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PLUTONIUM PYROPHORICITY

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SUBJECT DESCRIPTORS

Metal Burning
Plutonium Burning
Plutonium Ignition
Plutonium Oxidation

EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT
P. O. BOX 464
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ABSTRACT

A review of the published literature on ignition and burning of plutonium metal was conducted in order to better define the characteristics of pyrophoric plutonium. The major parameter affecting ignition is the surface area/mass ratio of the sample. Based on this parameter, plutonium metal can be classified into four categories: (1) bulk metal, (2) film and foils, (3) chips and turnings, and (4) powder. Other parameters that can alter the ignition of the metal include experimental, chemical, physical, and environmental effects. These effects are reviewed in this report. It was concluded from this review that pyrophoric plutonium can be conservatively defined as: *Plutonium metal that will ignite spontaneously in air at a temperature of 150 °C or below in the absence of external heat, shock, or friction.* The 150 °C temperature was used to compensate for the self-heating of plutonium metal. For a practical definition of whether any given metal is pyrophoric, all of the factors affecting ignition must be considered.

INTRODUCTION

Rocky Flats does not have a specific definition for pyrophoric material. In fact, this term is used quite loosely to characterize a number of materials that may be flammable but not pyrophoric and those that are flammable under vastly different conditions. Before one can understand and define pyrophoricity as it applies to plutonium, the broad range of chemical reactions involved in so-called "burning" processes must be understood.

Metal fires, like those of more common combustible solids and liquids (such as wood, paper, plastics, and gasoline), release significant quantities of heat. However, there are some important differences between the mechanisms of burning metal and burning combustibles. Bulk metal is usually more difficult to ignite than the more common organic materials. The ignition of a 1-kg plutonium button requires heating 50-60 seconds with a welding torch. Spread of the burning reaction to cover the button may take 10-15 minutes with the temperature reaching over 800 °C. Paper or gasoline, on the other hand, can be ignited by a spark, and the temperatures rarely exceed 500 °C.

The ignition of reactive metals is due to rapid surface oxidation. The ignition of solid combustibles is usually due to pyrolysis. Surface oxidation is like rusting of iron, and there is a limited area where the process can occur. Pyrolysis involves the thermochemical breakdown of the material and the release of combustible gases such as hydrogen and methane, which can then ignite. The difference between surface oxidation and pyrolysis also accounts for the different appearance of metal fires. Burning metal appears very bright, and the fire appears at the metal surface like the glowing of charcoal. The burning of a solid combustible or liquid is seen in the flame front, usually some distance from the surface.

The difference between surface oxidation and pyrolysis also accounts for the higher temperatures usually observed when metals burn. Burning plutonium is an exothermic reaction in which 1 kcal of heat is released per gram of plutonium. This heat is either deposited in the metal and oxide or released to the environment. As the temperature of the metal increases, its oxidation rate increases exponentially, releasing more heat.

The equilibrium temperature at which plutonium burns depends on a balance between heat generation and heat dissipation. Heat generation is controlled by factors that control the oxidation