Advanced Work on Increasing the Performance of Gun Propellants

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Abstract

The use of gun propellants, whose burning rates do not very strongly depend on the propellant temperature, is a good method of increasing the muzzle velocity of gun ammunition, because the permissible maximum pressure can be exploited to full advantage.

While other institutions try to reduce the temperature coefficient of a gun propellant by utilizing an appropriate surface coating or by igniting the propellant charge by means of a plasma jet, Diehl company in conjunction with the Fraunhofer Institut Chemische Technologie (ICT) has been developing a novel type of gun propellant, whose temperature coefficient as well as the temperature sensitivity is lowered by using a new energetic plasticizer.
This approach enables a complete family of propellants, whose specific energies vary in a wide range. The adiabatic flame temperatures of these propellants are up to 500 degrees below the temperature of the JA2 propellant at a same or higher level of the specific energy.

Due to the energetic plasticizer the novel propellants show the desired favourable temperature behaviour in that way that the maximum gun pressure is highest near 21°C and then decreases with increasing temperature.This temperature behaviour can even be observed in the closed vessel by means of the dynamic vivacity of the gun propellant for example.
Furthermore these propellants proved insensitive when subjected to a shaped charge attack and to fast heating.

Up to now a great deal of firings have been carried out in the closed vessel, in a 40mm proof gun barrel and in a 75mm canon, which is a scale model of the 120mm tank gun.
In case of the 75mm scale model gun for example we found that the novel propellant provides an increase of the muzzle velocity of nearly 100 m/s compared with the JA2 propellant, because of the better thermochemistry and the more favourable temperature gradient.

1. Introduction

The use of gun propellants, whose burning rates do not very strongly depend on the propellant temperature, is a good method of increasing the muzzle velocity of gun ammunitions. Because the permissible maximum pressure can be exploited to full advantage.

While other institutions try to reduce the temperature coefficient of a gun propellant by utilizing an appropriate surface coating or by igniting the propellant charge by means of a plasma jet, Diehl company in conjunction with the Fraunhofer Institut Chemische Technologie (ICT) has been developing a novel type of a gun propellant, whose temperature coefficient as well as the temperature sensitivity is lowered by using a new energetic plasticizer [1], [2].

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2. Chemicophysical characteristics

The novel gun propellants consist of a christalline explosive, a binder and a special plasticizer. Depending on the formulation, the performance data vary on a large scale allowing a wide application in machine gun, tank gun or artillery ammunition. The special feature of these propellants is a high specific energy at a comparatively low adiabatic flame temperature (Table 1). This turns out to be particularly valuable with respect to barrel erosion.

Table1: Performance data

Formulation	Impetus (J/g)	T_f (K)	M* (g/mol)
A	1080	2540	19.4
B	1180	2910	20.8
C	1300	3390	21.6

The safety features of the new gun propellants are improved compared to those of the conventional NC propellants. The ignition temperature ranging from about 230 °C to 240 °C is appreciably higher than that of the nitrocellulose propellants (Table 2). This high ignition temperature has an extremely positive effect on the cook-off temperature of the cartridge.
The chemical stability is also significantly improved in comparison with conventional propellants. The long term stability test at 90 °C after 18 days shows a loss of weight of only 0.80 to 1.10 %, after 30 days the loss of weight ranges between 1.30 and 1.65 %. The required value after 18 days is of the order of 3 % at the most. The vacuum stability test at 90 °C proved a gas production of about 1.06 ml only.

Table 2 : Safety data

Loss of weight after 18 days	1.10 %
Loss of weight after 30 days	1.65 %
Sensitivity to friction	160 N
Sensitivity to impact	4 J
Ignition temperature	230 °C
DDT test	no transition
Fast cook off test	burning
Shaped charge impact test	burning

3. Ballistic characteristics

Closed vessel firing tests at different temperatures and varying loading densities were carried out in order to examine the combustion behaviour. The dynamic vivacity and the burning rate were determined from the measured values.
This went to prove the particular temperature behaviour of the novel gun propellants, i.e. the vivacity and burning rate at a propellant temperature of 50 °C were lower than the corresponding values observed at 21 °C (Fig. 1 and 2). This temperature behaviour proved to be reproducible and was also found when different formulations were used.

Proceeding on the assumption that one-sided mechanical load on the propellant grains does not occur in the closed vessel at small loading densities, it follows that this particular temperature behaviour is a recipe-specific characteristic. Up to present, a behaviour such as this has not been observed with any other gun propellant.

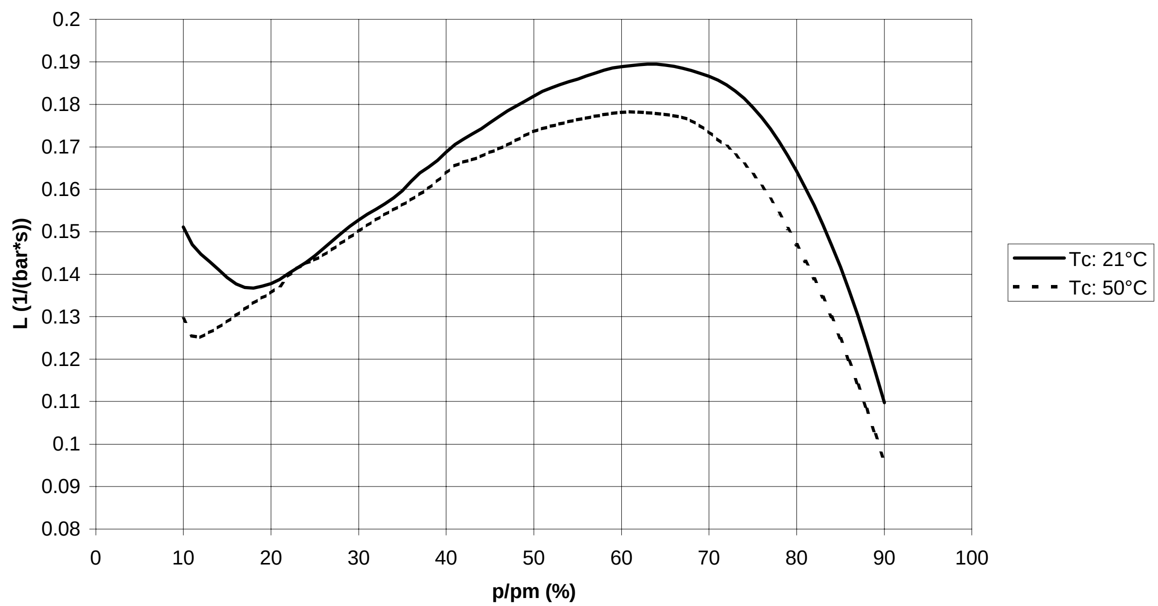

Fig. 1: Dynamic vivacitiy at 21 and 50 °C

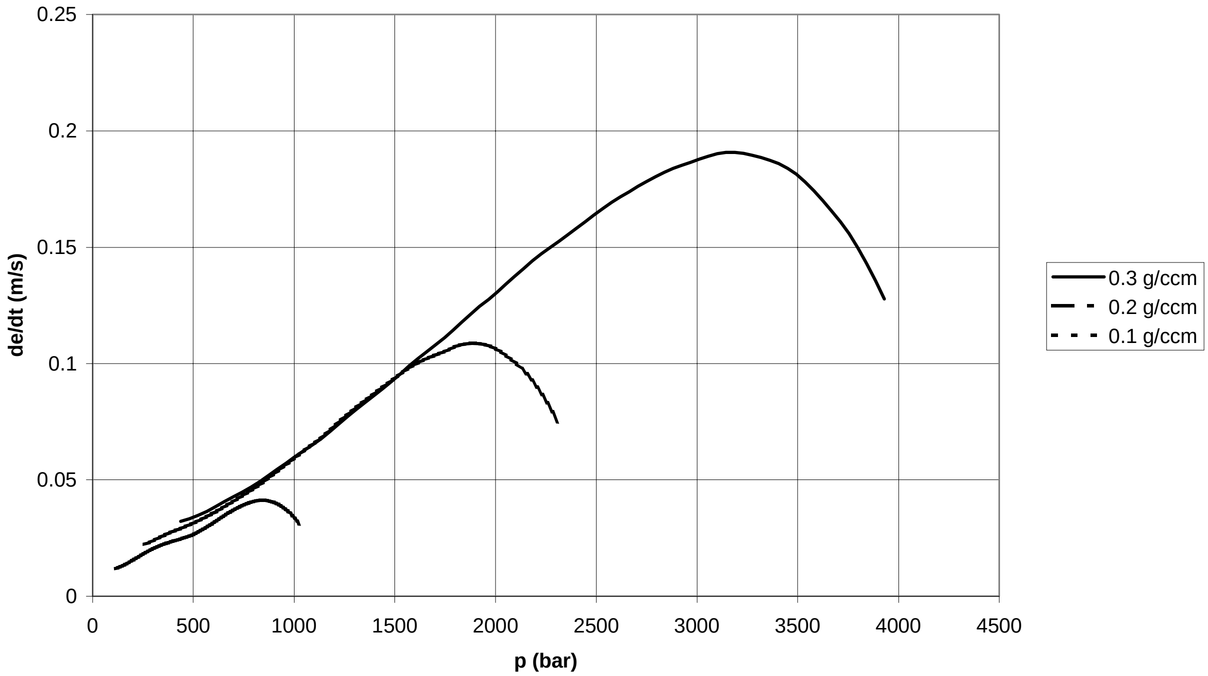

Fig. 2: Linear burning rates at different loading densities

In order to examine the novel propellants for an application in the tank gun, several different formulations were extensively tested in a 75 mm scale model gun. Based on internal ballistic similarity laws, this model gun was derived from the 120 mm tank gun of the Leopard 2 combat tank. Thus it was possible to compare directly the performance yielded by the novel-type propellants with that of the established JA2 propellants.
After determining the charge mass, the propellants were tested at the following temperatures: -40 °C, -20 °C, 0 °C, 21 °C, 35 °C and 50 °C. Fig. 3 shows a typical test result.

It appeared that the maximum pressure reached its highest value at around 21 °C and decreased with increasing temperature. This allowed to adjust the pressure at 21 °C to the value reached by the JA2 propellant at 50 °C. In this way it was possible to raise the muzzle velocity by approximately 100 m/s to 1750 m/s as compared to the JA2 propellant.

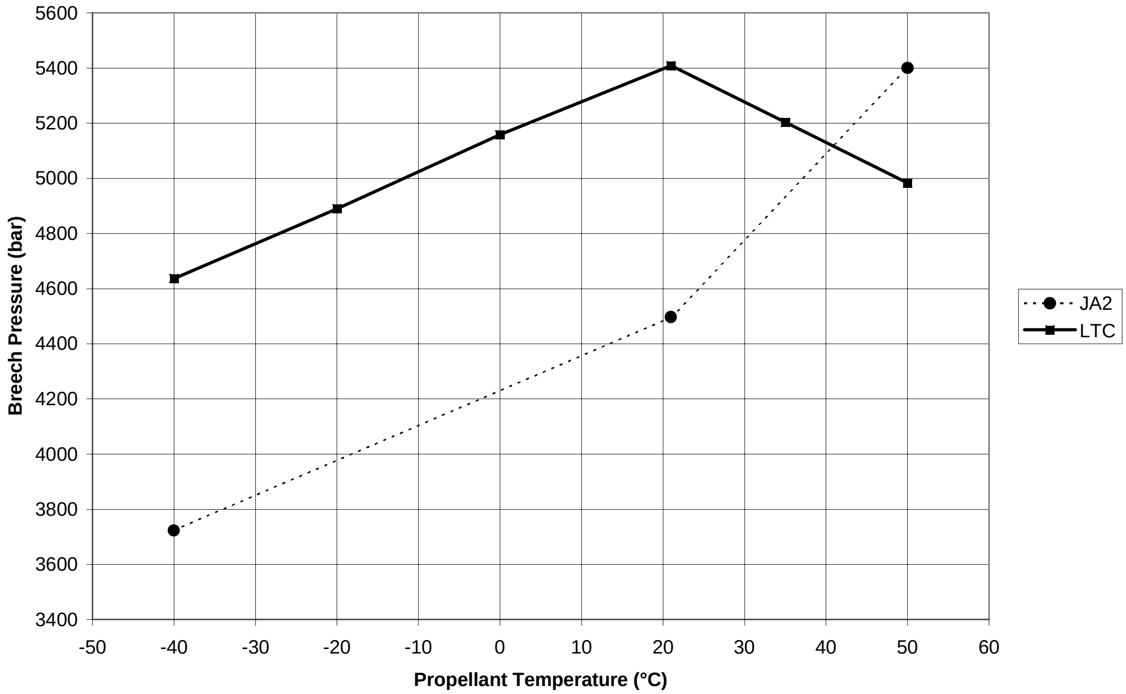

Fig. 3: Temperature behaviour in the gun compared to JA2

The steepness of the maximum pressure decline with continuously rising temperature was dependent on the respective formulation; hence follows that this steepness is a propellant-specific quantity.
A precise analysis of all firing test data obtained in the closed vessel as well as in the 75 mm gun showed that the propellant temperature coefficient, as determined in the closed vessel, is directly correlated with the temperature gradient in the gun on the one hand, and with the relevant formulation on the other hand (Fig. 4 and 5).

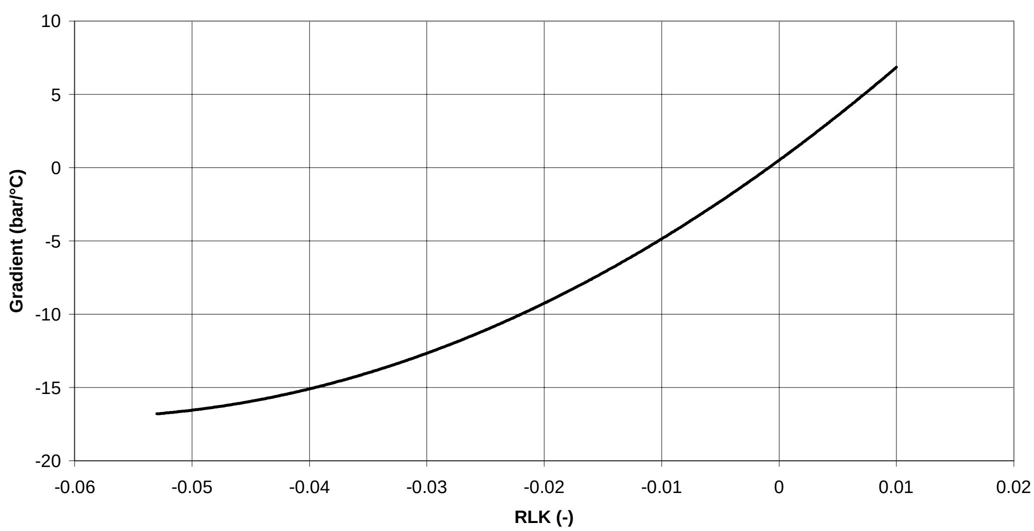

Fig. 4: Correlation between temperature coefficient and gradient

This correlation enables the temperature behaviour of a formulation to be examined by means of the closed vessel and, in the end, to be specifically adjusted without being obliged to carry out expensive tests in the weapon. Thus the closed vessel remains an important test equipment in the course of the development of new propellants.

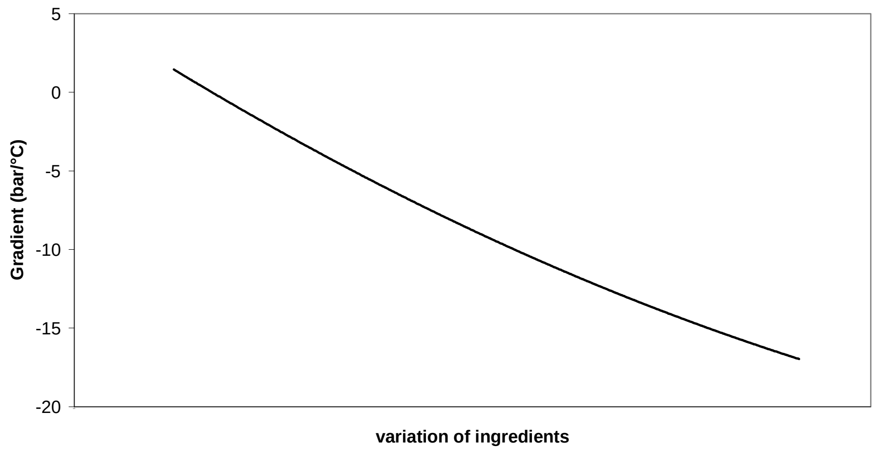

Fig. 5: Correlation between temperature gradient and formulation

4. Summary

The application of a novel plasticizer enables a whole family of propellants to be produced. It is possible to adjust the specific energy of the propellants within a wide range, and, at the same time, the respective flame temperature is considerably lower than what we are used to in case of conventional propellants. On that account new propellants are less erosive than comparable ones. Due to the fact that the ignition temperature of the novel propellants amounts to far more than 200 °C, they are well suited for cartridges requiring a high cook-off temperature. That's why these propellants are usable in machine gun ammunition, in tank gun ammunition and in artillery ammunition as well.
Besides their high energy density, which alone can be profitably used for an increase in performance, it is their particular temperature behaviour which produces another, by far more important increase in performance, since the permissible maximum pressure can now be utilized to full advantage.

5. References

[1] German patent DE 19757469 A1
[2] US patent application US 355,479