

Rapid cratering charge Redesign ACDA5022

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Introduction/Abstract

The author and team were tasked with the redesign of an energetic store currently employed by UK MOD and soon subject to obsolescence. They have requested a thorough proposal explaining the design of the store, to be presented separately to this report.

The store in question is a rapid cratering kit, comprising a shaped charge tunnelling charge contained within a rolled steel casing, complete with detachable legs to create standoff. The kit also includes two “digging” charges and a booster charge, which when employed with the shaped charge, are used to dig a deep hole, and then expel the earth in a large area around the hole in order to create a crater.

Details of the work undertaken, in respect of the Design (including Safety by Design) of the replacement store and work undertaken to produce the above proposal are presented here. This report concerns only the authors contribution and group work undertaken, and should be viewed alongside HDS reports produced in respect of Test and Evaluation/Safety (Jake Smith - JS), R&D/Manufacturing/Safety (William Noakes - WN), and Breakdown and Disposal/R&D/Environmental (Peter Down - PD).

Meeting 1: Division of Roles and Strategy

An initial meeting was held in order to effectively divide work required and determine each individuals’ roles within the team. Work was delegated according to individuals’ area of expertise and with respect to the work’s position within the design cycle.

Safety was determined within the group as of likely overriding importance, and therefore responsibility for this was split between the early stages of the design and all individuals contributing to this part of the design process, with an aim to ensuring a store Safe by design throughout its lifecycle.

It was decided that responsibility for the various packages of work required will fall as per the below, with each individual contributing work to the generation of requirements for safety and some aspects of R&D within their area of responsibility, to lesser or greater extents, with an aim to ensuring Safety throughout the life of the store and providing a robust innovative design. Feedback on the members areas of responsibility was to be presented periodically to all, in order to ensure effective promulgation of information.

Discord was selected as a suitable team discussion forum for information and ideas sharing, with all documentation and information being shared via email. It was agreed that meetings would take place largely in-person, with an option for using MS Teams for any online meetings required.

Design and Safety – Ryan Garry (Author)

Primarily responsible for the gathering, generation and analysis of requirements to produce functional and non-functional requirements, as well as initial work such as generating a Manufacture to Disposal Sequence (MTDS), to feed into following packages of work. Further responsibility for ensuring the promulgation of requirements and ensuring safety by design in all stages of the design process.

Developing Initial User requirements was undertaken using a range of techniques to determine what the customer wishes to accomplish with the final design, including creating use cases and utilising user experience.

Functional requirements were generated from the above in order to highlight critical components and relationships within the design, and all requirements were reported back to the wider group in order to manage their implementation.

A secondary responsibility within the group was to manage the composition of the proposal presentation, later to be created in separate parts by respective members of the team, and assembled largely sequentially as per the order listed here.

The bulk of the author's contribution to the project occurred in the early stages of this project and this report will largely deal with the generation of requirements, and their implementation at later stages. Additional responsibility throughout was also held for maintaining communication with other members of the team responsible for other areas, in order to ensure that Requirement Implementation and Safety was managed throughout the separate work packages.

Test and Evaluation, and Safety - Jake Smith

A Sequential Environmental Trial plan was developed from the MTDS developed by JS, in order to demonstrate Safety and performance throughout the life-cycle of the store, and provide adequate assurance of same.

R&D, Manufacturing, and Safety - William Noakes

Materiel to be employed, along with the proposals for the manufacture of the store, were produced from the User and Functional requirements generated above. Research on potential alternative materials was also conducted and the most suitable materiel selected to accomplish the required effect, while balancing economic and safety requirements for manufacture and the store's use.

Breakdown and Disposal, R&D, and Environmental - Peter Down

Alongside manufacturing techniques, including Safety thereof, and Environmental Impact, potential Disposal of the munition was also considered by PZ. This work informed both the selection of materiel and generation of some requirements later in the process as well as being developed using input from other members of the team..

Strategy for meetings

1. Opening Meeting: Division of roles and delegation of work

Held at University of Wales, Trinity St Davids (UWTSD)

Division of roles and discussion on work required. Members retire to conduct research on respective areas of responsibility.

2. Meeting 2: Initial research discussed and potential solutions identified

Held at University of Wales, Trinity St Davids (UWTSD)

Discussion of proposed MTDS and initial user requirements, alongside discussion of initial research conducted.

3. Meeting 3: Detailed plans for design discussed and resultant routes of manufacture

To be held at University of Wales, Trinity St Davids (UWTSD)

To discuss final design and review in view of requirements and Safety.

4. Design Agenda Review

To be held at University of Wales, Trinity St Davids (UWTSD)

5. Meeting 4: Confirming final design and discussing proposal content

To be held at University of Wales, Trinity St Davids (UWTSD)

6. Meeting 5: Review of final proposal

To be held at University of Wales, Trinity St Davids (UWTSD)

7. Ad-hoc meetings to be held as required via MS Teams

Generation of Requirements

Requirements were generated initially from an initial discussion with the client, who also represents the user. Due to the high level nature of these requirements, further information was gathered by the author from discussions with end-user representatives as well as the collective knowledge and experience of the HDS Team during our initial discussion of requirements.

Initial requirements and a preliminary MTDS was presented by the author to members of the group and comments were taken in order to validate the methods employed and fill any gaps in evidence. Some research on manufacturing techniques was undertaken primarily by PD and WN and discussed at this time, along with the Regulatory Standards selected by JS in respect of Sequential and Environmental Testing, in order to add to the ongoing generation of requirements and for discussion at meeting 2.

Initial Requirements

Requirements generated at this point and discussed and agreed in Meeting 2 are listed below:

1. Can be rapidly deployed to “dig” a hole in the ground.
2. Should not be significantly more difficult to safely transport.
3. Should not be more difficult to hand-carry the individual components.
4. Should be simple to employ with brief training
5. Must be safe to carry on person, as well as during transport etc
6. Would like to achieve a similar price point per unit
7. Operable in any climate, but focus is on Desert/Hot Climates.
 - a. Unlikely to be used in Arctic environments but cold environments

Further requirements generated from initial use cases, end-user experience and preliminary research, as well as the authors experience:

8. IM response – Exhibit Type V or better for Fast Heating, Slow Heating, Bullet Impact and Fragment Impact and Type III reaction or better for Sympathetic Reaction. Response to Shaped charge preferably II or better. (From research by JS).
9. Must remain safe to transport by fixed and rotary wing transport (all platforms) as well as by tracked and wheeled transport.
 - a. Authors note: Requires tests for Vibration
 - b. Authors note: ESD testing is important for ensuring safety during rotary wing deployment (potentially 10 KW exposure)

Standards Identification

The use of UK and European Regulations were assumed/chosen for the proposed design, due to the exacting nature of the UK MODs requirements and to ensure ease of qualification from testing evidence.

The below standards were suggested by the author from initial research due to their potential impact on the physical design of the store.

UK Defence Standards (Def-Stans):

- DSA OME 02 – overarching Regulatory document concerning the acquisition of OME systems for the UK MOD.
- 00-035 – Environmental Handbook for Defence Materiel – Concerns the Test and Evaluation of Energetic Materiel in respect of the various climatic and mechanical environment it may encounter during its lifetime. This includes approved test methods and exposure spectrums for sequential environmental testing, and provides a roadmap for its design. [1]
- Various Standards potentially relating to safety in various aspects of the store including 59-114 – Relating to Electrical Safety incl Electromagnetic Hazards and characterisation of Electro-Explosive devices (EEDs)(this may dictate the use of existing EEDs for use in electrically instigated initiation trains. [2]

European Standards

NATO Standardisation Agreements (STANAGs):

- AOP-15 – Guidance on Lifting of Energetic Stores [3]
- STANAG 4497 – Guidance on Safety in the design of Hand Emplaced Munitions [4]
- STANAG 4170 – Principles and methodology for the qualification of energetic materiel for service use [5]

UN Regulatory Agreements

UN Recommendations on the Transport of Dangerous Goods Model Regulations [6]

Generation of a Manufacture to Disposal Sequence

An MTDS was generated from use-cases provided by end-user representatives on similar stores and from the authors own experience to illustrate the various environments to which the store may be subjected.

These initial use-cases were combined to produce an MTDS, showing the various life-cycles of the store from manufacture to disposal, that will later form the basis of a more detailed MTDS and Sequential Test Plan to be developed by JS. This will also later aid the population of the NATO Allied Ordnance Publication (AOP-)15 [3] questionnaire.

Manufacture to Disposal Sequence and associated Test Requirements:

Individual stages of the MTDS were then considered in respect of the environmental and handling/processing requirements and annotated using brainstorming exercises conducted by the author to suggest what tests and certification (or regulatory requirements) would be important for each stage of the product's lifecycle.

The requirements for each stage of the MTDS can be seen below, with explanatory notes in red and purple text, for testing and certification/regulatory requirements respectively:

- Manufacture
 - EMTAP [7] Testing on potential materiel for use - to determine sensitivity to shock, friction, etc – **for use in determining appropriate materiel for use according to requirements for store.**
 - EMTAP [7] Testing on materiel selected for use - **to determine appropriateness of materiel for UN Classification and Safe Transportation**
- Transport by road transport to Defence Munitions Depot
 - UN Tests [6] – 1m Drop,
 - (Fast and) Slow Heating,
 - Shock
 - **To demonstrate Safety during activities that are likely to be required for standard initial processing of stores, and relocation to a UK-based storage site.**
- Processed for storage at DM Depot [6]
 - Spigot intrusion test
 - IM Testing Sympathetic Reaction
 - UN Hazard Classification and Grouping
 - **To demonstrate Safety during activities required for storage in UK depot.**
- Storage (including any maintenance requirements in DM depot) – Non temp controlled but UK Climate.
 - Sequential Diurnal Tests (accelerated Aging) [1]
 - **To demonstrate Safety and Stability during longer term Storage in UK-based depots**
- Processing for Transport [6]
 - UN Number (Hazard classification, UN packaging mark and packaging requirements)
 - **Certification required for transport under UN Regulations [6]**
- Road Transport from DM Depot [1]
 - Vibration testing for Road transport
 - **To ensure energetic materiel will withstand sufficient vibration from road transportation without significantly impacting Safety and performance.**
- Sea and/or Air transport to theatre
 - 12m drop testing for craning onto ship [6]
 - Transport Vibration for Air – All types required (in this case fixed and rotary wing) [1]

- Appropriate vibration spectrums are selected at this point to ensure that likely types of transportation to-be-employed will not unduly affect performance, or the Safe use of the store at a later date.
 - Restrictions to be listed – I.E. A400 Cargo area outside of requirement (say).
 - ESD Testing for Rotary Wing Deployment [1] (Optional test if required by user) [2]
- Temporary storage potentially (in holding areas awaiting processing for longer-term storage – this may be unsheltered runway or dock storage subject to a wide range of temperatures for a brief period of time or number of days.
 - Sequential Diurnal cycling – High temp/low temps
 - While it is not expected that stores remain in temporary holding areas for an extended period of time, it is important that consideration is given to the likely extreme temperatures that stores may experience during storage in various areas during its life-cycle.
- Allocated for operational use – Carried in wheeled/Tracked Transport or Carried Individually on-person.
- Use and Stock management:
 - Book-keeping and control of stock – difficult to track when issued to individuals –
 - Requires identification numbers to be clearly visible on individual stores and packaging.
- Transport for disposal – to include similar amount of distance, vibration etc.
- Disposal in Licensed/Approved premises

The above information was provided to the group via email and stored in group storage on MS Teams in advance of meeting 2.

Other Considerations recorded for discussion in Meeting 2:

- Different Classifications/Tests for each packaging arrangement will be required if components are packaged and/or transported separately
 - Packaging and Transport for each component
- Can we use common use components (i.e Initiator) or in current service-use items.
- Stacking in Storage – is this required? – seems beneficial.
- Constraints/Limitations/Non-Conformances and Justifications for same (i.e. Operational Use in Arctic conditions potentially less feasible due to difficulty of digging through solid ice ground)
- Means of initiation – Novel means/EEDs will need to be proven/qualified/characterised, increasing cost to user.

Meeting 2: Initial Discussion of Requirements and Initial Design Discussion

The initial draft of an MTDS and associated requirements and notes were circulated to the wider group prior to the meeting to allow for review.

A loose agenda for the meeting was proposed and agreed through brief discussion and can be described loosely as follows:

1. Discuss implications of Requirement 1 relating to the general capability (effect desired)
2. Brainstorm solutions and agree on direction of further research
3. Discuss remaining requirements – is there any common ground that will satisfy multiple requirements?
4. Other considerations raised above.
5. Other members research
6. Review the inclusion of any requirements noted as a result of discussions

Agenda Points 1 and 2:

Discussion on the different methods of achieving the desired capability centred largely on whether or not an energetic solution is required in this case, as multiple options for achieving the effect already exist. It was decided that an energetic solution would be the most feasible option for our proposal given the mechanical advantage that energetic materials can provide relative to other factors such as weight, cost, etc.

Agenda Point 3 and 4:

One of the solutions discussed, and agreed as the likely candidate for further research was effectively a like-for-like replacement, that should, by nature, satisfy all remaining initial requirements to a lesser or greater extent. Commercial or Government off-the-shelf replacements were considered for this, however due to the relatively simple operation of the store it was decided that further research into more novel fill material and alternative methods of delivering the capability would be more beneficial, both for potential increased safety and for possible improvements in the design.

It was proposed by the author and agreed by all that the most simple route to achieving the initial requirements was to produce a replacement energetic store to the same physical dimensions, and with a very similar method of deployment and effects, as well as utilising the existing initiation system of detonator and shock cord. This would help to ensure compatibility with existing storage arrangements, including custom built storage on weapon and transport platforms if applicable, as well as to fit in well with existing training, and provide a simple adjustment to service personnel who have used the now-obsolete store, without adversely impacting Safety.

This method of initiation would also allow the use of common-use existing components such as the shock cord and initiator used with the previous store. These will be in current service use and therefore will not require additional work to be undertaken in testing, qualifying, certifying, codifying, and in the end, carrying new stores by the end-user, and allow a considerable cost saving overall.

It was agreed that maintaining the rolled metal casing design would provide a suitable and cost-effective casing for the store, but consideration was given to the optimum angle and stand-off of

the shaped charge cone and its tolerance of variation for maximum penetration. Further discussion on the operational temperature range was also considered in order to inform materiel selection by WN and PZ. It was agreed that further research was to be directed largely into the energetic fill of the various components of the store and the shaped charge design, with the aim of increasing the performance of the munition in terms of safety and its effectiveness.

JS Presented an initial Example of a test plan, and continued to develop the plan for final review.

Critical Design Features identified

The following features were noted by the author as critical features in order to help inform an effective design at later stages.

- Shaped Charge cone-angle and general design
- Initiation characteristics of main fill materiel, both for effect and extended life in adverse climatic conditions.
- Size and shape should fit with existing storage lockers and arrangements as previous store.

Meeting 3: Detailed Design Discussion

A detailed design discussion was held to confirm final design points prior to the generation of the final proposal.

WN, and PZ presented their research on the various energetic materiel under selection, and the likely benefits and drawbacks of these.

Discussion was held on the methods of filling the shaped charges with regards to the stores vulnerability to degradation under high temperatures (in cast explosives). Size/performance ratio was also discussed, with a potentially more effective fill for use within the shaped charge, an aluminium rolled casing may be possible and may be more desirable in terms of carrying weight.

A likely final solution was proposed dependent on ongoing research into energetic fill, and agreed for use within the group as a nominal solution.

Meeting 4: Proposal Generation

The proposal was constructed from notes produced by the respective members and compiled during the teams' final meeting to the authors design. Formatting and final edits performed by PZ and other members.

References

- [1] UK MOD, *Def-Stan 00-035 - Environmental Handbook for Defence materiel*.
- [2] UK MOD, *Def-Stan 59-114 Safety Principles for Electrical Circuits in Systems Incorporating Explosive Components Part 1 Principles, Design Recommendations and Electrical/Electromagnetic Environments*, MOD.
- [3] NATO, *AOP-15- Guidance on the Assessment of Safety and Suitability for Service of Non-Nuclear Munitions for Service-Use*, NATO, 2009.
- [4] NATO, *STANAG 4497 - H.E.M. (Hand Emplaced Munitions)*, Nato.
- [5] NATO, *STANAG 4170 - Principles and Methodology for the Qualification of Energetic Materiel for Service Use*, NATO.
- [6] United Nations, *UN Recommendations on the Transport of Dangerous Goods Model Regulations*, 2023.
- [7] HSE, *Energetic Materials Testing Assessment Policy Manual of Tests (EMTAP)*, HSE.