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# Experimental investigation of a cook-off temperature in a hot barrel

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**Abstract**

The experimental investigations of the effect of contact time/temperature on initiating the cook-off using 7.62 mm calibre cartridge cases (CC) were conducted previously. These cartridges were filled with commercial off-the-shelf (COTS) double based (DB) propellant (Bulls Eye) and were loaded in a hot chamber. The thermal explosion temperature is of great significance to both weapon designers and safety inspectors as it provides the operational limit and safe operating temperature. For CC under test, it was found that the cook-off temperatures of this propellant were encountered with the heat transfer profile of the simulated gun barrel between 151.4 °C and 153.4 °C, with a reaction occurring in less than 300 s after the round was chambered. Usefully, each experiment was found to be consistent and repeatable.


*Keywords:* Gun barrel; Cook-off; Barrel heating; Propellant cook-off temperature

## 1. Introduction

As the gun fires, the chamber surface temperature increases due to propellant burning. If it continues to fire at a high rate, the chamber surface temperature will continue to increase with every firing. During this event, if the propellant cartridge is loaded in the hot chamber, the heat transfer from chamber to propellant will take place. As the propellant heats up, the thermal decomposition reaction initiates, and in the limit it could lead to thermal explosion or 'cook off'. The rate at which the chamber heats up defines the operational limit of the weapon and its ammunition propellant. Therefore it is important for both the weapon designer and the safety inspector to understand and appreciate this thermal limitation while designing the weapon and defining the appropriate rate of fire and storage procedure. Currently operational and training limits for hot gun weapons are typically defined in terms of a set number of rounds in a specified time period. A further understanding of the cook-off mechanism will allow development of systems, particularly in platform mounted weapons, where the hot gun limits can be based on weapon temperature readings.

In the event of a chambered round in a hot gun, the standard means of dealing with the situation is to leave the weapon on target, or in a known safe direction, for the duration of the safe cook-off wait-time. This necessitates remaining in contact with, and being exposed to, the target for the duration of the period. In the case of man-portable small arms, this is likely to mean an increase in exposure while weapon arcs significantly constrain manoeuvrability in a larger platform.

By further understanding of cook-off mechanisms, and therefore of the time and temperature limits of the reaction mechanism, such operational constraints can potentially be reduced. An increase in the temperature at which the weapon is considered to be in a too hot will allow greater flexibility in firing rate before overheating. An accurate understanding of the cook-off reaction times for the weapon at a specific temperature can reduce the safe wait-time and allow manoeuvring

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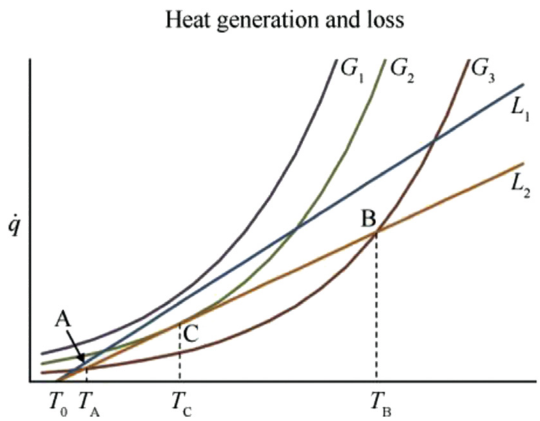


Fig. 1. Heat generated in (*G*) and loss (*L*).

sooner. In addition, understanding the minimum time before a reaction occurs may allow action to be taken, such as ejecting the round to prevent the reaction from occurring.

## 2. Propellant cook-off in hot gun

In a system where there is a cook-off event, cook-off arises due to an acceleration of the heat released by the internal decomposition reaction that is greater than the degree of cooling. This may be due to the weapon being hot, which causes a high temperature difference and induces a rapid heat gain within the round, or alternatively low levels of heat loss preventing the reaction from taking place.

In a gun system, heat is lost from the system at a rate which is dependent on the conditions at the boundary of the system. Each system can be considered to be made up of two curves representing heat generation (*G*) and heat loss (*L*) which are independent but interact to form the system heat balance. The thermal behaviour of the system can be described by Eq. (1) [3] below.

$$mc_v \frac{dT}{dt} = G - L \quad (1)$$

where $m$ is propellant mass and $c_v$ is specific heat. While the rate of heat being generated by the system is an exponential function, governed by the Arrhenius equation, the heat loss from the system is a linear function based on the boundary conditions. When heat loss is subtracted from heat generated as shown in Fig. 1, the change in thermal energy is obtained.

The gradient of $L$ is set by the heat transfer properties of the boundary while the $x$-intercept ($T_0$) is the ambient temperature at the boundary of the system. From this if the system temperature is higher than $T_0$, there is a net heat loss from the system, however if the system temperature is lower than $T_0$, $L$ will be negative and there will be a net heat flow into the system.

From Fig. 1, it can be seen that, for heat curves $G_3$ and $L_2$, a stable region exists below $T_B$ in which temperatures will tend to $T_A$. For a small temperature increase above $T_A$, heat loss $L$ is greater than heat generated $G$, and therefore the temperature will decrease to $T_A$. Similarly, the temperatures below $T_A$ will increase as heat gain $G$ is greater than heat loss $L$. At temperatures above $T_B$, there exists an unstable state where heat gain $G$ always exceeds heat loss $L$ and thermal runaway commences.

For the systems where $L$ is minimal when compared to $G$, such as with $G_1$ and $L_2$, there is no capacity for a stable condition to exist and the system always undergoes thermal runaway. As $L$ decreases further as compared to $G$, there exists a situation where the system is thermally stable at only one temperature, as can be seen from $G_2$ and $L_2$, and is unable to withstand any temperature increase without undergoing thermal runaway.

## 3. Cook-off situation

In a weapon cook-off situation, $T_c$ is the barrel temperature and therefore $L$ is a significant portion of the temperature profile. This has the effect of reducing the stable region between $T_A$ and $T_B$ to the point where there is no overlap between $G$ and $L$. Under these conditions, the system is always

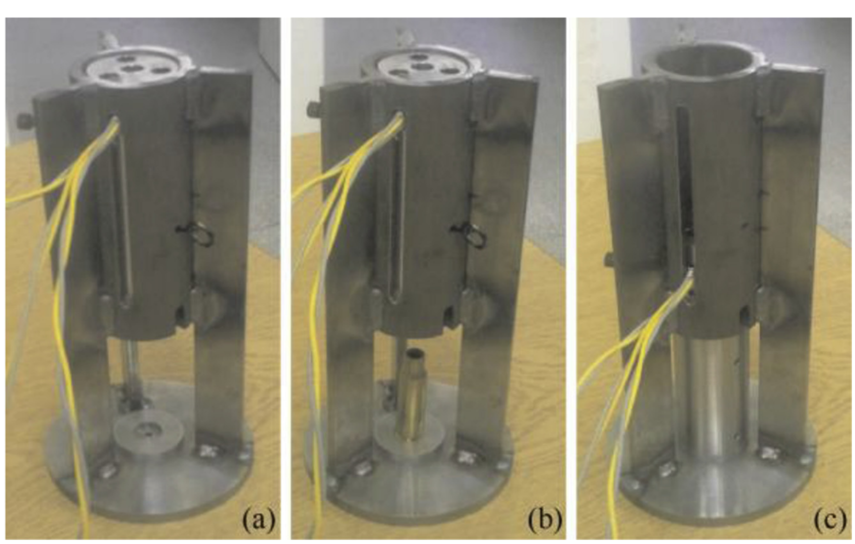


Fig. 2. Test apparatus: (a) unloaded, (b) loaded and (c) activated.