Studies in comparative detonation sensitivities

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Abstract. Detonation testing has been conducted by the National Fertilizer Development Center of the Tennessee Valley Authority to determine the relative detonation sensitivity for solid fertilizer materials which contain ammonium nitrate. Selected data are given that describe the application of the procedure to various types of mixtures. The test sample is placed in a cardboard cylinder with a kraft paper bottom. These containers vary in diameter from 3 3/8 to 6 inches; the smaller diameter containers are used for relatively sensitive materials and the larger diameter containers are used for less sensitive items. To provide a quantitative measure of the relative sensitivity to detonation, an index of sensitivity \( I_s \) is given, defined as 100/mean weight of booster in grams. The mean weight is that at which one-half of the tests would be expected to detonate. The booster used was pentaerythritol tetranitrate (PETN).

A test procedure is described for predicting the behavior of fertilizer materials containing ammonium nitrate when exposed to flame or heat. Illustrative data from such testing of materials, both with and without potassium chloride, are given.

It is recommended that additives be used to reduce detonation sensitivities.

Introduction

An explosion of ammonium nitrate at Oppau, Germany, in 1921 [5] and fire-related explosions at Traskwood, Arkansas, and Norton, Virginia [8], in 1960 and 1961, respectively, are examples of incidents that cause public concern regarding the safety of ammonium nitrate. Attention is drawn to the hazards associated with the preparation, handling, and storage of materials containing nitrogen. After each spectacular disaster, there follows a period of investigations into the causes of the explosions, with subsequent recommendations of preventative measures. The major explosions are cyclical in time, following periods of international hostilities. In the aftermath of such conflicts, there are stockpiles of ammonium nitrate for ammoniation purposes and surplus facilities for its manufacture. Thus, there are efforts to find profitable uses of the surplus items.

The greatest demand for ammonium nitrate and related materials is often
for fertilizer use. The preparation of ammonium nitrate, its conditioning, and the handling procedures are the same as those previously employed for uses related to military operations. When manufacture and distribution activities are performed by personnel inexperienced in handling hazardous materials requiring special precautions, serious incidents have occurred, resulting in the loss of life and property. Most of these incidents occurred when ammonium nitrate was handled casually.

One of the more damaging incidents, the explosion at Oppau, apparently occurred because workers were accustomed to breaking caked fertilizers with dynamite; this method was applied to a large quantity of caked material containing ammonium nitrate. The post-World War II years brought a disastrous ammonium nitrate explosion at Texas City, Texas, in 1947. The incident was extensively investigated by the United States Coast Guard. In the resulting report, the statement was made that "... persons concerned with the handling, storage, and transportation of the cargo displayed a lack of knowledge of the provisions and regulations governing the safety of the operations." [7]

One of the difficulties that investigators encountered when studying the hazards associated with ammonium nitrate was the diversity and unpredictability of the decomposition processes. Berthelot postulated the following eight thermal decomposition reactions as the probable reaction routes [1]:

\[
\text{NH}_4\text{NO}_3 = \text{HNO}_3(g) + \text{NH}_3(g) \tag{1}
\]

This reaction occurs at about 100 °C, is actually an endothermic reaction, and will not in itself cause a detonation. However, if the gases thus formed remain under pressure, they may lead to a detonation following further reaction:

\[
\text{HNO}_3(g) + \text{NH}_3(g) = \text{N}_2\text{O}(g) + 2\text{H}_2\text{O}(g) \tag{2}
\]

Another decomposition route is:

\[
\text{NH}_4\text{NO}_3 = \text{N}_2\text{O}(g) + 2\text{H}_2\text{O}(g) \tag{3}
\]

This particular decomposition pattern occurs most often in the temperature range 180 °-200 °C.

Explosive reactions occur when the materials are placed so that pressure develops. Among the potential detonation reactions are:

\[
2\text{NH}_4\text{NO}_3 = 2\text{N}_2(g) + \text{O}_2(g) + 4\text{H}_2\text{O}(g) \tag{4}
\]