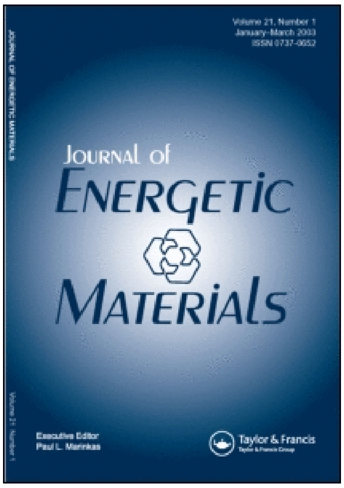

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ASSESSING THE RESPONSE OF NAVAL ARMAMENT STORES IN CREDIBLE ACCIDENT ENVIRONMENTS

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ABSTRACT

The paper reviews the credible accident environments to which an armament store could be subjected in service. The current fast cook-off, slow cook-off and impact tests for naval armament stores are described. The extent to which theoretical studies are needed to further the understanding of the response of stores in these environments is discussed.

INTRODUCTION

It must always be assumed that an armament store will be subjected to some accidental stimulus during its lifetime. Procedural controls can be devised to reduce the chance of an accident occurring and also to minimise the magnitude of the stimulus. For example in using a crane to lift a weapon every effort can be made to ensure that the crane is fit for its purpose; control can be exercised on the type of crane used to ensure it has those safety features which would reduce the chance of an uncontrolled lowering (in the worst case dropping the weapon). For the designer of an armament store an objective must be to minimise the consequences of the worst credible stimulus; this may be achieved by the appropriate choice of the energetic material, by optimising the design of the components which surround the energetic material or by combining both approaches.

In establishing the worst credible stimulus the manufacture to target sequence is reviewed. From a careful assessment of the activities the worst credible accident scenarios can be defined.

Two particular types of accident have been chosen for discussion in this paper:

a. those resulting in a fire

b. those resulting in impact of the armament store

ACCIDENTS

When accidents occur they are a reminder of the need for continuing vigilance in ensuring high standards of safety both in the design of weapons and the procedures which are followed in handling and storage. Accidents are analysed to determine the cause and to identify any lessons which should be learned. It is important that these should be applied not just to the particular area in which the accident occurred but more generally as well. An analysis of accidents can lead to the introduction of new or improved methods of testing armament stores.

USS Forrestal Accident

The disastrous fires which occurred on the US aircraft carriers Forrestal and Enterprise in 1967 led to an increased awareness of the hazard of fire on the flight deck of a carrier. Analysis of the accidents led to improvements in fire fighting procedures and to more stringent tests of the response of armament stores to fire. Where the response was unsatisfactory then there was a requirement for thermal protection to increase the survival time of the store. The UK has followed a similar policy to the US.

Recent UK Accident Experience

The naval experience over a number of years has shown that impact is one of the more likely accident stimuli but fortunately in recent times the consequences have not been serious. Damage to the store has ranged from cosmetic to gross damage but explosive events have not occurred. Action has been taken to improve some of the procedures to reduce both the chance of an impact and the severity of damage if the store were to be dropped. Additionally the impact test of the store has been made more representative of credible scenarios.

ASSESSMENT THROUGH TRIAL

Subjecting an armament store to a specified environment and monitoring its response is still the most satisfactory method of assessing its safety. A review of the stockpile-to-target sequence will lead to the identification of a range of credible accidents with a range of stimuli. Trials of complete stores are expensive so the policy is to test armament stores to the worst credible stimulus and to build in a safety factor.

Fire Trials

The current fuel fire trial involves supporting the armament store in its package (if applicable) at a specified height above a 6m by 6m pool of kerosene floating on water; the hearth is surrounded by a wall of spaced blocks to protect the fire from the effect of wind. The characteristics of the fire its duration and heat transfer parameters have been established in a series of experiments during the initial development of the facility. The fuel is ignited and a prerequisite for a successful fire must be that the temperature reaches 550 degrees C. 35 seconds after ignition; the fire normally lasts up to 30 minutes.

The response of the store in a fuel fire gives an indication of the likely response to potential fires on the flight deck of a carrier and similar hydrocarbon fires. There may be a similar read-across to other credible accidents in which heat is transferred rapidly to the casing of the store and a significant differential temperature is set up between the outer surface of the explosive and its bulk temperature.

Some credible thermal environments may involve a slower rate of temperature rise and a consequent lower rate of transfer of heat to the store. In the limit it could be envisaged that the temperature of the energetic material was substantially uniform and close to the value of the external temperature until such time as the heat generated by thermal decomposition of the energetic material becomes significant. Where the design of the store is such that the reaction is confined, this type of environment can lead to a more severe response than the fast cook-off environment. This has been shown in recent UK slow cook-off trials in which the surface temperature of the store following preconditioning to a constant elevated temperature has been raised at the rate of 3.3 degrees C per hour.

Whether the response of the store to environments between fast and slow cook-off can be deduced from the trials results is being considered.

Impact Testing

Over a period of years the specification of the impact test has developed from dropping sections or complete armament stores onto a target plate to the more recent forms of test which have specified dropping on to an inverted section of steel angle. A review of ammunitioning in practice has shown that spigot-like objects exist beneath the ammunitioning path and that although some protection can be applied the possibility of an impact exists. Investigations [1] lead to the view that armament stores are more sensitive to spigot intrusion than to the flat plat or inverted angle. The total weight of the load can influence the reponse to a localised spigot intrusion. This underlines the importance in trials of dropping the stores in their service handling configuration particularly where the load being handled is made up of several units. The orientation of the load at impact has been shown to affect the response.

During handling alongside a ship dropping an armament store onto another one must be regarded as a credible accident. Similarly inert objects may drop onto the store as opposed to the store dropping. The current impact test allows for this eventuality and seeks to cover the worst accident situation which can be foreseen from a careful review of the expected hazards arising in the stockpile-to-target sequence.

Where it can be shown to be valid, dropping a weighted spigot onto a store provides a more consistent and convenient way of testing the impact response of a store than dropping a store on to a spigot.

ASSESSMENT THROUGH MODELLING

It has been stated earlier that economic factors dictate the number of trials which can be carried out. The confidence in the safety of a particular armament store is achieved through overtests of the store combined with engineering judgement based on the growing database of experience.

Theoretical modelling can improve the understanding of the response of stores to an abnormal environment but has not reached the stage where it can replace the need for confirmatory trials. Once validated against trials information it provides a possible means of assessing the response to other environments.

There are two aspects of the response which are of interest. The first is to establish the onset of a reaction in the energetic material to the accident stimulus. The second is to assess the severity of the effect of the reaction; this will indicate the direct hazard to personnel and the hazard to any adjacent armament stores.

Theoretical Modelling of Response to Fire

There are a number of computer programmes which will effectively model the transfer of heat to an armament store in an adverse thermal environment. These programmes can also be used to evaluate the transient temperatures within the store and will take into account the variation in the thermal parameters of the materials. Heat generation within the energetic material due to chemical decomposition has been modelled simply in codes such as TRUMP but there is some difficulty in establishing reliable Arrhenius data for the energetic materials. The time to explosion of armament stores is dependent on the balance between the heat generated in the energetic material and the heat lost to the surroundings.

TRUMP [2] can be used effectively to predict the fast cook-off behaviour; here the chemical kinetics are less important in determining the surface temperature of the store at which thermal runaway commences. It does not deal effectively with slow cook-off predictions, where the chemical kinetics dominate. TRUMP allows for just two reactants with a single step decomposition and this has been found to be inadequate to describe the response when it is largely controlled by the decomposition heating

Improvements have been made [3] in the modelling of the kinetics of the decomposition and more recent versions of TRUMP are multi-species and multi-step decompositions. Establishing the validity of the assumptions of the decomposition steps can be itself an extensive exercise and studies such as those described by Catalano et al [4] are necessary. In these studies a spherical sample of explosive is inserted and clamped between two pre-heated anvils; the time to explosion is then measured. By inserting a number of samples at different anvil temperatures a relationship between temperature and time to explosion can be established. The validity of the thermal model is assessed against the results from this one-dimensional system. An indication of the severity of the decomposition can be obtained from the damage to the anvils.

The theoretical modelling of the onset of thermal runaway between the extremes of fast and slow cook-off is possible. However the severity of response has not been predicted quantitatively, although subjective estimates have been made.

Theoretical Modelling of Response to Impact

Whilst the modelling of jet and high velocity missilė impacts on cased and bare explosive has attracted considerable research effort the comparatively low velocity end of the range (around

15 m/s) has not received the same interest.
The physical mechanisms in the low velocity impact and penetration of the weapon case, insulation layer and explosive have been studied and the factors which lead to initiation of the explosive investigated. The studies directed by Chief Inspector of Naval Ordnance staff [1] and those initiated through MSc projects [5,6] at the Royal Military College of Science at Shrivenham are leading to a better understanding of the problem. Theoretical models are being developed to provide a predictive capacity. In order to assess these theoretical models experimental studies on small scale and representative sections have been initiated.

As with the thermal modelling the assessment of the severity of response is subjective.

CONCLUSIONS

Trials on the armament store still provide the most acceptable way of assessing the response in abnormal thermal and impact environments.

The standard of thermal modelling is improving but requires supporting studies to be done.

Much remains to be done on the modelling of the impact initiation of armament stores.

Theoretical modelling of the severity of the response to the abnormal environments is lacking.

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