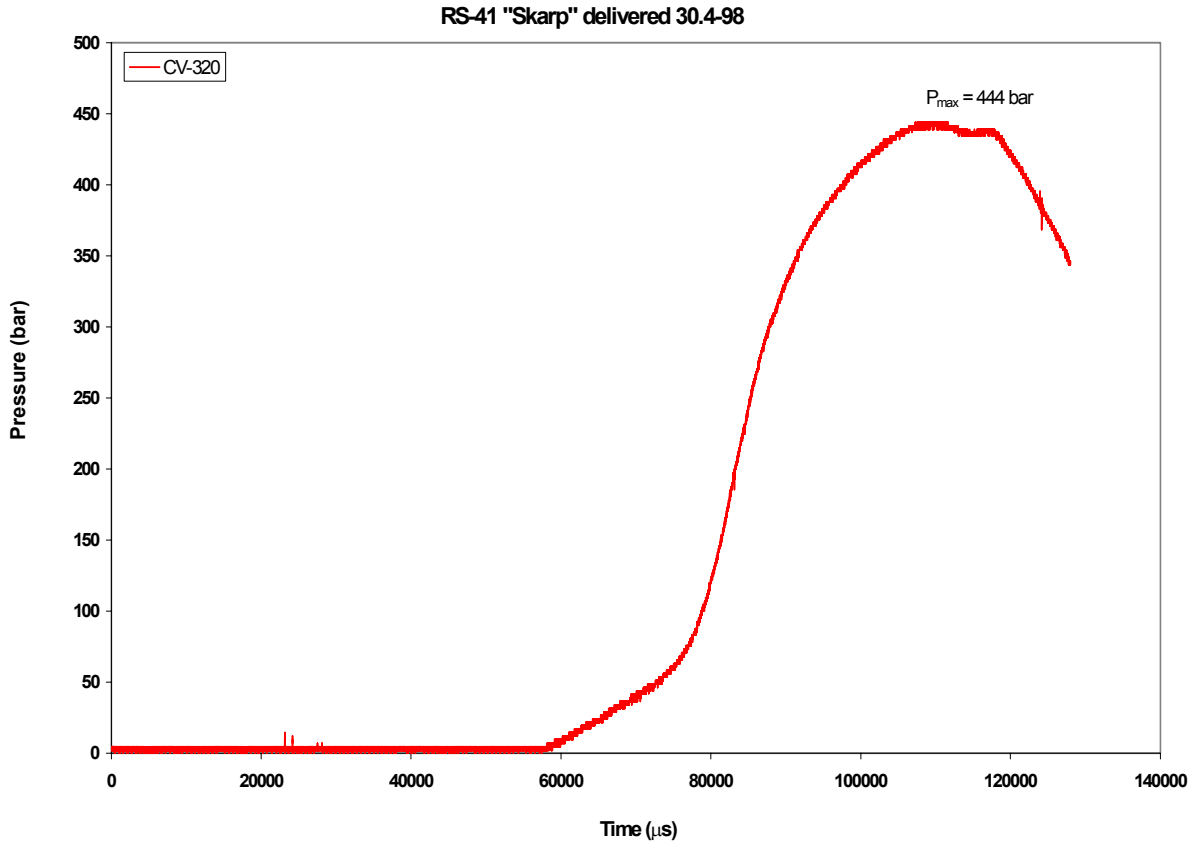

Figure 3.24 Pressure-time curve for firing CV-320, RS-41, load density 0.20 g/cm^3.

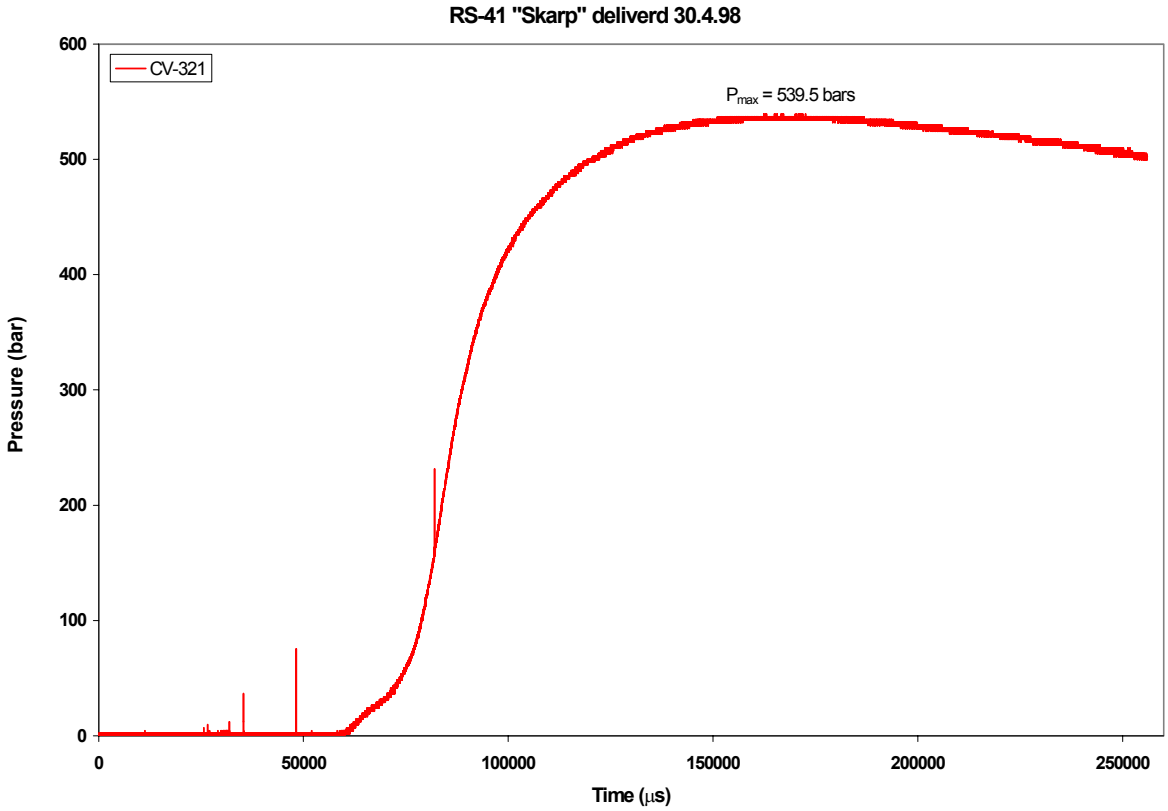

Figure 3.25 Pressure-time curve for firing CV-321, RS-41, load density 0.20 g/cm^3

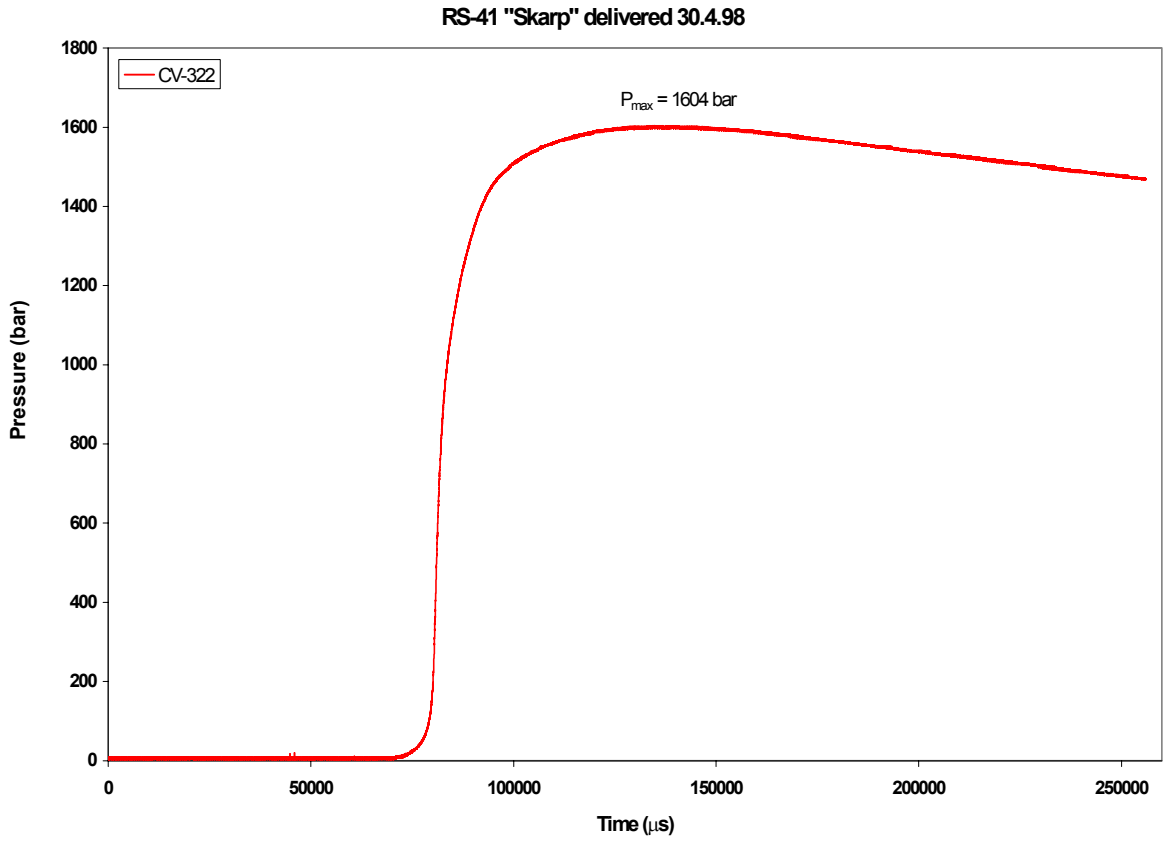

Figure 3.26 Pressure-time curve for firing CV-322, RS-41, load density 0.60 g/cm^3.

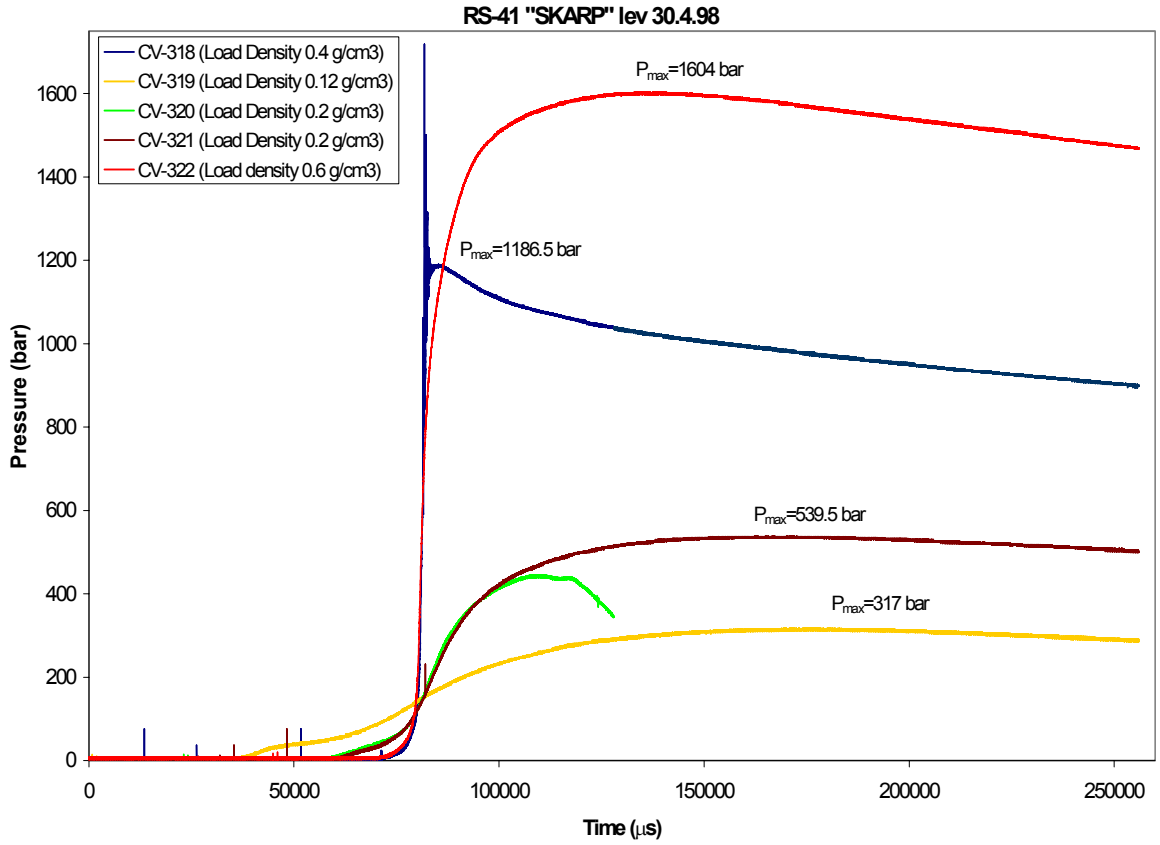

Figure 3.27 Pressure-time curves for CV-firings with RS-41.

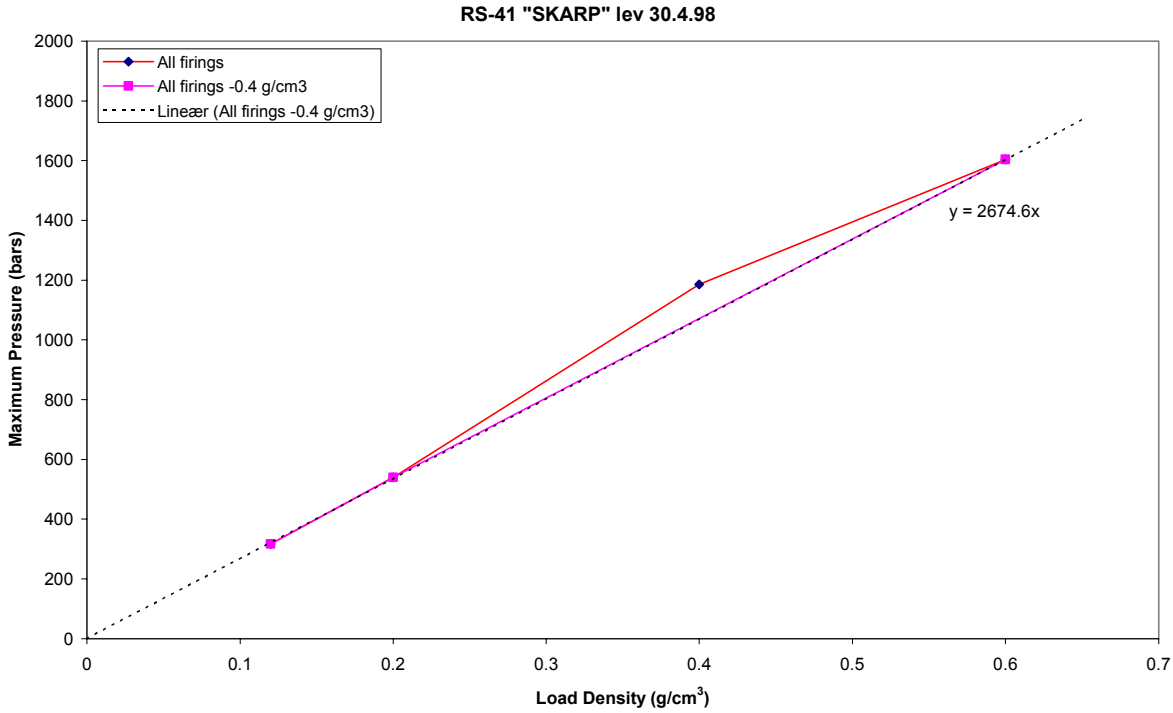

Figure 3.28 Maximum pressures as function of load density for firings with RS-41.

abnormal pressure increase which is faster than one expects for a normal burn reaction. However, the reaction did stop in the same way and does not go to detonation. If we plot the

maximum pressure as function of loading density, we get a straight line that goes through the point (0,0). The point for loading density 0.4 g/cm^3 deviates from this line. However, if we look at the pressure-time curve for CV-318, we see that after some few μs this firing will have a pressure that fit to the curve given in Figure 3.28.

With regard to burn rate have we slightly slower burn rate or pressure increase for RS-41 than for the Mg-powder firings, but faster than for the firings that contain Al-powder.

4 THEORETICAL CALCULATIONS

4.1 RS-41

In addition to the experimentally measuring pressures for given loading density of studied compositions, we have tried to calculate, by the use of Cheetah (2), what pressure one should expect to find in the closed vessel firings. Figure 4.1 gives calculated pressures for RS-41 + 2 g Black Powder and three other compositions with different ratio between Mg and Al powder.

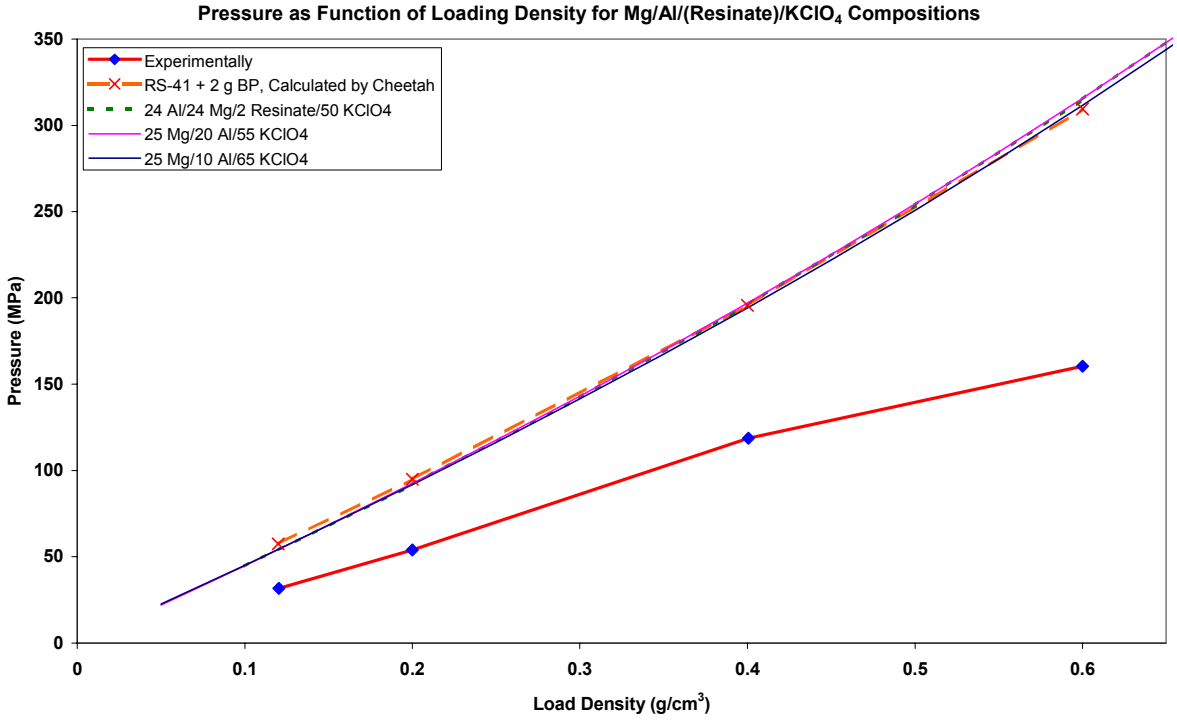

Figure 4.1 Experimentally measured and theoretically calculated pressures as function of loading density for RS-41and similar compositions.

Appendix C gives the data used for the calculations, and the full report as it is obtained from the Cheetah program for a representative choice of the performed calculations. The Cheetah code has a problem with compositions containing too much magnesium. However for RS-41 with Black Powder there are no problems, while we for pure RS-41 get problems. The composition 24/24/2/50 (Al/Mg/Res/$KClO_4$) has a content very close to the nominal content in RS-41. From Figure 4.1 we see that the experimental pressures are all significantly lower than the theoretically calculated. In addition, the difference increase with increasing loading density. For RS-41 there are no significant differences in maximum pressure due to Black

Powder, Resinate or lower content of aluminium powder. Figure 4.2 gives the main products and their concentration as a function of loading density for RS-41 + 2 g BP.

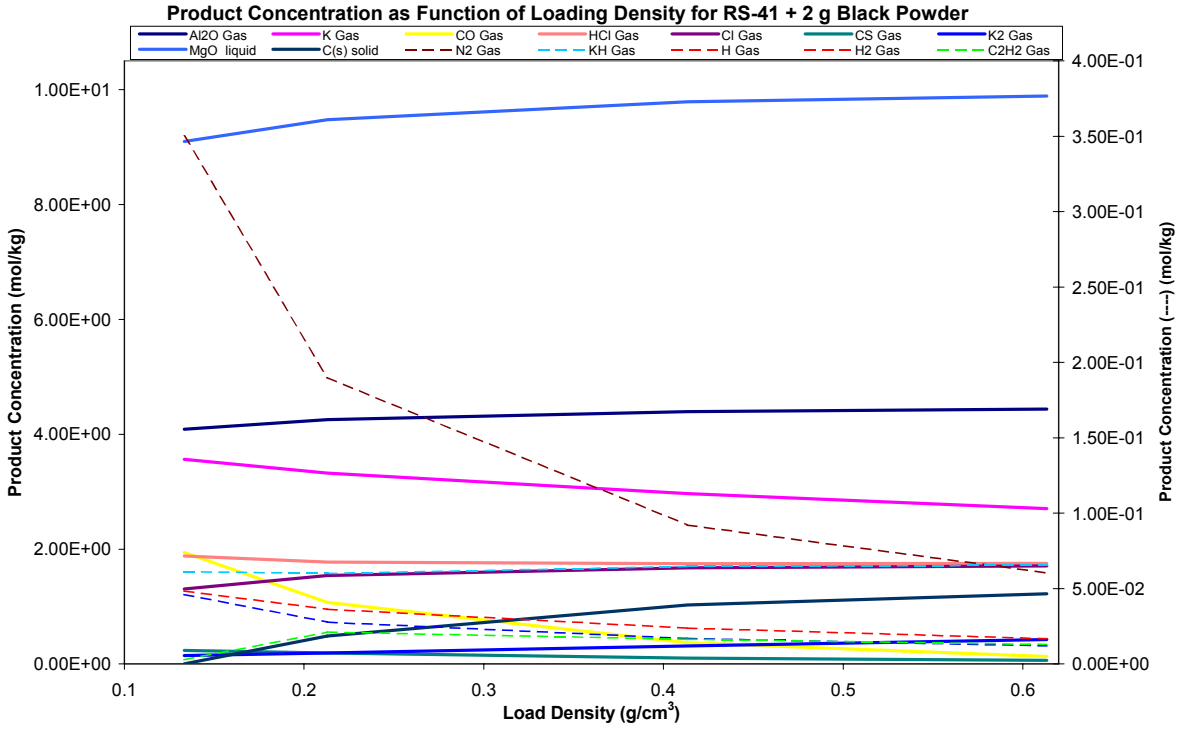

Figure 4.2 Product concentration as a function of load density for RS-41 + 2 g Black Powder.

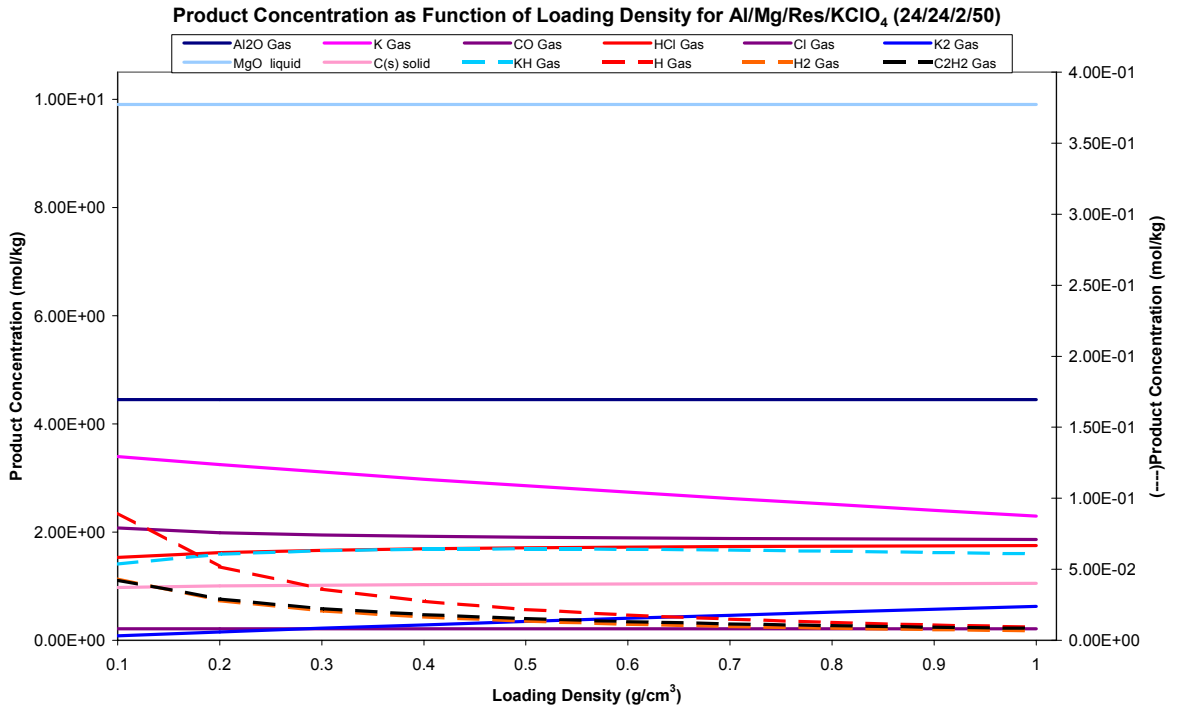

Figure 4.3 Product concentration as a function of loading density for the main products of Al/Mg/Res/$KClO_4$ (24/24/2/59).

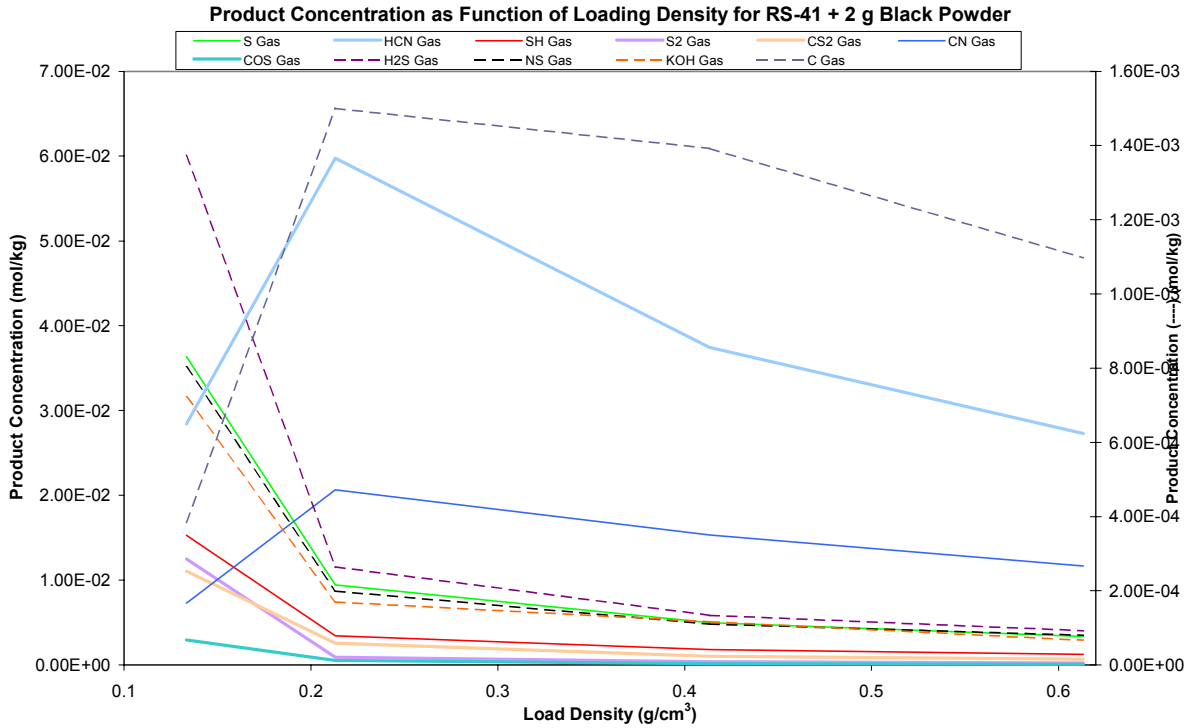

Figure 4.4 Product concentration as function of loading density for some of the minor products of RS-41 + 2 g Black Powder after combustion.

Figure 4.4 gives some of the minor products with the highest concentrations. Totally the code takes into consideration 68 products, but as can be seen in Appendix C, the majority of them exist in very low concentrations and have no significant influence on the maximum pressure. Figure 4.3 gives the main products for Al/Mg/Res/$KClO_4$ (24/24/2/50) with no BP, and comparing the products and their concentration with the products for RS-41 + BP give only small differences. For RS-41 + 2 g BP we get N2 (g) and CS (g) as new products but in low concentrations.

4.2 Mg/$KClO_4$

For magnesium and potassium perchlorate we were not able to use the same content in the calculations as for the experimentally tested compositions due to the problem with the code to handle high concentrations of magnesium. Figure 4.5 give a summery of calculated pressures for some compositions. Appendix A gives the complete print-out from the Cheetah programme, again taken into consideration that the BP used to ignite the compositions has no significant influence on the maximum pressure. The difference between calculated and experimentally measured pressures are significant and increase with increasing loading density. The difference is of the same magnitude as for RS-41.

In Figure 4.6 the concentrations for the main products as function of loading density has been given for Mg/$KClO_4$ (40/60) and for loading density 0.12 g/cm^3 of the Mg/$KClO_4$/BP (40/50/10) composition. The difference between the concentrations of the main products is small.

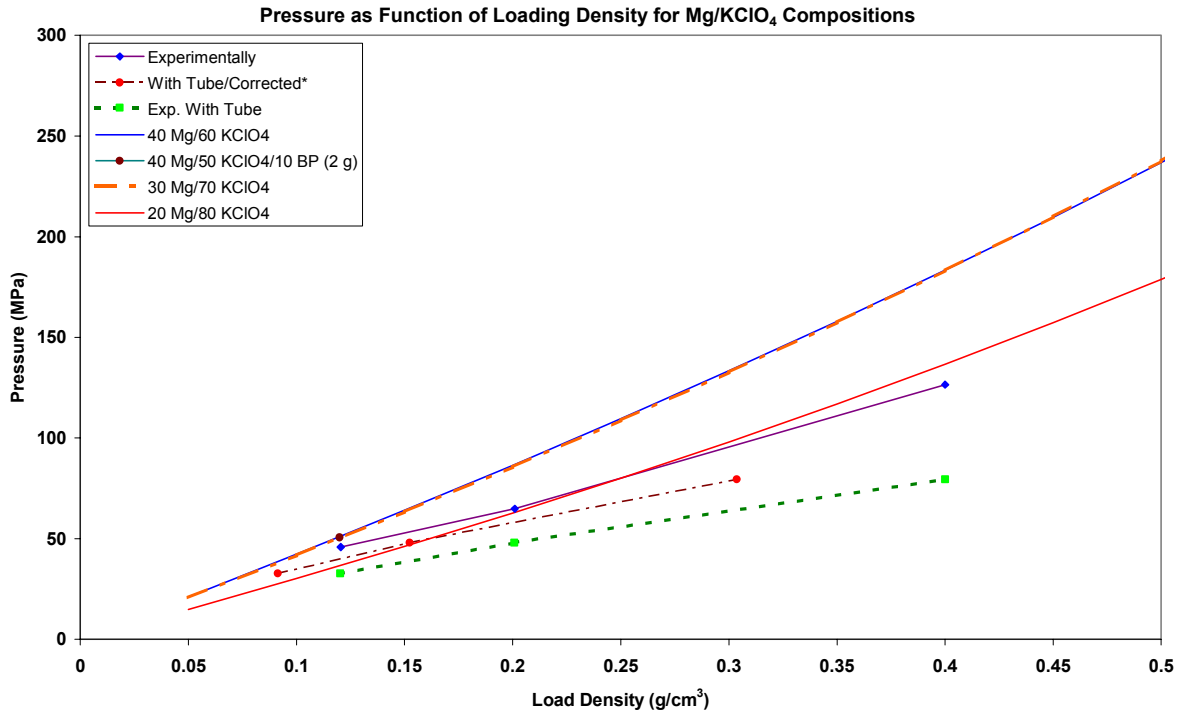

Figure 4.5 *Experimentally measured and theoretically calculated pressures as function of loading density for different compositions containing Mg-powder and $KClO_4$.*

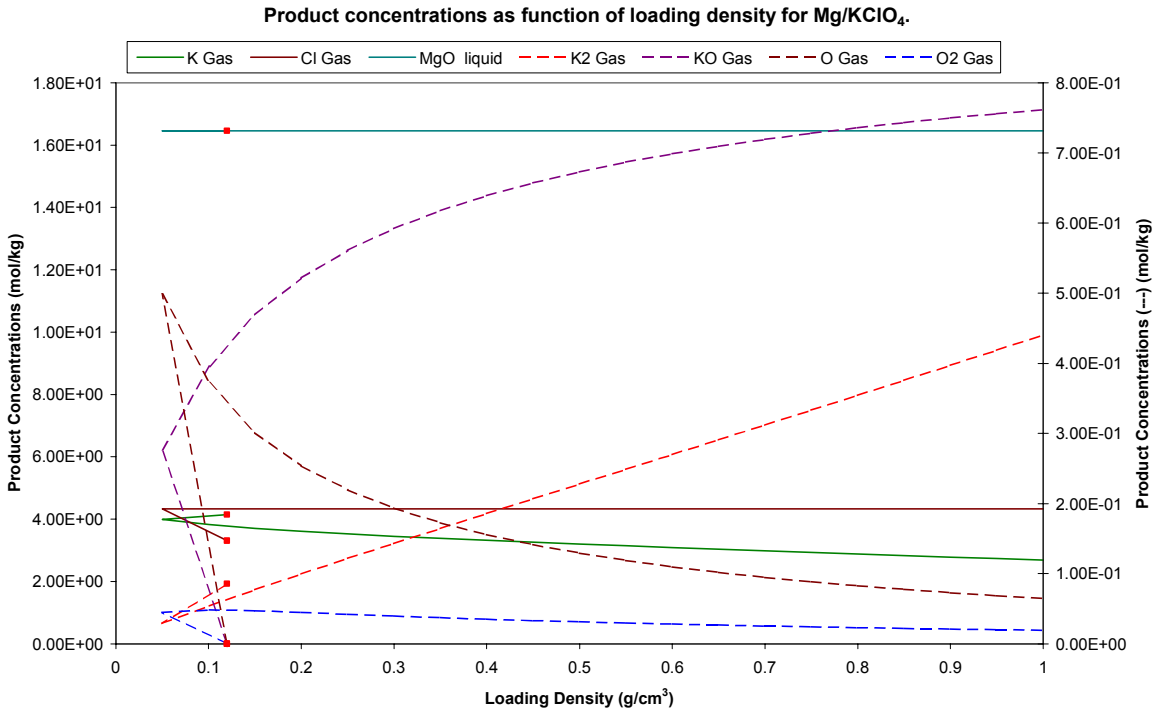

Figure 4.6 *Product concentration as function of loading density for Mg/$KClO_4$ and Mg/$KClO_4$ + 2 g Black Powder.*

4.3 Al/$KClO_4$

In Figure 4.7 the pressures for different compositions of Al-powder and potassium perchlorate are calculated by use of viral coefficients and the Blake database in Cheetah code and shown together with the experimentally measured pressures from testing in CV. For 50/50 Al/$KClO_4$

we obtain higher pressures if we include the BP in the calculations. Beyond that the calculations show little dependence on pressure for Al contents up to 50 wt%.. First at 60 wt.% Al do the calculations show significant lower pressures. The experimentally measured pressures are all significantly lower than the theoretically calculated, and the deviation increase with increasing loading density.

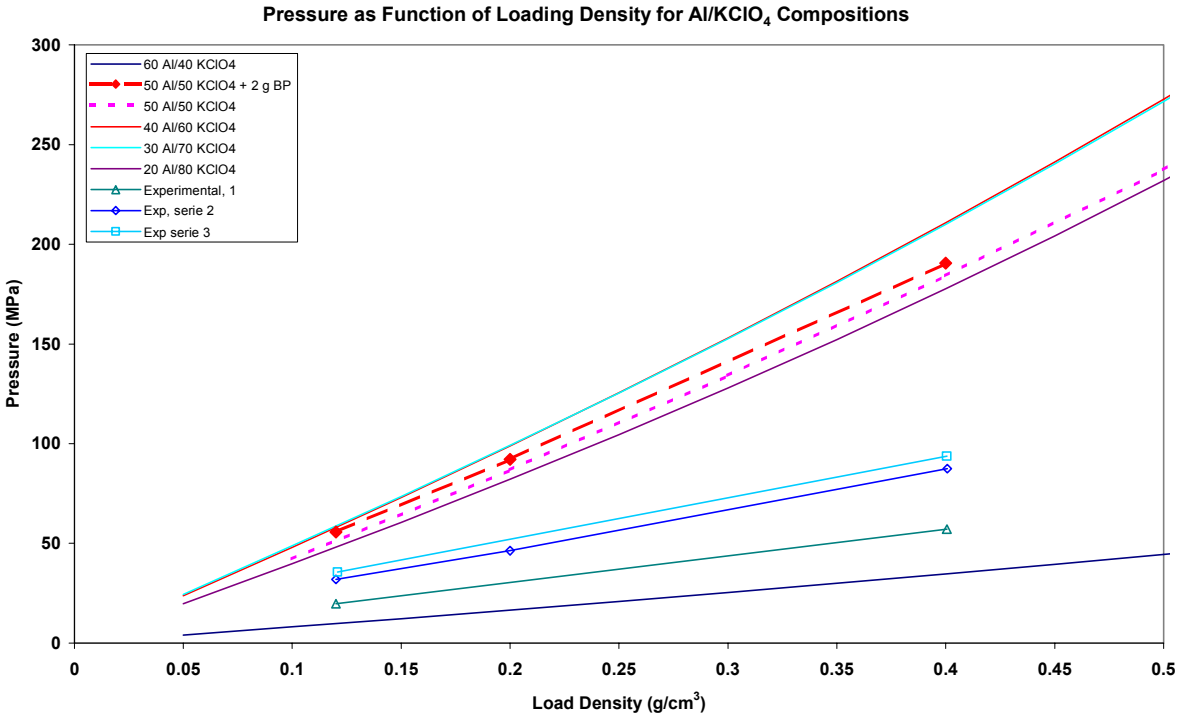

Figure 4.7 *Experimentally measured and theoretically calculated pressures as function of loading density for different compositions containing Al-powder and $KClO_4$.*

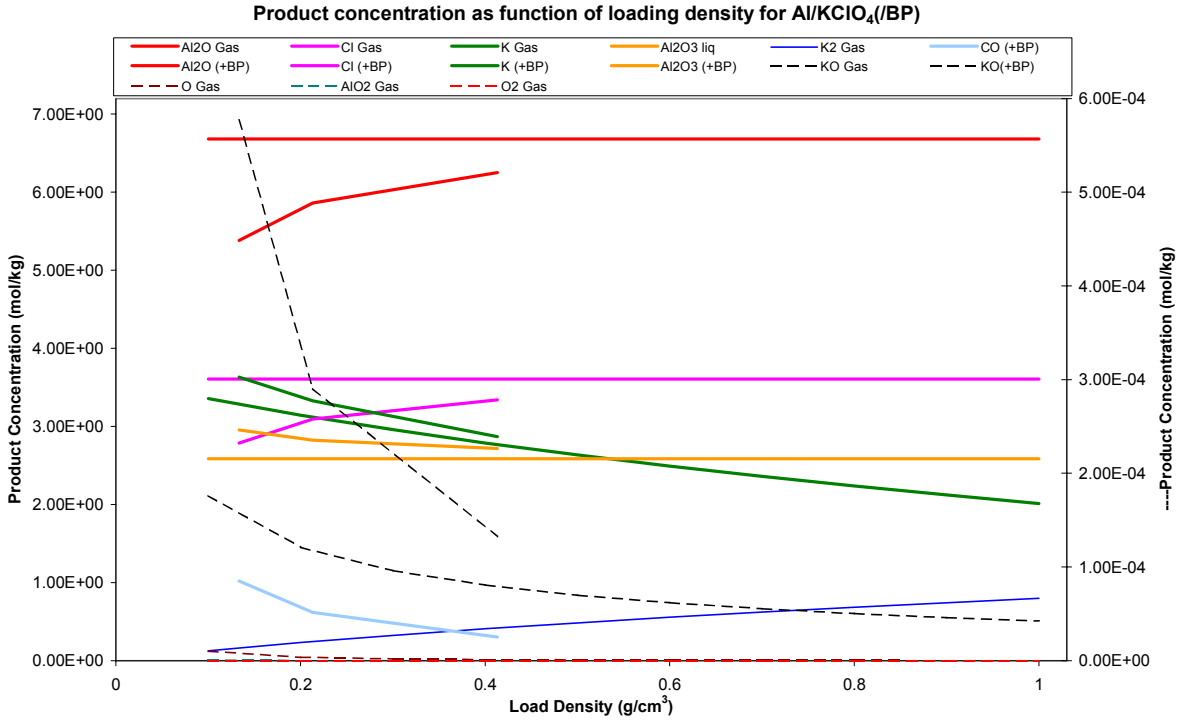

Figure 4.8 *Product concentrations as function of loading density for Al/$KClO_4$ and Al/$KClO_4$ + 2 g Black Powder.*

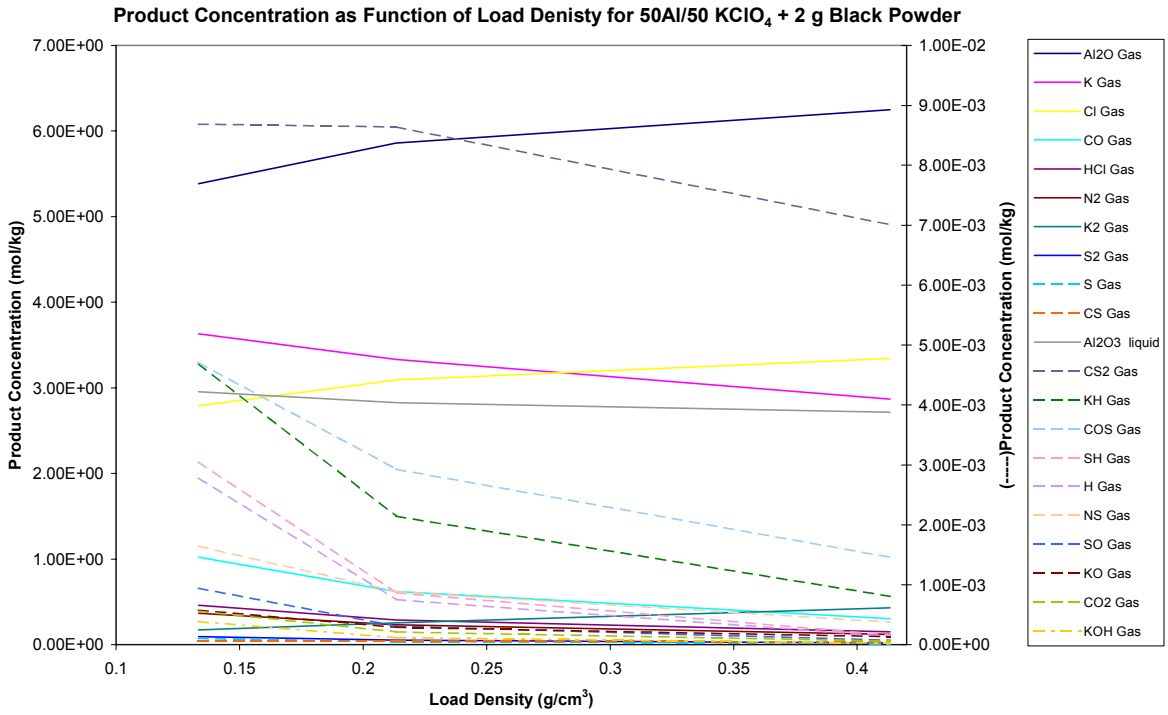

Figure 4.9 Product concentrations as function of loading density for Al/$KClO_4$ + 2 g BP.

Figure 4.8 shows the product concentrations for the main products for both 50/50 Al/$KClO_4$ and 50/50 Al/$KClO_4$ + 2 g BP. There are differences in the concentrations, and as shown in Figure 4.7, these differences have influence on the maximum pressure. However, these difference decrease as the loading density increase. Figure 4.9 gives some of the minor products for Al/$KClO_4$ + 2 g BP, while Appendix B gives the complete list.

5 SUMMARY

Pyrotechnic powders of different mixtures have been tested under different conditions in CV. Measured pressure-time curves give indication of several reaction mechanism for tested compositions. For the three main combinations (Al/$KClO_4$, Mg/$KClO_4$, RS-41) all give one firing with fast or very fast reaction rate. The burn rate or gas evolution rate is much higher than what one normally connects with burning. The observed phenomenon is observed when the powder was loosely packed as in the case of Al/$KClO_4$ or the loading density was high as in the case of RS-41 and Mg/$KClO_4$.

Measured maximum pressures are in general significantly lower than the theoretical calculations by use of Cheetah gives. In (1) we explained some of this deviation with incomplete reactions of the metal powders. Another effect must be the loss of heat to the CV.

APPENDIX

A THEORETICAL CALCULATION FOR Mg/$KClO_4$ COMPOSITIONS

A.1 Loading density 0.12 g/cm^3 40Mg/50 $KClO_4$ + 2 g Black Powder

```
Product library title: the blake product library
Executing library command: gas eos, virial
Reactant library title:# Version 2.0 by P. Clark Souers

Input>composition, sulfur, 1.07, susqkull, 1.499, potass nit, 7.417, ash,
0.014, potass per, 50, magnesium, 40, weight
                                    The Composition
Name      % wt.  % mol % vol.   Heat of  Standard Standard    Mol. Formula
                                formation  volume   entropy    wt.
                                (cal/mol) (cc/mol) (cal/K/mol)
sulfur      1.07  1.58   1.08        0     15.49   0.000     32.06 s1
susqkull    1.50  0.00   2.09 -4489962  12194.95   0.000  18292.43 c1321h573n4o100s6
potass nit  7.42  3.47   7.37  -118069     48.03   0.000    101.10 n1o3k1
ash         0.01  0.00   0.02  -271989    106.31   0.000    138.20 c1o3k2
potass per 50.00 17.07  41.36  -103250     54.81   0.000    138.55 o4cl1k1
magnesium  40.00 77.87  48.08        0     13.97   0.000     24.31 mg1

Heat of formation =   -463.180 cal/gm
Standard volume   =      0.478 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -463.192 cal/gm

The elements and percent by mole
     s              0.774
     c              2.476
     h              1.073
     n              1.684
     o             38.210
     k              9.928
     cl             8.247
     mg            37.608
The average mol. wt. =  47.314 g/mol
Input>gun, 0.120000, 0.013300, 0.150000
GUN calculation:
     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
     g/cc      K        MPa       J/g      Gas     cc/g  Cp/Cv
1.)  0.1200  5242.5     50.6    402.93 108.182    0.171   1.057   1.021
2.)  0.1333  5246.8     56.4    402.43 108.406    0.171   1.057   1.023
3.)  0.1466  5250.7     62.2    401.96 108.614    0.171   1.056   1.026

Product concentrations (mol/kg)
      Name              1.)         2.)         3.)
        k  Gas    4.146e+000  4.127e+000  4.109e+000
       cl  Gas    3.311e+000  3.307e+000  3.303e+000
       cs  Gas    3.130e-001  3.143e-001  3.153e-001
      hcl  Gas    2.979e-001  3.022e-001  3.058e-001
       cn  Gas    2.958e-001  2.983e-001  3.006e-001
       co  Gas    2.633e-001  2.633e-001  2.633e-001
       n2  Gas    1.967e-001  1.951e-001  1.935e-001
        c  Gas    1.492e-001  1.434e-001  1.383e-001
       k2  Gas    8.549e-002  9.457e-002  1.036e-001
        h  Gas    7.253e-002  6.643e-002  6.124e-002
      hcn  Gas    4.377e-002  4.477e-002  4.565e-002
       kh  Gas    2.779e-002  2.826e-002  2.865e-002
        s  Gas    2.272e-002  2.149e-002  2.042e-002
     c2h2  Gas    8.849e-003  9.335e-003  9.775e-003
       h2  Gas    4.200e-003  3.913e-003  3.659e-003
        n  Gas    3.443e-003  3.273e-003  3.125e-003
       sh  Gas    1.036e-003  9.973e-004  9.624e-004
      cs2  Gas    4.872e-004  5.139e-004  5.394e-004
       ns  Gas    3.367e-004  3.357e-004  3.349e-004
       s2  Gas    2.330e-004  2.315e-004  2.301e-004
      ch2  Gas    1.381e-004  1.375e-004  1.366e-004
       nh  Gas    5.862e-005  5.679e-005  5.511e-005
      cos  Gas    3.506e-005  3.699e-005  3.886e-005
      cho  Gas    2.193e-005  2.250e-005  2.300e-005
       ko  Gas    2.016e-005  2.123e-005  2.226e-005
        o  Gas    1.172e-005  1.114e-005  1.064e-005
      h2s  Gas    9.567e-006  9.362e-006  9.156e-006
```

```
      koh  Gas    3.989e-006  4.267e-006  4.532e-006
      ch3  Gas    3.237e-006  3.277e-006  3.301e-006
      nco  Gas    2.901e-006  3.082e-006  3.258e-006
       no  Gas    2.294e-006  2.290e-006  2.286e-006
      nh2  Gas    1.376e-006  1.356e-006  1.336e-006
       oh  Gas    1.261e-006  1.219e-006  1.180e-006
       so  Gas    9.880e-007  9.844e-007  9.813e-007
      co2  Gas    5.492e-007  5.782e-007  6.061e-007
     hnco  Gas    1.759e-007  1.899e-007  2.034e-007
    ch3cl  Gas    1.435e-007  1.614e-007  1.790e-007
   ketene  Gas    1.040e-007  1.155e-007  1.268e-007
      h2o  Gas    8.155e-008  8.005e-008  7.855e-008
    ch3cn  Gas    5.026e-008  5.696e-008  6.360e-008
     ch2o  Gas    3.485e-008  3.640e-008  3.780e-008
      nh3  Gas    2.127e-008  2.131e-008  2.128e-008
     c2h4  Gas    1.302e-008  1.423e-008  1.534e-008
      ch4  Gas    1.029e-008  1.057e-008  1.078e-008
      hno  Gas    5.783e-010  5.901e-010  6.005e-010
      n2o  Gas    5.040e-010  5.312e-010  5.576e-010
      s2o  Gas    4.379e-010  4.590e-010  4.792e-010
       o2  Gas    8.521e-011  8.524e-011  8.531e-011
    ch2oh  Gas    8.077e-012  8.633e-012  9.141e-012
      so2  Gas    6.038e-012  6.334e-012  6.621e-012
   formac  Gas    5.364e-013  5.908e-013  6.439e-013
      ho2  Gas    1.023e-013  1.047e-013  1.068e-013
      no2  Gas    6.644e-014  7.023e-014  7.391e-014
     ch4o  Gas    2.689e-014  2.925e-014  3.143e-014
   k2h2o2  Gas    1.080e-015  1.380e-015  1.721e-015
     hno2  Gas    6.173e-016  6.651e-016  7.114e-016
     h2o2  Gas    5.808e-016  6.048e-016  6.264e-016
   mgo2h2  Gas    1.786e-018  1.767e-018  1.746e-018
      mgo liquid 1.646e+001  1.646e+001  1.646e+001
    *koh liquid 0.000e+000  0.000e+000  0.000e+000
      mgo  solid 0.000e+000  0.000e+000  0.000e+000
     c(s)  solid 0.000e+000  0.000e+000  1.827e-018

     Total Gas   9.244e+000  9.225e+000  9.207e+000
     Total Cond. 1.646e+001  1.646e+001  1.646e+001
```

A.2 40 Mg/60 $KClO_4$

```
Input>composition, mg, 40, potass per, 60, weight
                                    The Composition
Name      % wt.   % mol % vol.   Heat of  Standard     Standard     Mol.   Formula
                                 formation  volume       entropy     wt.
                                 (cal/mol) (cc/mol)    (cal/K/mol)
mg        40.00  79.17  49.20        0     13.97        0.000      24.31  mg1
potass per 60.00  20.83  50.80  -103250     54.81        0.000     138.55  o4cl1k1

Heat of formation =   -447.130 cal/gm
Standard volume   =      0.467 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -447.141 cal/gm

The elements and percent by mole
     mg            38.778
     o             40.815
     cl            10.204
     k             10.204
The average mol. wt. =  48.105 g/mol
Input>gun, 0.050000, 0.050000, 1.050000
GUN calculation:
     Rho     Temp   Pressure  Impetus  Mol Wt.  Covol  Frozen    Phi
     g/cc     K       MPa       J/g     Gas      cc/g  Cp/Cv
1.)  0.0500  5408.5    21.0    412.61 108.988   0.158   1.056   1.008
2.)  0.1000  5434.5    42.3    407.94 110.767   0.157   1.055   1.016
3.)  0.1500  5450.1    64.1    404.77 111.956   0.157   1.054   1.024
4.)  0.2000  5461.1    86.5    402.31 112.868   0.157   1.054   1.032
5.)  0.2500  5469.6   109.6    400.26 113.622   0.157   1.053   1.041
6.)  0.3000  5476.6   133.4    398.48 114.275   0.157   1.053   1.050
7.)  0.3500  5482.5   157.9    396.88 114.859   0.158   1.053   1.058
8.)  0.4000  5487.7   183.3    395.41 115.394   0.158   1.052   1.068
9.)  0.4500  5492.3   209.6    394.04 115.893   0.159   1.052   1.077
10.)  0.5000  5496.5   236.7    392.75 116.364   0.159   1.052   1.087
11.)  0.5500  5500.4   264.9    391.52 116.813   0.160   1.052   1.096
12.)  0.6000  5504.1   294.0    390.33 117.246   0.160   1.051   1.107
13.)  0.6500  5507.5   324.2    389.18 117.666   0.161   1.051   1.117
14.)  0.7000  5510.8   355.5    388.06 118.076   0.162   1.051   1.128
15.)  0.7500  5513.9   388.0    386.96 118.477   0.163   1.051   1.139
16.)  0.8000  5516.9   421.7    385.89 118.873   0.163   1.051   1.150
17.)  0.8500  5519.8   456.8    384.83 119.263   0.164   1.050   1.162
18.)  0.9000  5522.7   493.2    383.78 119.650   0.165   1.050   1.174
```

```
19.)  0.9500  5525.5   531.1   382.75 120.034   0.165   1.050   1.187
20.)  1.0000  5528.2   570.5   381.72 120.417   0.166   1.050   1.199
Product concentrations (mol/kg)
Name           1.)         2.)         3.)         4.)         5.)         6.)
cl   Gas   4.331e+000  4.331e+000  4.331e+000  4.331e+000  4.331e+000  4.331e+000
k    Gas   3.996e+000  3.827e+000  3.707e+000  3.610e+000  3.526e+000  3.452e+000
o    Gas   4.986e-001  3.724e-001  3.012e-001  2.538e-001  2.196e-001  1.934e-001
ko   Gas   2.768e-001  3.955e-001  4.693e-001  5.215e-001  5.610e-001  5.922e-001
o2   Gas   4.460e-002  4.837e-002  4.708e-002  4.466e-002  4.204e-002  3.951e-002
k2   Gas   2.904e-002  5.391e-002  7.721e-002  9.965e-002  1.216e-001  1.431e-001
mgo liqui 1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001
mgo solid 0.000e+000  0.000e+000  0.000e+000  0.000e+000  0.000e+000  0.000e+000

Total Gas 9.175e+000  9.028e+000  8.932e+000  8.860e+000  8.801e+000  8.751e+000
Total Con 1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001

Product concentrations (mol/kg)
Name           7.)         8.)         9.)        10.)        11.)        12.)
cl   Gas   4.331e+000  4.331e+000  4.331e+000  4.331e+000  4.331e+000  4.331e+000
k    Gas   3.384e+000  3.320e+000  3.260e+000  3.202e+000  3.146e+000  3.092e+000
ko   Gas   6.178e-001  6.391e-001  6.573e-001  6.730e-001  6.867e-001  6.988e-001
o    Gas   1.725e-001  1.555e-001  1.413e-001  1.293e-001  1.189e-001  1.098e-001
k2   Gas   1.645e-001  1.857e-001  2.068e-001  2.278e-001  2.488e-001  2.698e-001
o2   Gas   3.716e-002  3.499e-002  3.301e-002  3.120e-002  2.954e-002  2.802e-002
mgo liqui 1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001
mgo solid 0.000e+000  0.000e+000  0.000e+000  0.000e+000  0.000e+000  0.000e+000

Total Gas 8.706e+000  8.666e+000  8.629e+000  8.594e+000  8.561e+000  8.529e+000
Total Con 1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001

Product concentrations (mol/kg)
Name          13.)        14.)        15.)        16.)        17.)        18.)
cl   Gas   4.331e+000  4.331e+000  4.331e+000  4.331e+000  4.331e+000  4.331e+000
k    Gas   3.039e+000  2.987e+000  2.936e+000  2.886e+000  2.836e+000  2.786e+000
ko   Gas   7.096e-001  7.192e-001  7.280e-001  7.359e-001  7.432e-001  7.499e-001
k2   Gas   2.909e-001  3.120e-001  3.331e-001  3.544e-001  3.757e-001  3.971e-001
o    Gas   1.018e-001  9.474e-002  8.840e-002  8.268e-002  7.750e-002  7.278e-002
o2   Gas   2.661e-002  2.532e-002  2.412e-002  2.300e-002  2.196e-002  2.099e-002
mgo liqui 1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001
mgo solid 0.000e+000  0.000e+000  0.000e+000  0.000e+000  0.000e+000  0.000e+000

Total Gas 8.499e+000  8.469e+000  8.440e+000  8.412e+000  8.385e+000  8.358e+000
Total Con 1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001  1.646e+001

Product concentrations (mol/kg)
      Name          19.)        20.)
       cl   Gas   4.331e+000  4.331e+000
        k   Gas   2.737e+000  2.688e+000
       ko   Gas   7.560e-001  7.617e-001
       k2   Gas   4.187e-001  4.403e-001
        o   Gas   6.846e-002  6.450e-002
       o2   Gas   2.008e-002  1.923e-002
      mgo liquid 1.646e+001  1.646e+001
      mgo  solid 0.000e+000  0.000e+000

     Total Gas   8.331e+000  8.304e+000
     Total Cond. 1.646e+001  1.646e+001
```

B THEORETICAL CALCULATION FOR Al/$KClO_4$ COMPOSITIONS

B.1 0.12 Al/$KClO_4$ + 2 g Black Powder

```
Product library title: the blake product library
Executing library command: gas eos, virial
Reactant library title:# Version 2.0 by P. Clark Souers
Input>composition, al, 45, potass per, 45, potass nit, 7.417, sulfur, 1.07,
susqkull, 1.499, ash, 0.014, weight

                                The Composition

Name      % wt.   % mol % vol.   Heat of  Standard  Standard     Mol.  Formula
                                 formation  volume    entropy     wt.
                                 (cal/mol) (cc/mol) (cal/K/mol)
al        45.00  79.44  42.18         0      9.99     0.000     26.98  al1
potass per 45.00  15.47  45.04   -103250     54.81     0.000    138.55  o4cl1k1
potass nit  7.42   3.49   8.92   -118069     48.03     0.000    101.10  n1o3k1
sulfur      1.07   1.59   1.31         0     15.49     0.000     32.06  s1
susqkull    1.50   0.00   2.53  -4489962  12194.95     0.000  18292.43  c1321h573n4o100s6
ash         0.01   0.00   0.03   -271989    106.31     0.000    138.20  c1o3k2

Heat of formation =   -425.919 cal/gm
Standard volume   =      0.395 cc/gm
```

```
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -425.929 cal/gm

The elements and percent by mole
     al            39.884
     o             36.536
     cl             7.767
     k              9.527
     n              1.762
     s              0.810
     c              2.591
     h              1.123
The average mol. wt. =  47.631 g/mol

Input>gun, 0.120000, 0.013300, 0.146600
GUN calculation:

     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
     g/cc      K        MPa       J/g      Gas     cc/g  Cp/Cv
1.)  0.1200  3782.2     55.7    443.19  70.958    0.273   1.114    1.034
2.)  0.1333  3786.0     62.1    442.86  71.081    0.273   1.114    1.038
3.)  0.1466  3789.5     68.6    442.53  71.201    0.272   1.113    1.042

Product concentrations (mol/kg)
      Name             1.)         2.)         3.)
     al2o  Gas   5.386e+000  5.383e+000  5.381e+000
        k  Gas   3.663e+000  3.632e+000  3.601e+000
       cl  Gas   2.791e+000  2.790e+000  2.790e+000
       co  Gas   1.025e+000  1.020e+000  1.014e+000
      hcl  Gas   4.573e-001  4.578e-001  4.582e-001
       n2  Gas   3.673e-001  3.673e-001  3.672e-001
       k2  Gas   1.575e-001  1.731e-001  1.884e-001
       s2  Gas   9.589e-002  9.472e-002  9.336e-002
        s  Gas   7.636e-002  7.216e-002  6.844e-002
       cs  Gas   4.485e-002  4.922e-002  5.345e-002
      cs2  Gas   7.569e-003  8.685e-003  9.805e-003
       kh  Gas   4.682e-003  4.692e-003  4.701e-003
      cos  Gas   4.500e-003  4.712e-003  4.906e-003
       sh  Gas   3.211e-003  3.050e-003  2.906e-003
        h  Gas   3.072e-003  2.786e-003  2.550e-003
       ns  Gas   1.642e-003  1.645e-003  1.645e-003
       so  Gas   1.046e-003  9.466e-004  8.637e-004
       ko  Gas   6.028e-004  5.771e-004  5.548e-004
      co2  Gas   5.873e-004  5.588e-004  5.341e-004
      koh  Gas   4.034e-004  3.864e-004  3.716e-004
       cn  Gas   3.520e-004  3.921e-004  4.325e-004
       h2  Gas   3.351e-004  3.049e-004  2.799e-004
      hcn  Gas   1.748e-004  1.945e-004  2.144e-004
        n  Gas   7.424e-005  7.129e-005  6.875e-005
       no  Gas   4.413e-005  4.036e-005  3.724e-005
        o  Gas   4.291e-005  3.727e-005  3.282e-005
      h2s  Gas   2.948e-005  2.806e-005  2.678e-005
      s2o  Gas   2.652e-005  2.516e-005  2.393e-005
        c  Gas   1.238e-005  1.312e-005  1.383e-005
       oh  Gas   8.220e-006  7.159e-006  6.320e-006
    alho2  Gas   7.599e-006  6.797e-006  6.148e-006
      cho  Gas   5.249e-006  5.312e-006  5.371e-006
     alo2  Gas   2.888e-006  2.589e-006  2.347e-006
      so2  Gas   2.481e-006  2.149e-006  1.885e-006
      h2o  Gas   1.642e-006  1.432e-006  1.266e-006
     halo  Gas   1.353e-006  1.273e-006  1.204e-006
      nco  Gas   1.001e-006  1.069e-006  1.135e-006
       nh  Gas   7.925e-007  7.659e-007  7.431e-007
     hnco  Gas   1.556e-007  1.664e-007  1.768e-007
     c2h2  Gas   1.045e-007  1.293e-007  1.568e-007
       o2  Gas   7.968e-008  6.621e-008  5.602e-008
      nh2  Gas   2.380e-008  2.309e-008  2.248e-008
      ch2  Gas   1.411e-008  1.508e-008  1.603e-008
      n2o  Gas   1.042e-008  1.013e-008  9.884e-009
     ch2o  Gas   7.821e-009  7.953e-009  8.080e-009
      hno  Gas   2.540e-009  2.351e-009  2.195e-009
      nh3  Gas   7.174e-010  6.980e-010  6.814e-010
      ch3  Gas   6.568e-010  7.038e-010  7.496e-010
   ketene  Gas   4.226e-010  5.006e-010  5.839e-010
    ch3cl  Gas   3.917e-010  4.655e-010  5.447e-010
      no2  Gas   5.626e-011  4.973e-011  4.453e-011
   k2h2o2  Gas   3.700e-011  3.785e-011  3.866e-011
   formac  Gas   2.672e-011  2.606e-011  2.550e-011
      ho2  Gas   2.094e-011  1.762e-011  1.508e-011
      ch4  Gas   3.349e-012  3.587e-012  3.819e-012
    ch3cn  Gas   5.726e-013  7.552e-013  9.715e-013
     hno2  Gas   3.006e-013  2.675e-013  2.410e-013
    ch2oh  Gas   1.829e-013  1.884e-013  1.937e-013
     h2o2  Gas   1.174e-013  9.919e-014  8.528e-014
     c2h4  Gas   4.440e-014  5.539e-014  6.767e-014
```

```
     ch4o  Gas   7.112e-016  7.356e-016  7.594e-016
    al2o3 liquid 2.953e+000  2.955e+000  2.958e+000
     *koh liquid 0.000e+000  0.000e+000  0.000e+000
     c(s)  solid 0.000e+000  0.000e+000  0.000e+000
    al2o3  solid 0.000e+000  0.000e+000  0.000e+000

     Total Gas   1.409e+001  1.407e+001  1.404e+001
     Total Cond. 2.953e+000  2.955e+000  2.958e+000
```

B.2 Load Density 0.2 g/cm^3 Al/$KClO_4$ + 2 g Black Powder

```
Al svart krutt
Product library title: the blake product library
Executing library command: gas eos, virial
Reactant library title:# Version 2.0 by P. Clark Souers

Input>composition, al, 75, potass per, 75, potass nit, 7.417, sulfur, 1.07,
susqkull, 1.499, ash, 0.014, weight
                                The Composition

Name      % wt.   % mol % vol.   Heat of  Standard  Standard     Mol.   Formula
                                 formation  volume    entropy     wt.
                                 (cal/mol) (cc/mol) (cal/K/mol)
al         46.88  81.09  44.45         0      9.99     0.000     26.98  al1
potass per 46.88  15.79  47.47   -103250     54.81     0.000    138.55  o4cl1k1
potass nit  4.64   2.14   5.64   -118069     48.03     0.000    101.10  n1o3k1
sulfur      0.67   0.97   0.83         0     15.49     0.000     32.06  s1
susqkull    0.94   0.00   1.60 -4489962  12194.95     0.000  18292.43  c1321h573n4o100s6
ash         0.01   0.00   0.02   -271989    106.31     0.000    138.20  c1o3k2

Heat of formation =   -405.928 cal/gm
Standard volume   =      0.391 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -405.937 cal/gm

The elements and percent by mole
     al             42.163
     o              36.312
     cl              8.211
     k               9.327
     n               1.118
     s               0.514
     c               1.644
     h               0.712
The average mol. wt. =  46.676 g/mol
Input>gun, 0.20000, 0.013300, 0.226600
GUN calculation:

     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
     g/cc      K        MPa       J/g     Gas      cc/g  Cp/Cv
1.)  0.2000  3719.1     92.1    428.30  72.200   0.260   1.115    1.055
2.)  0.2133  3721.3     98.7    428.00  72.293   0.260   1.115    1.059

Product concentrations (mol/kg)
      Name            1.)        2.)
     al2o  Gas   5.862e+000  5.861e+000
        k  Gas   3.358e+000  3.331e+000
       cl  Gas   3.094e+000  3.094e+000
       co  Gas   6.229e-001  6.198e-001
      hcl  Gas   2.893e-001  2.894e-001
       k2  Gas   2.412e-001  2.549e-001
       n2  Gas   2.296e-001  2.296e-001
       s2  Gas   5.441e-002  5.341e-002
       cs  Gas   4.285e-002  4.518e-002
        s  Gas   3.895e-002  3.735e-002
      cs2  Gas   8.004e-003  8.639e-003
      cos  Gas   2.859e-003  2.928e-003
       kh  Gas   2.146e-003  2.143e-003
       sh  Gas   9.031e-004  8.689e-004
       ns  Gas   8.872e-004  8.838e-004
        h  Gas   8.020e-004  7.531e-004
       so  Gas   3.320e-004  3.100e-004
       cn  Gas   3.146e-004  3.368e-004
       ko  Gas   2.994e-004  2.906e-004
      co2  Gas   2.189e-004  2.119e-004
      koh  Gas   1.197e-004  1.163e-004
      hcn  Gas   9.253e-005  9.897e-005
       h2  Gas   5.064e-005  4.766e-005
        n  Gas   3.478e-005  3.389e-005
       no  Gas   1.354e-005  1.279e-005
        o  Gas   1.162e-005  1.062e-005
        c  Gas   9.064e-006  9.390e-006
      s2o  Gas   8.929e-006  8.549e-006
      h2s  Gas   4.533e-006  4.363e-006
```

```
      cho  Gas    1.517e-006  1.528e-006
    alho2  Gas    1.483e-006  1.382e-006
       oh  Gas    1.278e-006  1.170e-006
     alo2  Gas    9.014e-007  8.415e-007
      nco  Gas    5.538e-007  5.775e-007
      so2  Gas    4.962e-007  4.510e-007
     halo  Gas    3.776e-007  3.630e-007
       nh  Gas    2.001e-007  1.958e-007
      h2o  Gas    1.524e-007  1.397e-007
     hnco  Gas    5.057e-008  5.278e-008
     c2h2  Gas    4.772e-008  5.452e-008
       o2  Gas    1.312e-008  1.166e-008
      nh2  Gas    3.388e-009  3.323e-009
      n2o  Gas    3.371e-009  3.317e-009
      ch2  Gas    3.217e-009  3.351e-009
     ch2o  Gas    1.251e-009  1.263e-009
      hno  Gas    3.996e-010  3.807e-010
   ketene  Gas    1.205e-010  1.341e-010
    ch3cl  Gas    1.192e-010  1.330e-010
      ch3  Gas    8.671e-011  9.047e-011
      nh3  Gas    5.916e-011  5.814e-011
      no2  Gas    9.638e-012  8.924e-012
   k2h2o2  Gas    6.170e-012  6.239e-012
   formac  Gas    2.606e-012  2.565e-012
      ho2  Gas    1.764e-012  1.580e-012
      ch4  Gas    2.483e-013  2.587e-013
    ch3cn  Gas    1.501e-013  1.788e-013
     hno2  Gas    2.767e-014  2.572e-014
    ch2oh  Gas    1.411e-014  1.437e-014
     c2h4  Gas    5.610e-015  6.429e-015
     h2o2  Gas    5.470e-015  4.917e-015
     ch4o  Gas    3.078e-017  3.143e-017
    al2o3 liquid 2.824e+000  2.826e+000
     *koh liquid 0.000e+000  0.000e+000
     c(s)  solid 0.000e+000  0.000e+000
    al2o3  solid 0.000e+000  0.000e+000

     Total Gas    1.385e+001  1.383e+001
     Total Cond.  2.824e+000  2.826e+000
```

B.3 Load Density 0.4 g/cm^3 Al/$KClO_4$ + 2 g Black Powder

```
Product library title: the blake product library
Executing library command: gas eos, virial
Reactant library title:# Version 2.0 by P. Clark Souers

Input>composition, al, 150, potass per, 150, potass nit, 7.417, sulfur,
1.07, susqkull, 1.499, ash, 0.014, weight
                                The Composition

Name      % wt.   % mol % vol.   Heat of  Standard  Standard     Mol.   Formula
                                 formation  volume    entropy     wt.
                                 (cal/mol) (cc/mol) (cal/K/mol)
al         48.39  82.37  46.32        0      9.99    0.000      26.98  al1
potass per 48.39  16.04  49.47  -103250     54.81    0.000     138.55  o4cl1k1
potass nit  2.39   1.09   2.94  -118069     48.03    0.000     101.10  n1o3k1
sulfur      0.35   0.49   0.43        0     15.49    0.000      32.06  s1
susqkull    0.48   0.00   0.83 -4489962  12194.95    0.000   18292.43  c1321h573n4o100s6
ash         0.00   0.00   0.01  -271989    106.31    0.000     138.20  c1o3k2

Heat of formation =   -389.805 cal/gm
Standard volume   =      0.387 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -389.815 cal/gm

The elements and percent by mole
     al             44.051
     o              36.126
     cl              8.579
     k               9.162
     n               0.584
     s               0.268
     c               0.859
     h               0.372
The average mol. wt. =  45.934 g/mol
Input>gun, 0.40000, 0.013300, 0.426600
GUN calculation:

     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen    Phi
     g/cc      K       MPa       J/g      Gas      cc/g  Cp/Cv
1.)  0.4000  3668.0   190.6    413.53  73.751    0.248   1.115   1.110
2.)  0.4133  3669.2   197.8    413.29  73.819    0.248   1.115   1.114
3.)  0.4266  3670.4   205.0    413.05  73.885    0.247   1.115   1.118
```

```
Product concentrations (mol/kg)
      Name              1.)          2.)          3.)
     al2o  Gas    6.250e+000   6.250e+000   6.249e+000
       cl  Gas    3.342e+000   3.342e+000   3.342e+000
        k  Gas    2.891e+000   2.869e+000   2.847e+000
       k2  Gas    4.191e-001   4.300e-001   4.407e-001
       co  Gas    3.061e-001   3.050e-001   3.040e-001
      hcl  Gas    1.503e-001   1.503e-001   1.503e-001
       n2  Gas    1.185e-001   1.185e-001   1.185e-001
       cs  Gas    3.479e-002   3.564e-002   3.648e-002
       s2  Gas    2.192e-002   2.148e-002   2.104e-002
        s  Gas    1.497e-002   1.455e-002   1.414e-002
      cs2  Gas    6.783e-003   7.009e-003   7.230e-003
      cos  Gas    1.442e-003   1.456e-003   1.469e-003
       kh  Gas    8.070e-004   8.043e-004   8.016e-004
       ns  Gas    3.796e-004   3.772e-004   3.748e-004
       cn  Gas    2.674e-004   2.779e-004   2.885e-004
       sh  Gas    1.645e-004   1.602e-004   1.561e-004
        h  Gas    1.432e-004   1.382e-004   1.335e-004
       ko  Gas    1.349e-004   1.324e-004   1.301e-004
       so  Gas    7.500e-005   7.190e-005   6.899e-005
      co2  Gas    6.154e-005   6.041e-005   5.933e-005
      hcn  Gas    3.901e-005   4.052e-005   4.205e-005
      koh  Gas    2.735e-005   2.688e-005   2.643e-005
        n  Gas    1.378e-005   1.359e-005   1.340e-005
        c  Gas    6.147e-006   6.263e-006   6.379e-006
       h2  Gas    4.497e-006   4.350e-006   4.212e-006
       no  Gas    3.221e-006   3.123e-006   3.031e-006
        o  Gas    2.397e-006   2.281e-006   2.174e-006
      s2o  Gas    2.031e-006   1.966e-006   1.903e-006
      h2s  Gas    3.780e-007   3.679e-007   3.582e-007
      cho  Gas    3.221e-007   3.238e-007   3.254e-007
      nco  Gas    2.753e-007   2.823e-007   2.894e-007
     alo2  Gas    2.327e-007   2.243e-007   2.165e-007
    alho2  Gas    2.014e-007   1.941e-007   1.874e-007
       oh  Gas    1.292e-007   1.232e-007   1.176e-007
     halo  Gas    7.918e-008   7.752e-008   7.595e-008
      so2  Gas    6.658e-008   6.297e-008   5.963e-008
       nh  Gas    3.687e-008   3.646e-008   3.606e-008
     c2h2  Gas    1.657e-008   1.786e-008   1.921e-008
     hnco  Gas    1.256e-008   1.290e-008   1.324e-008
      h2o  Gas    7.875e-009   7.519e-009   7.189e-009
       o2  Gas    1.531e-009   1.435e-009   1.347e-009
      n2o  Gas    9.086e-010   9.033e-010   8.984e-010
      ch2  Gas    5.000e-010   5.117e-010   5.233e-010
      nh2  Gas    3.015e-010   2.987e-010   2.960e-010
     ch2o  Gas    1.263e-010   1.272e-010   1.281e-010
      hno  Gas    4.332e-011   4.226e-011   4.127e-011
    ch3cl  Gas    2.589e-011   2.757e-011   2.930e-011
   ketene  Gas    2.468e-011   2.624e-011   2.786e-011
      ch3  Gas    6.656e-012   6.821e-012   6.986e-012
      nh3  Gas    2.612e-012   2.593e-012   2.575e-012
      no2  Gas    1.257e-012   1.208e-012   1.163e-012
   k2h2o2  Gas    7.801e-013   7.840e-013   7.880e-013
   formac  Gas    1.521e-013   1.512e-013   1.504e-013
      ho2  Gas    9.340e-014   8.807e-014   8.319e-014
    ch3cn  Gas    2.710e-014   2.994e-014   3.301e-014
      ch4  Gas    8.856e-015   9.057e-015   9.257e-015
     hno2  Gas    1.675e-015   1.614e-015   1.558e-015
    ch2oh  Gas    6.040e-016   6.115e-016   6.190e-016
     c2h4  Gas    3.809e-016   4.102e-016   4.410e-016
     h2o2  Gas    1.377e-016   1.302e-016   1.233e-016
     ch4o  Gas    6.339e-019   6.430e-019   6.522e-019
    al2o3 liquid 2.716e+000   2.717e+000   2.717e+000
     *koh liquid 0.000e+000   0.000e+000   0.000e+000
     c(s)  solid 0.000e+000   0.000e+000   0.000e+000
    al2o3  solid 0.000e+000   0.000e+000   0.000e+000

     Total Gas   1.356e+001   1.355e+001   1.353e+001
     Total Cond. 2.716e+000   2.717e+000   2.717e+000
```

B.4 50 Al/50 $KClO_4$

```
Product library title: the blake product library
Executing library command: gas eos, virial
Reactant library title:# Version 2.0 by P. Clark Souers

                                        The Composition

Name      % wt.   % mol % vol.   Heat of   Standard     Standard     Mol.   Formula
                                 formation  volume       entropy      wt.
                                 (cal/mol) (cc/mol)    (cal/K/mol)
al         50.00  83.70  48.36        0      9.99         0.000      26.98  al1
potass per 50.00  16.30  51.64  -103250     54.81         0.000     138.55  o4cl1k1
```

```
Heat of formation =   -372.608 cal/gm
Standard volume   =      0.383 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -372.617 cal/gm

The elements and percent by mole
     al             46.116
     o              35.923
     cl              8.981
     k               8.981
The average mol. wt. =  45.168 g/mol
Input>composition, al, 50, potass per, 50, weight
                                The Composition

Name      % wt.   % mol % vol.   Heat of  Standard     Standard     Mol.   Formula
                                 formation  volume       entropy     wt.
                                 (cal/mol) (cc/mol)    (cal/K/mol)
al         50.00  83.70  48.36        0      9.99        0.000      26.98  al1
potass per 50.00  16.30  51.64  -103250     54.81        0.000     138.55  o4cl1k1

Heat of formation =   -372.608 cal/gm
Standard volume   =      0.383 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -372.617 cal/gm

The elements and percent by mole
     al             46.116
     o              35.923
     cl              8.981
     k               8.981
The average mol. wt. =  45.168 g/mol
Input>gun, 0.100000, 0.100000, 1.050000
GUN calculation:
     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
     g/cc      K        MPa       J/g      Gas     cc/g  Cp/Cv
1.)  0.1000  3564.6     42.2    408.22   72.605   0.245   1.120    1.025
2.)  0.2000  3572.0     86.8    405.90   73.172   0.243   1.119    1.051
3.)  0.3000  3578.4    134.1    403.84   73.678   0.241   1.118    1.078
4.)  0.4000  3584.2    184.3    401.97   74.138   0.239   1.117    1.106
5.)  0.5000  3589.3    237.5    400.26   74.562   0.238   1.117    1.135
6.)  0.6000  3594.1    294.1    398.67   74.958   0.236   1.116    1.165
7.)  0.7000  3598.4    354.3    397.18   75.330   0.234   1.116    1.196
8.)  0.8000  3602.5    418.3    395.78   75.682   0.233   1.116    1.229
9.)  0.9000  3606.2    486.5    394.45   76.017   0.231   1.116    1.262
10.) 1.0000  3609.8    559.2    393.18   76.338   0.229   1.116    1.298

Product concentrations (mol/kg)
Name          1.)          2.)          3.)          4.)          5.)          6.)
al2o  Gas 6.681e+000 6.681e+000 6.681e+000 6.681e+000 6.681e+000 6.681e+000
cl    Gas 3.609e+000 3.609e+000 3.609e+000 3.609e+000 3.609e+000 3.609e+000
k     Gas 3.359e+000 3.145e+000 2.958e+000 2.789e+000 2.636e+000 2.494e+000
k2    Gas 1.250e-001 2.318e-001 3.256e-001 4.098e-001 4.865e-001 5.573e-001
ko    Gas 1.763e-004 1.211e-004 9.594e-005 8.059e-005 6.990e-005 6.186e-005
o     Gas 1.032e-005 3.624e-006 1.943e-006 1.235e-006 8.595e-007 6.333e-007
alo2  Gas 6.245e-007 2.693e-007 1.650e-007 1.165e-007 8.870e-008 7.086e-008
o2    Gas 9.685e-009 2.421e-009 1.063e-009 5.855e-010 3.642e-010 2.444e-010
al2o3 liq 2.585e+000 2.585e+000 2.585e+000 2.585e+000 2.585e+000 2.585e+000
al2o3 sol 0.000e+000 0.000e+000 0.000e+000 0.000e+000 0.000e+000 0.000e+000

Total Gas 1.377e+001 1.367e+001 1.357e+001 1.349e+001 1.341e+001 1.334e+001
Total Con 2.585e+000 2.585e+000 2.585e+000 2.585e+000 2.585e+000 2.585e+000

Product concentrations (mol/kg)
      Name          7.)          8.)          9.)         10.)
     al2o  Gas   6.681e+000   6.681e+000   6.681e+000   6.681e+000
       cl  Gas   3.609e+000   3.609e+000   3.609e+000   3.609e+000
        k  Gas   2.362e+000   2.239e+000   2.122e+000   2.012e+000
       k2  Gas   6.232e-001   6.850e-001   7.433e-001   7.985e-001
       ko  Gas   5.551e-005   5.032e-005   4.598e-005   4.227e-005
        o  Gas   4.848e-007   3.815e-007   3.064e-007   2.500e-007
     alo2  Gas   5.847e-008   4.941e-008   4.252e-008   3.711e-008
       o2  Gas   1.727e-010   1.266e-010   9.540e-011   7.348e-011
    al2o3 liquid 2.585e+000   2.585e+000   2.585e+000   2.585e+000
    al2o3  solid 0.000e+000   0.000e+000   0.000e+000   0.000e+000

     Total Gas   1.327e+001   1.321e+001   1.315e+001   1.310e+001
     Total Cond. 2.585e+000   2.585e+000   2.585e+000   2.585e+000
```

C THEORETICAL CALCULATIONS FOR Mg/ Al/$KClO_4$ COMPOSITIONS

C.1 0.12 g/cm^3 RS-41 + 2 g Black Powder

```
Input>composition, magnesium, 22.05, al, 22.05, potass per, 44.1, potass
nit, 7.417, resinat, 1.8, sulfur, 1.07, susqkull, 1.499, ash, 0.014, weight
                                The Composition

Name      % wt.   % mol % vol.  Heat of  Standard  Standard     Mol.   Formula
                                formation  volume    entropy     wt.
                                (cal/mol) (cc/mol  (cal/K/mol)
magnesium  22.05  42.15  28.16        0     13.97     0.000     24.31  mg1
al         22.05  37.97  18.15        0      9.99     0.000     26.98  al1
potass per 44.10  14.79  38.77  -103250     54.81     0.000    138.55  o4cl1k1
potass nit  7.42   3.41   7.83  -118069     48.03     0.000    101.10  n1o3k1
resinat     1.80   0.13   3.70   -23901    580.75     0.000    627.20  c40h58o4mg1
sulfur      1.07   1.55   1.15        0     15.49     0.000     32.06  s1
susqkull    1.50   0.00   2.22 -4489962  12194.95     0.000  18292.43  c1321h573n4o100s6
ash         0.01   0.00   0.02  -271989    106.31     0.000    138.20  c1o3k2

Heat of formation =   -419.898 cal/gm
Standard volume   =      0.450 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -419.909 cal/gm

The elements and percent by mole
     mg            20.248
     al            18.181
     o             33.666
     cl             7.081
     k              8.718
     n              1.639
     c              4.965
     h              4.748
     s              0.753
The average mol. wt. =  46.457 g/mol
Input>gun, 0.120000, 0.013300, 0.13330000
GUN calculation:

     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
     g/cc      K        MPa       J/g     Gas      cc/g  Cp/Cv
1.)  0.1200  3983.6     57.6    457.19  72.448   0.290   1.108    1.036
2.)  0.1333  3987.9     64.3    456.94  72.566   0.289   1.108    1.040

Product concentrations (mol/kg)
      Name            1.)          2.)
     al2o  Gas   4.086e+000   4.086e+000
        k  Gas   3.590e+000   3.562e+000
       co  Gas   1.941e+000   1.941e+000
      hcl  Gas   1.869e+000   1.879e+000
       cl  Gas   1.314e+000   1.304e+000
       n2  Gas   3.501e-001   3.501e-001
       cs  Gas   2.352e-001   2.346e-001
       k2  Gas   1.337e-001   1.472e-001
       kh  Gas   6.035e-002   6.127e-002
        h  Gas   5.275e-002   4.842e-002
       h2  Gas   4.958e-002   4.621e-002
        s  Gas   3.771e-002   3.636e-002
      hcn  Gas   2.832e-002   2.842e-002
       sh  Gas   1.559e-002   1.529e-002
       s2  Gas   1.217e-002   1.252e-002
      cs2  Gas   1.037e-002   1.104e-002
       cn  Gas   7.344e-003   7.288e-003
      cos  Gas   2.766e-003   2.973e-003
     c2h2  Gas   2.703e-003   2.717e-003
      h2s  Gas   1.380e-003   1.373e-003
       ns  Gas   7.851e-004   8.027e-004
      koh  Gas   6.589e-004   7.220e-004
        c  Gas   4.070e-004   3.842e-004
      co2  Gas   1.615e-004   1.745e-004
      cho  Gas   1.593e-004   1.641e-004
        n  Gas   1.538e-004   1.477e-004
       ko  Gas   1.272e-004   1.377e-004
       so  Gas   7.362e-005   7.680e-005
      ch2  Gas   4.177e-005   4.075e-005
      h2o  Gas   3.610e-005   3.643e-005
       oh  Gas   2.295e-005   2.285e-005
       nh  Gas   1.728e-005   1.691e-005
      ch3  Gas   1.655e-005   1.637e-005
        o  Gas   1.374e-005   1.348e-005
       no  Gas   1.081e-005   1.117e-005
     halo  Gas   8.089e-006   8.185e-006
      nh2  Gas   4.782e-006   4.753e-006
```

```
    alho2  Gas    4.575e-006  4.973e-006
     hnco  Gas    3.834e-006  4.173e-006
      nco  Gas    3.031e-006  3.254e-006
    ch3cl  Gas    2.794e-006  3.043e-006
     ch2o  Gas    2.313e-006  2.424e-006
   ketene  Gas    1.539e-006  1.673e-006
      nh3  Gas    1.236e-006  1.247e-006
      ch4  Gas    7.435e-007  7.444e-007
      s2o  Gas    5.529e-007  6.170e-007
     alo2  Gas    2.569e-007  2.765e-007
    ch3cn  Gas    1.486e-007  1.613e-007
     c2h4  Gas    1.339e-007  1.391e-007
      so2  Gas    2.398e-008  2.704e-008
      hno  Gas    7.868e-009  8.327e-009
       o2  Gas    3.770e-009  3.996e-009
      n2o  Gas    2.593e-009  2.848e-009
   formac  Gas    1.198e-009  1.359e-009
    ch2oh  Gas    7.920e-010  8.509e-010
   k2h2o2  Gas    7.849e-011  1.051e-010
     ch4o  Gas    2.881e-011  3.146e-011
      ho2  Gas    1.262e-011  1.370e-011
      no2  Gas    2.810e-012  3.169e-012
     h2o2  Gas    6.871e-013  7.589e-013
     hno2  Gas    1.597e-013  1.835e-013
   mgo2h2  Gas    4.892e-017  5.012e-017
      mgo liquid 9.101e+000  9.101e+000
     c(s)  solid 0.000e+000  0.000e+000
      mgo  solid 0.000e+000  0.000e+000
     *koh liquid 0.000e+000  0.000e+000
    al2o3  solid 0.000e+000  0.000e+000
    al2o3 liquid 0.000e+000  0.000e+000

     Total Gas    1.380e+001  1.378e+001
     Total Cond.  9.101e+000  9.101e+000
```

C.2 0.40 g/cm^3 RS-41, + 2 g Black Powder

```
Input>composition, potass per, 47.42, al, 23.71, magnesium, 23.71, resinat, 1.9355,
potass nit, 2.39, sulfur, 0.345, susqkull, 0.4835, weight
                                The Composition

Name      % wt.   % mol % vol.   Heat of  Standard  Standard   Mol.   Formula
                                 formation  volume    entropy   wt.
                                 (cal/mol) (cc/mol) (cal/K/mol)
potass per 47.42  15.32  42.07  -103250     54.81    0.000    138.55  o4cl1k1
al         23.71  39.33  19.70        0      9.99    0.000     26.98  al1
magnesium  23.71  43.67  30.56        0     13.97    0.000     24.31  mg1
resinat     1.94   0.14   4.02   -23901    580.75    0.000    627.20  c40h58o4mg1
potass nit  2.39   1.06   2.55  -118069     48.03    0.000    101.10  n1o3k1
sulfur      0.35   0.48   0.37        0     15.49    0.000     32.06  s1
susqkull    0.48   0.00   0.72 -4489962   12194.95  0.000  18292.43  c1321h573n4o100s6

Heat of formation =   -383.240 cal/gm
Standard volume   =      0.446 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -383.251 cal/gm

The elements and percent by mole
     o             33.010
     cl             7.765
     k              8.302
     al            19.937
     mg            22.203
     c              3.593
     h              4.404
     n              0.539
     s              0.248
The average mol. wt. =  44.760 g/mol
Input>gun, 0.400000, 0.01330000, 0.440000
GUN calculation:


     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen    Phi
     g/cc      K        MPa       J/g      Gas     cc/g  Cp/Cv

1.)  0.4000  4281.3    195.6    422.01  84.355   0.231   1.090   1.102
2.)  0.4133  4282.9    203.0    421.78  84.431   0.231   1.090   1.106
3.)  0.4266  4284.4    210.5    421.55  84.507   0.231   1.090   1.109
4.)  0.4399  4285.9    218.1    421.32  84.583   0.231   1.090   1.113

Product concentrations (mol/kg)
      Name            1.)          2.)          3.)          4.)
     al2o  Gas    4.394e+000   4.394e+000   4.394e+000   4.394e+000
        k  Gas    2.987e+000   2.969e+000   2.951e+000   2.934e+000
      hcl  Gas    1.744e+000   1.746e+000   1.749e+000   1.751e+000
```

cl	Gas	1.679e+000	1.676e+000	1.674e+000	1.671e+000
co	Gas	3.692e-001	3.692e-001	3.692e-001	3.692e-001
k2	Gas	3.039e-001	3.127e-001	3.214e-001	3.301e-001
cs	Gas	9.920e-002	9.911e-002	9.901e-002	9.890e-002
n2	Gas	9.199e-002	9.224e-002	9.251e-002	9.277e-002
kh	Gas	6.457e-002	6.464e-002	6.471e-002	6.477e-002
hcn	Gas	3.776e-002	3.743e-002	3.707e-002	3.673e-002
h	Gas	2.457e-002	2.378e-002	2.304e-002	2.234e-002
h2	Gas	1.737e-002	1.691e-002	1.646e-002	1.604e-002
c2h2	Gas	1.674e-002	1.639e-002	1.602e-002	1.566e-002
cn	Gas	1.549e-002	1.532e-002	1.514e-002	1.496e-002
s	Gas	5.026e-003	5.012e-003	5.003e-003	4.994e-003
sh	Gas	1.831e-003	1.835e-003	1.842e-003	1.848e-003
c	Gas	1.438e-003	1.392e-003	1.348e-003	1.306e-003
cs2	Gas	9.997e-004	1.034e-003	1.069e-003	1.105e-003
s2	Gas	3.616e-004	3.732e-004	3.856e-004	3.981e-004
cos	Gas	1.680e-004	1.746e-004	1.815e-004	1.885e-004
h2s	Gas	1.331e-004	1.338e-004	1.346e-004	1.354e-004
koh	Gas	1.121e-004	1.168e-004	1.217e-004	1.267e-004
n	Gas	1.095e-004	1.081e-004	1.068e-004	1.055e-004
ns	Gas	1.081e-004	1.103e-004	1.127e-004	1.151e-004
ch2	Gas	1.047e-004	1.024e-004	1.001e-004	9.795e-005
cho	Gas	5.331e-005	5.391e-005	5.451e-005	5.510e-005
ko	Gas	3.349e-005	3.476e-005	3.609e-005	3.744e-005
ch3	Gas	3.035e-005	2.981e-005	2.928e-005	2.876e-005
ch3cl	Gas	1.326e-005	1.351e-005	1.375e-005	1.398e-005
nh	Gas	1.187e-005	1.178e-005	1.171e-005	1.163e-005
co2	Gas	5.698e-006	5.927e-006	6.167e-006	6.410e-006
halo	Gas	3.591e-006	3.623e-006	3.658e-006	3.691e-006
nh2	Gas	2.666e-006	2.660e-006	2.655e-006	2.650e-006
h2o	Gas	2.473e-006	2.507e-006	2.545e-006	2.582e-006
oh	Gas	2.350e-006	2.371e-006	2.395e-006	2.419e-006
o	Gas	1.867e-006	1.875e-006	1.886e-006	1.897e-006
so	Gas	1.818e-006	1.889e-006	1.964e-006	2.041e-006
ketene	Gas	1.735e-006	1.768e-006	1.800e-006	1.832e-006
nco	Gas	1.210e-006	1.246e-006	1.283e-006	1.320e-006
no	Gas	1.077e-006	1.104e-006	1.132e-006	1.161e-006
hnco	Gas	1.056e-006	1.093e-006	1.129e-006	1.167e-006
ch4	Gas	9.863e-007	9.703e-007	9.541e-007	9.383e-007
ch3cn	Gas	9.013e-007	9.083e-007	9.136e-007	9.188e-007
c2h4	Gas	7.474e-007	7.361e-007	7.238e-007	7.118e-007
ch2o	Gas	6.764e-007	6.875e-007	6.988e-007	7.100e-007
nh3	Gas	5.119e-007	5.132e-007	5.147e-007	5.161e-007
alho2	Gas	2.392e-007	2.508e-007	2.632e-007	2.759e-007
alo2	Gas	2.478e-008	2.591e-008	2.711e-008	2.834e-008
s2o	Gas	3.655e-009	3.933e-009	4.237e-009	4.557e-009
hno	Gas	9.953e-010	1.029e-009	1.065e-009	1.101e-009
ch2oh	Gas	3.440e-010	3.524e-010	3.609e-010	3.695e-010
n2o	Gas	2.956e-010	3.109e-010	3.272e-010	3.439e-010
so2	Gas	1.045e-010	1.130e-010	1.224e-010	1.323e-010
o2	Gas	9.626e-011	1.006e-010	1.052e-010	1.099e-010
formac	Gas	7.037e-011	7.454e-011	7.896e-011	8.353e-011
ch4o	Gas	1.037e-011	1.068e-011	1.099e-011	1.131e-011
k2h2o2	Gas	6.641e-012	7.505e-012	8.475e-012	9.541e-012
ho2	Gas	4.122e-013	4.344e-013	4.584e-013	4.831e-013
no2	Gas	8.575e-014	9.194e-014	9.866e-014	1.057e-013
h2o2	Gas	1.947e-014	2.063e-014	2.188e-014	2.317e-014
hno2	Gas	4.778e-015	5.153e-015	5.561e-015	5.992e-015
mgo2h2	Gas	8.205e-018	8.367e-018	8.541e-018	8.715e-018
mgo	liquid	9.787e+000	9.787e+000	9.787e+000	9.787e+000
c(s)	solid	1.026e+000	1.027e+000	1.028e+000	1.030e+000
mgo	solid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
*koh	liquid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
al2o3	solid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
al2o3	liquid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
Total	Gas	1.185e+001	1.184e+001	1.183e+001	1.182e+001
Total	Cond.	1.081e+001	1.081e+001	1.082e+001	1.082e+001

C.3 0.60 g/cm^3 RS-41, + 2 g Black Powder

```
Input>composition, potass per, 47.93, al, 23.96, magnesium, 23.96, resinat,
1.957, potass nit, 1.612, sulfur, 0.233, susqkul1, 0.326 weight
                              The Composition

Name      % wt.  % mol % vol. Heat of Standard Standard Mol.   Formula
                              formation volume   entropy  wt.
                              (cal/mol) cc/mol)(cal/K/mol)
potass per47.94 15.40 42.59 -103250    54.81  0.000  138.55  o4cl1k1
al        23.97 39.54 19.94       0     9.99  0.000   26.98  al1
magnesium 23.97 43.89 30.94       0    13.97  0.000   24.31  mg1
resinat    1.96  0.14  4.07  -23901   580.75  0.000  627.20  c40h58o4mg1
potass nit 1.61  0.71  1.72 -118069    48.03  0.000  101.10  n1o3k1
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sulfur     0.23  0.32  0.25       0    15.49  0.000   32.06  s1
susqkull   0.33  0.00  0.49-4489962 12194.95  0.00018292.43  C1321H573N4O100S6

Heat of formation =   -377.636 cal/gm
Standard volume   =      0.445 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -377.647 cal/gm

The elements and percent by mole
     o             32.909
     cl             7.874
     k              8.237
     al            20.212
     mg            22.509
     c              3.377
     h              4.351
     n              0.365
     s              0.168
The average mol. wt. =  44.512 g/mol
Input>gun, 0.600000, 0.01330000, 0.640000
GUN calculation:

     Rho      Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
     g/cc      K        MPa       J/g      Gas     cc/g  Cp/Cv
1.)  0.6000  4343.2    309.4    413.55  87.324    0.222  1.087    1.154
2.)  0.6133  4344.4    317.8    413.33  87.392    0.222  1.087    1.157
3.)  0.6266  4345.5    326.2    413.12  87.460    0.222  1.087    1.161
4.)  0.6399  4346.6    334.7    412.90  87.527    0.222  1.087    1.165

Product concentrations (mol/kg)
      Name              1.)          2.)          3.)          4.)
     al2o  Gas   4.441e+000   4.441e+000   4.441e+000   4.441e+000
        k  Gas   2.725e+000   2.709e+000   2.693e+000   2.678e+000
      hcl  Gas   1.749e+000   1.751e+000   1.752e+000   1.754e+000
       cl  Gas   1.711e+000   1.709e+000   1.708e+000   1.706e+000
       k2  Gas   4.147e-001   4.226e-001   4.304e-001   4.382e-001
       co  Gas   1.291e-001   1.291e-001   1.290e-001   1.290e-001
       cs  Gas   6.706e-002   6.701e-002   6.696e-002   6.691e-002
       kh  Gas   6.552e-002   6.548e-002   6.543e-002   6.538e-002
       n2  Gas   6.036e-002   6.051e-002   6.065e-002   6.079e-002
      hcn  Gas   2.751e-002   2.731e-002   2.713e-002   2.694e-002
        h  Gas   1.719e-002   1.677e-002   1.637e-002   1.598e-002
     c2h2  Gas   1.323e-002   1.300e-002   1.278e-002   1.256e-002
       h2  Gas   1.231e-002   1.206e-002   1.182e-002   1.158e-002
       cn  Gas   1.179e-002   1.169e-002   1.159e-002   1.150e-002
        s  Gas   3.385e-003   3.380e-003   3.375e-003   3.369e-003
       sh  Gas   1.277e-003   1.280e-003   1.283e-003   1.285e-003
        c  Gas   1.125e-003   1.097e-003   1.070e-003   1.045e-003
      cs2  Gas   6.615e-004   6.789e-004   6.963e-004   7.139e-004
       s2  Gas   2.372e-004   2.432e-004   2.492e-004   2.552e-004
      h2s  Gas   9.217e-005   9.248e-005   9.276e-005   9.303e-005
      ch2  Gas   8.633e-005   8.481e-005   8.336e-005   8.195e-005
        n  Gas   8.402e-005   8.326e-005   8.252e-005   8.179e-005
       ns  Gas   7.854e-005   7.988e-005   8.121e-005   8.254e-005
      koh  Gas   6.445e-005   6.649e-005   6.853e-005   7.061e-005
      cos  Gas   6.319e-005   6.515e-005   6.714e-005   6.916e-005
      ch3  Gas   2.502e-005   2.466e-005   2.431e-005   2.398e-005
      cho  Gas   2.271e-005   2.292e-005   2.313e-005   2.333e-005
       ko  Gas   1.973e-005   2.030e-005   2.086e-005   2.144e-005
    ch3cl  Gas   1.671e-005   1.693e-005   1.716e-005   1.739e-005
       nh  Gas   9.593e-006   9.545e-006   9.499e-006   9.453e-006
     halo  Gas   2.553e-006   2.572e-006   2.590e-006   2.608e-006
      nh2  Gas   2.198e-006   2.195e-006   2.192e-006   2.189e-006
      co2  Gas   1.144e-006   1.179e-006   1.215e-006   1.252e-006
      h2o  Gas   1.033e-006   1.046e-006   1.058e-006   1.070e-006
       oh  Gas   9.910e-007   9.992e-007   1.007e-006   1.015e-006
    ch3cn  Gas   8.074e-007   8.113e-007   8.154e-007   8.195e-007
   ketene  Gas   7.972e-007   8.086e-007   8.203e-007   8.321e-007
        o  Gas   7.833e-007   7.872e-007   7.908e-007   7.945e-007
      ch4  Gas   7.824e-007   7.711e-007   7.601e-007   7.494e-007
       so  Gas   7.147e-007   7.370e-007   7.594e-007   7.821e-007
     c2h4  Gas   6.119e-007   6.025e-007   5.936e-007   5.849e-007
      nco  Gas   5.393e-007   5.522e-007   5.653e-007   5.785e-007
     hnco  Gas   4.654e-007   4.780e-007   4.908e-007   5.038e-007
       no  Gas   4.470e-007   4.561e-007   4.652e-007   4.743e-007
      nh3  Gas   4.248e-007   4.258e-007   4.267e-007   4.277e-007
     ch2o  Gas   2.981e-007   3.019e-007   3.058e-007   3.097e-007
    alho2  Gas   9.105e-008   9.456e-008   9.813e-008   1.018e-007
     alo2  Gas   9.993e-009   1.036e-008   1.072e-008   1.110e-008
      s2o  Gas   1.448e-009   1.535e-009   1.624e-009   1.717e-009
      hno  Gas   4.689e-010   4.818e-010   4.948e-010   5.080e-010
    ch2oh  Gas   1.734e-010   1.767e-010   1.799e-010   1.832e-010
      n2o  Gas   1.381e-010   1.438e-010   1.497e-010   1.558e-010
      so2  Gas   2.374e-011   2.528e-011   2.687e-011   2.855e-011
       o2  Gas   2.317e-011   2.400e-011   2.484e-011   2.570e-011
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   formac  Gas    1.838e-011  1.924e-011  2.011e-011  2.102e-011
     ch4o  Gas    5.354e-012  5.474e-012  5.595e-012  5.718e-012
   k2h2o2  Gas    3.536e-012  3.877e-012  4.243e-012  4.638e-012
      ho2  Gas    1.126e-013  1.174e-013  1.224e-013  1.275e-013
      no2  Gas    2.337e-014  2.471e-014  2.611e-014  2.756e-014
     h2o2  Gas    5.489e-015  5.747e-015  6.012e-015  6.285e-015
     hno2  Gas    1.377e-015  1.462e-015  1.551e-015  1.644e-015
   mgo2h2  Gas    4.131e-018  4.200e-018  4.269e-018  4.339e-018
      mgo liquid 9.891e+000  9.891e+000  9.891e+000  9.891e+000
     c(s)  solid 1.220e+000  1.221e+000  1.222e+000  1.222e+000
      mgo  solid 0.000e+000  0.000e+000  0.000e+000  0.000e+000
     *koh liquid 0.000e+000  0.000e+000  0.000e+000  0.000e+000
    al2o3  solid 0.000e+000  0.000e+000  0.000e+000  0.000e+000
    al2o3 liquid 0.000e+000  0.000e+000  0.000e+000  0.000e+000

     Total Gas   1.145e+001  1.144e+001  1.143e+001  1.143e+001
     Total Cond. 1.111e+001  1.111e+001  1.111e+001  1.111e+001
```

C.4 The Composition 24 Al/24 Mg/2 Res/50 $KClO_4$

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Product library title: the blake product library
Executing library command: gas eos, virial
Reactant library title:# Version 2.0 by P. Clark Souers

Input>composition, potass per, 50, al, 24, resinat, 2, magnesium, 24, weight
                                The Composition

Name      % wt.   % mol % vol.   Heat of  Standard  Standard    Mol.   Formula
                                formation  volume    entropy    wt.
                                (cal/mol) (cc/mol) (cal/K/mol)
potass per 50.00  16.10  44.63  -103250     54.81    0.000     138.55  o4cl1k1
al         24.00  39.69  20.06        0      9.99    0.000      26.98  al1
resinat     2.00   0.14   4.18   -23901    580.75    0.000     627.20  c40h58o4mg1
magnesium  24.00  44.06  31.13        0     13.97    0.000      24.31  mg1

Heat of formation =   -373.370 cal/gm
Standard volume   =      0.443 cc/gm
Standard entropy  =      0.000 cal/k/gm
Standard energy   =   -373.381 cal/gm

The elements and percent by mole
     o             33.319
     cl             8.257
     k              8.257
     al            20.351
     c              2.918
     h              4.232
     mg            22.666
The average mol. wt. =  44.623 g/mol
Input>gun, 0.100000, 0.100000, 1.000000
GUN calculation:
      Rho     Temp    Pressure  Impetus  Mol Wt.  Covol  Frozen     Phi
      g/cc     K        MPa       J/g      Gas     cc/g  Cp/Cv
1.)   0.1000  4314.3    44.5    429.65  83.491   0.225   1.091    1.023
2.)   0.2000  4348.8    91.9    427.95  84.493   0.224   1.090    1.047
3.)   0.3000  4367.2   142.3    426.17  85.204   0.223   1.089    1.072
4.)   0.4000  4380.0   196.1    424.42  85.807   0.223   1.088    1.098
5.)   0.5000  4390.0   253.6    422.71  86.352   0.223   1.088    1.125
6.)   0.6000  4398.5   315.0    421.04  86.863   0.222   1.088    1.154
7.)   0.7000  4406.0   380.7    419.41  87.348   0.222   1.087    1.184
8.)   0.8000  4412.8   451.1    417.82  87.816   0.222   1.087    1.216
9.)   0.9000  4419.1   526.6    416.26  88.270   0.221   1.087    1.249
10.)  1.0000  4425.0   607.7    414.74  88.712   0.221   1.087    1.283

Product concentrations (mol/kg)
Name           1.)         2.)         3.)         4.)         5.)         6.)
al2o   Gas 4.447e+000  4.447e+000  4.447e+000  4.447e+000  4.447e+000  4.447e+000
k      Gas 3.395e+000  3.245e+000  3.107e+000  2.977e+000  2.854e+000  2.735e+000
cl     Gas 2.075e+000  1.986e+000  1.945e+000  1.920e+000  1.903e+000  1.890e+000
hcl    Gas 1.534e+000  1.623e+000  1.664e+000  1.689e+000  1.706e+000  1.719e+000
co     Gas 2.088e-001  2.088e-001  2.088e-001  2.087e-001  2.087e-001  2.087e-001
h      Gas 8.970e-002  5.181e-002  3.611e-002  2.734e-002  2.169e-002  1.773e-002
k2     Gas 8.000e-002  1.518e-001  2.194e-001  2.837e-001  3.454e-001  4.049e-001
kh     Gas 5.369e-002  6.054e-002  6.313e-002  6.410e-002  6.429e-002  6.401e-002
h2     Gas 4.324e-002  2.795e-002  2.068e-002  1.633e-002  1.341e-002  1.129e-002
c2h2   Gas 4.244e-002  2.901e-002  2.221e-002  1.802e-002  1.516e-002  1.306e-002
c      Gas 7.828e-003  4.311e-003  2.946e-003  2.207e-003  1.741e-003  1.419e-003
ch2    Gas 2.798e-004  1.963e-004  1.519e-004  1.238e-004  1.042e-004  8.975e-005
ch3    Gas 5.603e-005  4.373e-005  3.571e-005  3.019e-005  2.616e-005  2.308e-005
cho    Gas 2.139e-005  2.642e-005  2.974e-005  3.247e-005  3.497e-005  3.739e-005
koh    Gas 1.015e-005  2.360e-005  3.885e-005  5.585e-005  7.478e-005  9.588e-005
ch3cl  Gas 5.875e-006  8.684e-006  1.067e-005  1.232e-005  1.382e-005  1.528e-005
ko     Gas 4.449e-006  9.420e-006  1.479e-005  2.060e-005  2.690e-005  3.378e-005
halo   Gas 2.016e-006  2.474e-006  2.758e-006  2.976e-006  3.164e-006  3.337e-006
ch4    Gas 1.352e-006  1.156e-006  9.777e-007  8.394e-007  7.313e-007  6.449e-007
o      Gas 1.108e-006  1.223e-006  1.296e-006  1.355e-006  1.407e-006  1.456e-006
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c2h4	Gas	1.079e-006	9.410e-007	8.009e-007	6.884e-007	5.986e-007	5.258e-007
oh	Gas	9.662e-007	1.190e-006	1.333e-006	1.447e-006	1.547e-006	1.642e-006
h2o	Gas	6.841e-007	9.316e-007	1.101e-006	1.241e-006	1.369e-006	1.492e-006
ketene	Gas	4.858e-007	6.940e-007	8.451e-007	9.758e-007	1.100e-006	1.225e-006
co2	Gas	3.686e-007	7.674e-007	1.212e-006	1.710e-006	2.270e-006	2.901e-006
ch2o	Gas	1.909e-007	2.672e-007	3.208e-007	3.658e-007	4.074e-007	4.483e-007
alho2	Gas	1.419e-008	3.477e-008	6.019e-008	9.094e-008	1.279e-007	1.724e-007
alo2	Gas	2.195e-009	4.992e-009	8.322e-009	1.226e-008	1.692e-008	2.242e-008
ch2oh	Gas	7.208e-011	1.209e-010	1.594e-010	1.937e-010	2.267e-010	2.602e-010
o2	Gas	6.602e-012	1.517e-011	2.534e-011	3.731e-011	5.133e-011	6.779e-011
formac	Gas	2.217e-012	6.557e-012	1.259e-011	2.051e-011	3.072e-011	4.377e-011
ch4o	Gas	1.521e-012	2.876e-012	4.029e-012	5.104e-012	6.171e-012	7.277e-012
ho2	Gas	1.983e-014	5.421e-014	9.965e-014	1.573e-013	2.293e-013	3.188e-013
k2h2o2	Gas	1.099e-014	1.222e-013	5.191e-013	1.506e-012	3.567e-012	7.466e-012
h2o2	Gas	6.584e-016	2.037e-015	3.991e-015	6.574e-015	9.911e-015	1.418e-014
mgo2h2	Gas	2.388e-018	3.591e-018	4.496e-018	5.297e-018	6.069e-018	6.854e-018
mgo liqui		9.906e+000	9.906e+000	9.906e+000	9.906e+000	9.906e+000	9.906e+000
c(s)	solid	9.736e-001	1.004e+000	1.019e+000	1.028e+000	1.035e+000	1.039e+000
mgo solid		0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000
*koh liqu		0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000
al2o3 sol		0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000
al2o3 liq		0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000	0.000e+000
Total Gas		1.198e+001	1.184e+001	1.174e+001	1.165e+001	1.158e+001	1.151e+001
Total Con		1.088e+001	1.091e+001	1.093e+001	1.093e+001	1.094e+001	1.095e+001

Product concentrations (mol/kg)

Name		7.)	8.)	9.)	10.)
al2o	Gas	4.447e+000	4.447e+000	4.447e+000	4.447e+000
k	Gas	2.620e+000	2.509e+000	2.401e+000	2.296e+000
cl	Gas	1.880e+000	1.872e+000	1.865e+000	1.860e+000
hcl	Gas	1.729e+000	1.737e+000	1.743e+000	1.749e+000
k2	Gas	4.625e-001	5.184e-001	5.729e-001	6.261e-001
co	Gas	2.086e-001	2.086e-001	2.086e-001	2.085e-001
kh	Gas	6.345e-002	6.270e-002	6.180e-002	6.080e-002
h	Gas	1.479e-002	1.252e-002	1.072e-002	9.252e-003
c2h2	Gas	1.146e-002	1.019e-002	9.159e-003	8.304e-003
h2	Gas	9.683e-003	8.418e-003	7.393e-003	6.545e-003
c	Gas	1.182e-003	1.000e-003	8.565e-004	7.397e-004
koh	Gas	1.195e-004	1.459e-004	1.757e-004	2.094e-004
ch2	Gas	7.856e-005	6.961e-005	6.227e-005	5.613e-005
ko	Gas	4.130e-005	4.956e-005	5.868e-005	6.876e-005
cho	Gas	3.982e-005	4.234e-005	4.498e-005	4.778e-005
ch3	Gas	2.064e-005	1.866e-005	1.702e-005	1.564e-005
ch3cl	Gas	1.675e-005	1.826e-005	1.986e-005	2.157e-005
co2	Gas	3.615e-006	4.425e-006	5.345e-006	6.395e-006
halo	Gas	3.501e-006	3.663e-006	3.825e-006	3.990e-006
oh	Gas	1.734e-006	1.827e-006	1.922e-006	2.021e-006
h2o	Gas	1.616e-006	1.745e-006	1.879e-006	2.023e-006
o	Gas	1.504e-006	1.552e-006	1.601e-006	1.651e-006
ketene	Gas	1.354e-006	1.493e-006	1.643e-006	1.809e-006
ch4	Gas	5.743e-007	5.153e-007	4.653e-007	4.222e-007
ch2o	Gas	4.899e-007	5.333e-007	5.796e-007	6.294e-007
c2h4	Gas	4.656e-007	4.148e-007	3.713e-007	3.336e-007
alho2	Gas	2.258e-007	2.903e-007	3.683e-007	4.630e-007
alo2	Gas	2.894e-008	3.668e-008	4.590e-008	5.691e-008
ch2oh	Gas	2.951e-010	3.325e-010	3.732e-010	4.182e-010
o2	Gas	8.710e-011	1.098e-010	1.366e-010	1.682e-010
formac	Gas	6.045e-011	8.174e-011	1.090e-010	1.440e-010
k2h2o2	Gas	1.440e-011	2.621e-011	4.580e-011	7.765e-011
ch4o	Gas	8.459e-012	9.750e-012	1.118e-011	1.280e-011
ho2	Gas	4.299e-013	5.679e-013	7.393e-013	9.528e-013
h2o2	Gas	1.961e-014	2.652e-014	3.531e-014	4.651e-014
mgo2h2	Gas	7.681e-018	8.571e-018	9.547e-018	1.063e-017
mgo	liquid	9.906e+000	9.906e+000	9.906e+000	9.906e+000
c(s)	solid	1.043e+000	1.045e+000	1.048e+000	1.049e+000
mgo	solid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
*koh	liquid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
al2o3	solid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
al2o3	liquid	0.000e+000	0.000e+000	0.000e+000	0.000e+000
Total	Gas	1.145e+001	1.139e+001	1.133e+001	1.127e+001
Total	Cond.	1.095e+001	1.095e+001	1.095e+001	1.096e+001

References

(1) Moxnes John F, Nevstad Gunnar Ove, Eriksen Svein W (2000): Combustion of RS-41, FFI/RAPPORT-2000/02758
(2) Laurence E. fried, W. Michael Howard, P. Clark Souers (20 August 1998): Cheetah 2.0 User's Manual: *UCRL-MA-117541 Rev. 5*, Lawrence Livermore National Laboratory.

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