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Guidance for Preparation of a Life Cycle Environment Profile and Environmental Test Plan for Qualification of Explosive Ordinance

John Pisani

Approved for Public Release

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

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ABSTRACT

This report outlines a suggested approach to the preparation of a life cycle environmental profile and the consequent program of environmental tests required before an item of explosive ordnance can be accepted as safe and suitable for service with the Australian Defence Force. Likely environmental stresses and their effects, and a procedure for calculating the duration of accelerated ageing trials are included as appendices.

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EXECUTIVE SUMMARY

Assessment of Safety and Suitability for Service of explosive ordnance by the Australian Ordnance Council (AOC) requires that each store undergo a planned series of tests simulating the predicted service environment in order to provide confidence that safety and suitability will not be unacceptably degraded by that environment over the nominal life of the store.

This paper is an attempt to summarise procedures developed by members of the Explosives Environmental and Service Life Advisory Committee of the AOC for the preparation of LCEPs and ETPs.

This report outlines a suggested approach to the preparation of a life cycle environmental profile and the consequent program of environmental tests required before an item of explosive ordnance can be accepted as safe and suitable for service with the Australian Defence Force.

Contents

1 Introduction

Assessment of Safety and Suitability for Service of explosive ordnance by the Australian Ordnance Council (AOC) requires that each store undergo a planned series of tests simulating the predicted service environment in order to provide confidence that safety and suitability will not be unacceptably degraded by that environment over the nominal life of the store. These tests are normally defined in an Environmental Test Plan (ETP).

As the objective of the ETP is to demonstrate that the store can successfully withstand the predicted environment, it is therefore logical that the ETP for each store be "tailored" as far as possible to that environment.

It follows from this that there are three critical steps

Collation of information on the expected service environment and life requirements of the store. This is normally done by completion of an environmental questionnaire.

Determination of the Life Cycle Environmental Profile (LCEP) based on the environmental questionnaire, and assessment of the importance of each stage as a contributor to the total environmental stress imposed on the store.

Preparation of an appropriate ETP based on the environments identified as important in the LCEP.

An ETP derived as described above does not necessarily meet all the requirements for assessment of an item of explosive ordnance for introduction into service. For example, requirements such as compliance with insensitive munitions criteria may require certain additional tests. There may be operational and economic advantages in modifying the ETP to include these tests, and this should be considered when preparing the ETP.

2 Definition of Terms

Life Cycle Environmental Profile (LCEP)

"The sequence of events and conditions experienced by an item of explosive ordnance from manufacture to delivery to target or disposal. It includes both those events and conditions experienced in normal service, and abnormal hazards or events experienced as a result of mishap, hostile action or other credible happening".

The LCEP commences at filling or final assembly of the store by the manufacturer, and includes any holding period by the manufacturer before delivery to the user service.

For items manufactured overseas, including components of locally assembled stores, the LCEP may be taken to commence at the beginning of the major phase of shipment to Australia where information on earlier stages cannot be obtained. This would usually be the beginning of transport by sea.

Environmental Test Plan (ETP)

"The tests, derived from the LCEP, which permit assessment of the stores' ability to withstand the anticipated manufacturer to target environment without unacceptable degradation".

Life

The service life of an item of explosive ordnance is regarded as being made up of "storage" and "operational" phases. The following definitions, recommended by the Explosives Environmental and Service Life Advisory Committee (EESLAC), an advisory committee of the AOC, are based on those of the UK Ordnance Board Proceeding 41871 [1].

Storage Life is defined as:

> "The time for which an explosive item, in specified storage conditions, may be expected to remain safe and suitable for service."

Operational Life is defined as:

> "The time for which an explosive item may be expected to remain safe and suitable for service when used under its operational or training conditions, when these are different from its storage condition, but which is within the envelope of its Storage Life."

Service Life is defined as:

> "The time for which an explosive item, in specified storage conditions and when subsequently used under its operational or training conditions, may be expected to remain safe and suitable for service. This will never be longer than Storage Life."

In considering the sequence of events in the LCEP, it has been found convenient to divide the LCEP into two broad phases based on the above definitions. These are:

Storage phase:

> This phase commences immediately after manufacture. It includes storage by the manufacturer prior to delivery, transportation from manufacturer to depot, and storage by the user service at major depots. The term "storage" was chosen as it

is descriptive of the major activity experienced by the store, although transportation between manufacturer and depots and some handling of the item is included.

Operational phase:

This phase commences when store leaves a main depot or long term storage. It includes transport to operational bases or units, storage and handling at these, carriage on weapons platforms and all subsequent stages of deployment to the target or disposal.

Abnormal hazards or events may occur at any stage of the LCEP. They are therefore considered in a separate section.

3 Environmental Questionnaire

The completed environmental questionnaire [2] is the principal source of information used in deriving the likely storage and operational environments.

The questionnaire has been designed so that it can be completed as far as possible in a stage by stage sequence based on the expected deployment sequence of the store, and so that a specialised knowledge of environmental engineering is not required in order to answer the questions.

A questionnaire has the advantage that it can provide logically ordered responses, and can reduce the likelihood of important stages being overlooked, but it is inflexible and can limit responses. It is therefore important to supplement the completed environmental questionnaire with discussions with personnel involved in design, project management, deployment and operation of the store to obtain an appreciation of the limitations of the formal data, and of the practical difficulties experienced during actual deployment of the stores. Visits to storage facilities and operational units can be of considerable assistance, and should be encouraged.

Risk and Hazard Analysis

The assessment of safety normally involves a critical appraisal of the inherent safety of the design and an evaluation of the risk attendant upon deploying the store in the prescribed environments throughout its agreed service life.

The AOC has adopted MIL-STD-882 [3] as its guide for hazard analysis. A detailed discussion of risk and hazard assessment is not appropriate here, although the process is important in the overall assessment of the safety and suitability for service of explosive ordnance.

Essentially, the analysis attempts to identify all the hazards, with severity of consequence and probability of occurrence. This information should be taken into account when developing the test plan so that effort can be focussed on areas which are mission critical or which present special safety problems.

4 Life Cycle Environmental Profile

The LCEP is the result of an analysis in environmental terms of the information provided in the completed environmental questionnaire, plus relevant information gathered from other sources as suggested above. It should identify the environments which, acting singly or in combination, could affect the safety and suitability for service of the store. The LCEP should include the following sections:

Definition of the store

Flow chart of the manufacture to target sequence

Analysis of data and development of store environmental profile

Tabulated life cycle

Definition of the Store

Tests for assessment of safety and suitability for service must be performed on stores representative of normal build standard in all aspects likely to affect the assessment. It is therefore necessary that the precise formal designation of the store be included in all documents related to the assessment. This must include reference to the appropriate issue numbers of drawings and specifications, mark and modification numbers and any other details required to precisely and uniquely identify the store being assessed. Design changes introduced at later stages may necessitate re-assessment.

Flow Chart of the Manufacture to Target Sequence

It is useful, particularly for complex cases, to include a flow chart of the expected manufacture to target sequence.

Analysis of Data and Development of Store Environmental Profile

Each stage of the manufacture to target sequence as identified in the environmental questionnaire must be examined to determine the environmental stresses likely to act on the store.

Where applicable, the conditions experienced by the store should be expressed in terms of the nearest equivalent conditions defined in recognised standards, for example DEF AUST 5168 [4] for climatic conditions.

Listed in Appendix A for guidance are some common stages of a typical life cycle, and the environmental stresses which may be applicable at each stage. Each case must be examined to decide which stresses are present, and to what level of severity. The possibility that environmental stresses not included in this list may be present must not be overlooked.

Having identified the relevant stresses acting at each stage, the significance of them as contributors to the sum of the environmental stresses likely to be experienced by the store during its life should be considered, and conclusions given, with the reasons for each conclusion explained. As it is not necessary or practicable to apply tests simulating every stage of the LCEP, engineering judgement must be used in selecting those stages which are significant.

Factors to be considered in assessing the significance of each stage include:

Nature and severity of the environmental stresses.

Probability and frequency of their occurrence.

Duration of the stresses, including cumulative effect of similar stresses occurring at more than one stage of the LCEP.

Whether synergistic effects are likely (eg effects of vibration are likely to be aggravated at temperature extremes).

Whether the store has experienced, at an earlier stage, stresses which may render it more susceptible to damage (eg seals damaged by vibration may subsequently allow moisture ingress).

Whether the store is packaged, and the degree of protection provided at different stages by packaging or other means.

The results of the hazard analysis should also be taken into account to ensure firstly that no foreseeable hazardous condition is overlooked, and secondly that the test plan is designed, as far as possible, to focus on the aspects assessed as being most critical.

At the completion of this analysis each stage of the LCEP and the significant stresses acting during it will have been identified, and this information can then be used to formulate an appropriate environmental test plan.

Tabulated Life Cycle

In order to provide an overview of the sequence of stages identified in the LCEP, it is recommended that the stages be summarised in table form. The table should include reference to the section of the LCEP where the stage is discussed, identification of the stage, the duration, the state of the store (pallets, packaged, unpackaged etc), and a brief summary of the significant environmental conditions.

An example is included as Appendix B.

5 Environmental Test Plan

The environmental conditions significantly affecting the store at each stage of its life have been identified in the LCEP.

In the ETP, for each of the environmental conditions defined and found to be significant in the LCEP, appropriate test(s) are selected which will provide confidence in the ability of the store to withstand that condition. The reasoning by which the tests and their severities are derived should be explained.

A test schedule, giving test sequence, numbers of rounds, test instructions and proposed test agencies should be included in an appendix to the ETP. It is also desirable to present the test sequence and allocation of rounds to tests in tabular and flow chart forms.

The ETP should contain the following sections:

Definition of the store

Selection of appropriate environmental tests to simulate the significant stresses acting at each stage of the LCEP

Additional tests

Test sequence

Inspection and functioning tests

Tabulated test schedule, allocation of stores and flow chart

Definition of the Store

If the LCEP and ETP are issued as separate documents, the formal description of the store as given in the LCEP should also be included in the ETP.

Selection of Appropriate Environmental Tests

The following principles should be followed in selection of tests:

Tests should be based on the credible worst case environmental conditions identified in the LCEP.

Where possible, tests should be selected from recognised standards such as MIL-STD-810E [5] and DEF STAN 07-55 [6]. Such standards require or at least encourage tailoring of the test conditions and duration, which must be adjusted to levels appropriate to the environmental conditions.

Because of the probable long duration of many of the environments of the LCEP, accelerated testing is usually necessary. This should be achieved without use of conditions set at more stressful levels than those identified in the LCEP.

Maximum confidence in the safety and suitability of the store is derived from functioning tests carried out at temperature extremes on an adequate number of stores after completion of the test sequence.

The store should be tested in the packaging condition appropriate to the stage of the LCEP being simulated by each test.

The selection of tests and interpretation of results depends to some extent on the design criteria of the store. For example, if there is a requirement to meet Insensitive Munitions criteria, the appropriate tests should be included in the ETP.

In the case of stores procured from overseas, it is necessary to consider whether all environmental conditions anticipated for the Australian environment have been adequately covered by testing in the country of origin or elsewhere. If test results are available, their authenticity must be ascertained, and there must be sufficient detail to allow the adequacy of the testing to be assessed. If either of these requirements is not met, restrictions should be placed on the life of the store, the environment to which it may be subjected, or both, until adequate testing has been performed.

In addition to the normal manufacture to target sequence, possible abnormal hazards or events as identified in the LCEP should be considered, and appropriate tests selected.

Some of the principal effects of environmental stresses are shown in Appendix C, Table 1.

The effect of combined environmental stresses must also be considered when deciding on test conditions. For example, temperature extremes will usually intensify the effects of vibration, so that if this combination is significant in the LCEP, a test under corresponding conditions should be included in the ETP.

The effects of common combinations of environmental pairs are shown in Appendix C, Table 2.

In considering the various environments identified in the LCEP, it has been found useful to address them in order of their general categories, so that the most severe can be readily identified, and the appropriate test selected.

For each of the commonly occurring environments, a test method must be selected after consideration of the various sources of standard tests. Details of the test conditions must be tailored to suit the duration, severity, and other conditions applicable to the particular environment.

Some principles for guidance in selection of tests for some of the commonly occurring environments are given below.

Climatic Environments

High temperature

The effects of high temperature with or without high humidity are usually manifest in deterioration of materials. The purpose of high temperature tests is to establish that the store can withstand exposure to such conditions without unacceptable changes, hence heat/humidity tests need to be of sufficient duration to allow these effects to be detected. As the amount of time available for evaluation does not normally permit real-time testing it is necessary to use test conditions which introduce a degree of acceleration to the ageing process. For sequential testing it is necessary to select a test of practical duration which will give a reasonable degree of confidence in the store in an acceptable time frame.

Generally accepted practice is to test to diurnal temperature/humidity cycles selected to match the maximum values to which the store is likely to be exposed [5, 6, 7, 8]. These cycles have been specified to represent the extreme conditions attained or exceeded for approximately 7.4 hours (ie 1% of one month) during the hottest month of the year. As the cycle is repeated daily a higher average temperature and hence a degree of acceleration is achieved without going beyond the range of conditions which could be experienced by the store during its life [1]. Use of a cyclic rather than steady state test also has the advantage that it represents possible actual daily fluctuations, and can thus also indicate faults such as inadequate seals allowing moisture ingress, creep or thermal stress cracking.

1 As an example, the acceleration factor of a diurnal cycle test at the extreme of climatic category B2 storage conditions (maximum temperature 63°C) relative to a typical year of actual storage, and assuming a degradation reaction with activation energy of 70 kJ mole^{-1} is approximately 4. The factor varies as the exponent of the activation energy.

MIL-STD-810E [5] suggests (Method 501.3, "High Temperature") a minimum of 7 cycles, based on the 1% frequency of occurrence of the hours of extreme temperature, for assessment of the effect of storage at high temperatures on the test item's safety and performance, but states that this method is not suitable for identification of time dependent performance degradation. In Method 507.3, "Humidity", a minimum of 30 cycles under "induced" conditions is recommended for hazardous items which will be held in hot wet conditions.

DEF STAN 07-55 [6] requires sufficient cycles for the equipment to attain temperature stability. This is considered to be directed to electrical and mechanical equipment whose operation is likely to be affected by temperature extremes, but is regarded as insufficient where, as in the case of most explosives, material degradation is likely to be the cause of failure.

OB Proceeding 42351 [8] specifies 28 cycles in the trials plan, but does not specify the test in the schedule.

In view of the above recommendations, the minimum test duration recommended for detection of adverse effects arising from material degradation is 28 days. It must be recognised that the purpose of this test is to give, in a practical time scale, reasonable assurance of freedom from adverse effects. It does not provide a basis for assessment of predicted life, but only an early indication of unacceptable degradation. Assessment of likely service life would normally require a considerably longer test duration. The design of such tests is discussed in a separate section below.

Humidity and high temperature

The combination of humidity with high temperature generally has a more deleterious effect then high temperature alone. The same considerations of duration and severity as discussed above apply to this combined environment. Unless there is a particular need to assess the effect of hot dry conditions, tests for hot dry and hot wet storage conditions may be combined in a cycle combining both heat and high humidity.

Low temperature

Low temperature can harden and embrittle some materials, cause cracking and condense or freeze water vapour or water. Following the same reasoning as for high temperature, the preferred test consists of the appropriate diurnal cycling.

It may also be necessary to perform an icing test.

As material failures are likely to become apparent relatively quickly, there is less need for extended testing than in the case of hot cycling.

OB Proceeding 42351 [8] recommends a seven day diurnal cycle. DEF STAN 07-55 [6] specifies sufficient cycles for stabilisation (of the order of three), and MIL-STD-810E [5], which specifies only a constant low temperature test, requires that for materials such as explosives and plastics the condition be maintained for 72 hours. In view of the above information, a minimum of seven days cycling is recommended.

Fungus

Fungus growth requires high humidity, and can occur only within a limited temperature range, which however is frequently encountered in sub tropical and tropical climates. Stores likely to be held under such conditions should be subjected, in the appropriate packaging state, to a standard test for fungus growth. A test such as that in MIL-STD-810E [5] (Method 508.3) is generally preferred because it is applicable to packaged stores, and includes a cyclic change of 5°C to induce moisture to enter the item.

Altitude

High altitude (ie low pressure) may be associated, in combat aircraft, with severe vibration and temperature extremes and this should be taken into account when specifying tests. The rate of pressure change can also be important and in the extreme case of explosive decompression can cause catastrophic failure. Vibration representative of the aircraft environment during a controlled pressure change may be necessary.

Rain

Exposure to rain during storage and handling may result in water penetration and subsequently affect storage life or functioning. A range of tests is given in MIL-STD-810E [5] and DEF STAN 07-55 [6] covering varying intensities of rain and water immersion. Unless precluded by other factors, an immersion test such as MIL-STD-810E Method 512.2 would give assurance of ability of unpackaged stores to withstand any of the wet environments. However if packaging is required to provide protection from rain, a suitable spray type test may be preferred to immersion, as not all protective packaging is designed to withstand immersion.

The functioning of a store may also be affected by firing through rain. There are considerable difficulties in simulating this test, and consequently the firing of stores through natural rain is usually included in the proof requirements of the store. If performance in rain is likely to be affected by prior exposure to other environments of the LCEP, firing in rain should be included in the functioning tests after exposure to other environments.

Salt spray

As the effect of salt spray is likely to be corrosion, the selected test should be of sufficient duration allow salt penetration and development of corrosion. Both MIL-STD-810E [5] and DEF STAN 07-55 [6] specify salt fog and salt spray tests consisting of periods of spray interspersed with holding periods under specified conditions. None of the tests claim to simulate real conditions, but are indicative of where problems may occur. There is little information on the relative severity of the tests, so no particular recommendation is made. Relatively short cycles of spraying and holding, of the order of 24 hours each, are commonly used as this is more representative of actual environments.

Solar radiation

Explosive stores should be protected from direct solar radiation, so that the effect of solar radiation on storage facilities or packages will be confined to an increase in the temperature within the facilities or packages. This is taken into account in the "storage" category of high temperature test conditions. However externally carried stores are likely to be exposed directly to solar radiation, and appropriate tests should be selected for these cases.

Selection of conditions for solar radiation tests depends principally on the expected effect of the radiation. The differential heating of directional radiation may cause short term and reversible malfunctions, while actinic effects may lead to material degradation, and require a longer duration test. Method 505.3 of MIL-STD-810E [5] provides guidance in selection of suitable test conditions.

Dynamic Environments

Transport Vibration

Vibration of various types and severities may be experienced during transport by land, sea or air. The nature of the vibration will be dependent on the type of transport and the environment in which it operates. Because of the variety of possible modes of transport, it is unlikely that data for specific types and conditions will be available.

Both DEF STAN 07-55 [6] and MIL-STD-810E [5] specify tests to cover basic transportation. DEF STAN 07-55 specifies a sinusoidal test to cover all forms of transport, while recognising that the actual vibration is random. MIL-STD-810E specifies a random test for basic transport, with a different spectrum for each axis. The recommended duration is 60 minutes for each 1000 miles (1600 km) in each axis.

The only Australian information available [9], [10] refers to Trucks, Cargo, Heavy MC3 and confirms the MIL-STD-810E data for the vertical axis, but generally lower levels were obtained. No data is given for the other axes.

In view of the above, the MIL-STD-810E test would be appropriate for most land transport situations, with test duration selected to suit the anticipated transport distances.

The above specifications also list a bounce (unrestrained vibration) test. This environment is encountered when an item is carried on a wheeled vehicle without being tied down. Whether this test is appropriate for a particular store will depend on whether it is likely to be transported in this manner.

Vibration during transport by air is considered by both the above specifications to be less severe than surface transport, and to be adequately covered by surface transport testing.

Both the above specifications include ship transport vibration in the surface transport specification, but additionally specify tests for equipment installed in ships, though the levels are lower than for transport. There is no Australian data available which would cause modification to the British and American approach. Although ship transport vibration levels are lower than those for road transport, duration may be much longer. Damage is therefore likely only if some resonances are excited within the frequency range. A sinusoidal resonance search, using for want of better data the level and frequencies specified in DEF STAN 07-55 [6] for installed equipment would be an appropriate means of detecting any resonances. If a resonance is detected, a vibration endurance test at that intensity and frequency should be conducted.

The effect of vibration is dependent on temperature as well as vibration severity. Brittle type failures are likely to occur at low temperatures, and softening of many materials at high temperatures may lead to other types of failures. Appropriate temperatures must therefore be selected for each vibration test condition. In particular, land transport in mainland Australia involves the possibility of exposure to high temperatures in poorly ventilated enclosures. The maximum temperature of the DEF AUST 5168 [4] Climatic Category A2 "Storage" temperature cycle (63°C) would be appropriate for this situation.

Vibration during deployment

The vibration environments experienced during deployment on platforms such as tracked vehicles, combat aircraft, and combat vessels are highly dependent on the particular platform and the location and method of attachment of the stores. It is therefore not possible to discuss them here. MIL-STD-810E Method 514 [5] gives guidance on selection of test conditions and representative vibration data for several categories of vibration environments.

Shock

Shock can be caused by bumps and bounce during transportation, rough handling, accidental drop, underwater and air blast and weapon system operation. Apart from bounce, which has been referred to under vibration above, shocks are usually relatively infrequent and non repetitive, and are often the result of mishaps, such as drop.

Rough handling and drop tests are included in DEF STAN 07-55 [6] and MIL-STD-810E [5]. Test conditions should be selected to represent the most severe drop the store could realistically experience. Depending on the LCEP, it may be necessary to test both unpackaged, and packaged or palletised stores, and to use different drop heights for each.

For stores which may be lifted to a significant height, the standard 12m drop test as specified in DEF STAN 07-55 may be appropriate.

Additional Tests

As stated in the introduction, certain additional tests may be required for the assessment of an item of explosive ordnance for introduction into service. These tests may be conducted independently, or alternatively it may be more efficient and cost-effective to incorporate them into the ETP.

Tests for abnormal hazards or events should be considered. These situations are expected to occur only in the event of an unplanned incident. The requirement for such tests could arise from one of two sources. Firstly the LCEP may identify potential hazards, such as exposure to fire or to projectile attack. Alternatively, it may be necessary for the store to be assessed against the applicable Insensitive Munitions (IM) criteria described in DI(G) LOG 07-10 [11]. In either case, any testing required should be conducted in accordance with DI(G) LOG 07-10. These tests are conducted to provide information only. In the case of the hazards being identified through the LCEP, information regarding the threat that the store presents to emergency personnel, adjacent facilities and other items of explosive ordnance stored nearby may be obtained. Where the tests are conducted to satisfy IM requirements, the information provided can also be compared with test results from similar stores to determine the "least sensitive" option.

Some possible hazards include:

Fire:

Exposure to fire is possible at all stages of the LCEP, and can range from direct involvement in intense fires such as burning aviation fuel to slow heating from fire in an adjacent compartment. The packaging state and quantity of stores can have a major effect on the response, and this must be taken into consideration in selection of test conditions.

Bullet/Fragment Impact:

The effect on both bare and packaged stores should be considered, although it may not be necessary in all situations to test both configurations. The standard tests simulate impact by armour piercing bullets, and by fragments from exploding warheads.

Electromagnetic Radiation:

If the store is subject to significant levels of electromagnetic radiation, the advice of the Electrical Explosives Hazards Committee should be sought to determine the possible effects of exposure, and to specify appropriate tests.

There may also be a requirement for tests to establish the UN Hazard Classification of the store, or store plus packaging. Such requirements should be considered in liaison with authorities such as the Explosives Storage and Transport Committee (ESTC), so that a coordinated test program can be prepared. UN Hazard Classification tests are defined in the United Nations Recommendations on the Transport of Dangerous Goods [12]. Tests performed for these purposes may be found to substantially meet some of the other requirements of the ETP, in which case further tests would be unnecessary.

With both the UN Hazard Classification tests and the tests for abnormal hazards described above, the store is not necessarily expected to remain safe and suitable for service after exposure to these conditions.

Test Sequence

Sequential Tests

Stores subjected to a series of tests will become worn, and this is likely to affect their ability to withstand further adverse environments. For this reason, the majority of stores in a trial should be subjected to the whole sequence of tests representing the LCEP.

Stores should be subjected to tests in a sequence which simulates the LCEP as far as practicable, as an earlier phase may affect response to a later one. However this order may be varied to have the greatest cumulative effect on the store, or to combine in a rational way several tests simulating a range of environments which may occur in an unpredictable sequence, if this is considered advantageous. For example, stores could experience both transport vibration and extended high temperature storage at several stages in their life, and this can be in an unpredictable sequence as they are transferred to and stored at different locations as logistic requirements dictate. In this situation it is recommended that the tests for transport vibration be performed first, as vibration could cause damage to seals, which could affect the ability of the store to survive storage in hot humid conditions. If there was also a requirement, for example, to test for combat aircraft vibration, this would logically follow the climatic storage tests. Failure to withstand vibration because of material deterioration during storage would thus be revealed.

Tests such as rain, water penetration and salt spray should follow vibration and climatic cycling, as the latter can affect the ability of the store to withstand penetration by such agents.

Sequential tests should follow one another as quickly as practicable to prevent reversible effects from wearing off, and to avoid the introduction of unknown factors due to time spent in uncontrolled storage conditions. Similarly, transport between tests should be minimised.

Non Sequential tests

Those tests which represent events in the deployment sequence such as drops, shock, bullet attack etc. are applied non-sequentially; a separate group of stores is used for each test. However it is usually desirable that the stores subjected to these tests should have undergone the sequential tests representing the normal deployment sequence. This may be waived if it is considered that the response to the non-sequential test would not be affected by prior sequential tests.

Climatic storage tests intended to provide information for life prediction of a store, and changes to its performance with increasing age, are, because of the extended test times required, normally also non-sequential. These may require storage periods ranging from six months to several years, depending on the required life of the store and the consequences of premature failure, and are discussed further in a separate section below.

Inspection and Functioning Tests

Where stores are required to remain safe and suitable for service after environmental testing, function tests are normally required to establish this. The ETP should require appropriate non destructive examination and testing in addition to function tests. Such tests include visual inspection, radiography or other non destructive examination for evidence of adverse effects of environmental exposure, possibly with partial disassembly, and measurement of electrical characteristics such as igniter resistance and earthing continuity. Visual inspection should be included at appropriate stages in the ETP, as the condition of the stores may determine whether they are passed to further tests. Disassembly at intermediate stages is not normally recommended for stores which are to proceed to further stages of the ETP, as the process of disassembly may introduce uncontrolled variables into the test sequence.

Function tests should be based on the normal acceptance tests and proof procedures for the store, and should include those performance parameters called up at proof. However some degradation in performance after environmental testing may be acceptable, and this should be carefully considered, and the criteria for assessment of suitability set accordingly.

It may be a necessary to perform additional tests on components such as primers to determine that safety critical properties such as no-fire threshold have not changed unacceptably.

It may be desirable to withdraw some stores from the ETP at intermediate stages to investigate the effect of particular environmental tests or determine the cause of failure. While this may be accommodated, it must be remembered that the primary purpose of the ETP is to establish confidence in the ability of the store to withstand the expected environment, and that this is provided by satisfactory functioning tests on an adequate number of stores which have undergone the complete series of sequential tests. If withdrawals are planned, sufficient stores must be provided to adequately satisfy the primary purpose.

Function tests should normally be carried out at the upper and lower temperature extremes identified in the LCEP. However, if these temperatures are more extreme than the proof temperatures of the store or weapon system, the proof temperatures should be used. In this situation, exposure to the more severe conditions during the ETP provides some assurance that the store can experience such temperatures in storage without unacceptably affecting safety or suitability, but it must be emphasised that this does not mean that it can be safely functioned at these temperatures (AOC Proceedings 82.83 [13] and 100.84 [14]).

Numbers of Rounds

The number of stores to be tested is usually constrained by economic and time factors. However, where possible sufficient stores must be tested to prevent results from being unduly influenced by single events. The numbers specified for proof requirements for the store can provide a starting point for selecting numbers for functioning tests. Allowance must be made for an adequate number of control stores, and for stores to be withdrawn during the ETP, when specifying the numbers of stores required for the ETP.

Tabulated Test Schedule, Allocation of Stores and Flow Chart

The ETP should be presented as a tabulated schedule which specifies clearly for each test:

Test number
Test title and specification
Stores to be tested, including number, identification, origin (ie. from which previous test, if applicable)
Test instructions, including marking of containers and individual stores, pre-test inspection, details of test, post-test inspection and disposal.
Test agency

To assist in understanding and carrying out the ETP, a chart showing the allocation of stores to each test, and a flow chart of the ETP should also be prepared.

6 Prediction of Service Life

Assessment of the safety and suitability for service of an item of explosive ordnance is incomplete without some estimate of the period for which the item is expected to remain so. This is normally given by the AOC as an initial estimate of service life, and is based on assessment of the design to identify likely modes of failure, information from research and development and designer trials and results of the environmental test plan derived as described above. Such initial estimates are usually limited to a maximum of 2 to 3 years, unless the experience of other users or knowledge of the life characteristics of very similar items can be called upon.

As the user requirement is generally for a considerably longer service life, it may be necessary to perform further trials to provide assurance that this can be achieved. These trials may permit initial estimates of life of up to 10 years. It is AOC policy to not give initial life estimates of greater than 10 years.

Tests to assess life commonly require periods of six months or more, and therefore may be more conveniently treated as separate from the environmental test plan as derived above. As the mechanical tests included in the sequential section of the ETP are generally designed to represent the total mechanical stress experienced during service life, the further tests required for life prediction usually concentrate on long term material deterioration, which is normally accelerated by heat and or moisture.

Before selection of test conditions and duration, an assessment of the likely failure modes of the store should be made. This should make use of the results of tests carried out during design and development phases, knowledge of the materials involved and of the design of the store.

Test conditions should be representative of the most severe environment to which the store is likely to be exposed, and would normally be based on the diurnal cycles selected for the sequential high temperature/high humidity tests. Cyclic conditions have the advantage that thermomechanical stresses such as may be encountered in service are induced. However, where maximum acceleration of chemical deterioration is required, and it can be demonstrated that the store is not affected in any other way by cyclic conditions, steady state storage at the maximum temperature likely to be experienced in the LCEP may be used. Exposure to temperatures above the maximum credibly possible in service is not recommended.

Test duration is dependent on the required life, and on the acceleration factor resulting from the relationship between the selected test conditions and actual service conditions. One approach to the estimation of acceleration factors is to assume that the life limiting step is a simple first order reaction in which the relationship between rate of deterioration and temperature in given by Arrhenius' law. The "effective" temperatures of the test and service conditions are calculated, and from the difference the acceleration factor is calculated. An example of the calculation is given in Appendix D. Use of this approach requires an assessment of potential failure modes to determine the rate determining step(s) and hence select an appropriate activation energy. Some typical activation energies are given in Table 1 below [15].

Table 1: Some Activation Energies of Failure Modes

Failure Mode	Activation Energy (kJ $mole^{-1}$)
Moisture ingress	70
Propellant plasticiser migration	50 - 90
Ageing of rubbers	40
Thermal decomposition of high explosive	ca 200
Thermal decomposition of primaries	ca 120
Propellant gas cracking	100

Although this method is based on scientific principles, it is very dependent on the reaction activation energy selected. Because of the considerable uncertainties present, acceleration factors should be treated conservatively, and factors greater than about 10 should not be used unless there is additional confirmatory information.

Prediction of life from accelerated tests is a highly uncertain process and care is required in converting the results of such climatic storage tests into estimates of minimum service life. All such estimates should be confirmed by an in-service surveillance program. Although recommended by the AOC, it is the responsibility of the in-service manager to carry out appropriate in-service surveillance.

7 Acknowledgments

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8 References

1 Ordnance Board Proceeding 41871 (1977), *Definition of Life of Explosive Items in Service*, Ministry of Defence, UK.

2 AOC Proceeding 194.91 (1991), *Environmental Questionnaire for Armament Stores*, Australian Ordnance Council, Department of Defence, Australia.

3 MIL-STD-882C (1993), *System Safety program Requirements*, US Department of Defense.

4 DEF AUST 5168 (1986), *The Climatic Environmental Conditions Affecting the Design of Military Materiel*, Department of Defence, Australia.

5 MIL-STD-810E (1989), *Environmental Test Methods and Engineering Guidelines*, US Department of Defense.

6 DEF STAN 07-55 (1975), *Environmental Testing of Service Materiel*, Ministry of Defence, UK.

7 Ordnance Board Proceeding 42242 (1983), *Environmental Testing of Armament Stores*, Ministry of Defence, UK.

8 Ordnance Board Proceeding 42351 (1985), *Assessment of Gun Ammunition of 40 mm Calibre and Above*, Ministry of Defence, UK.

9 EDE Report FD 2084, Engineering Development Establishment, Department of Defence, Australia.

10 EDE Report FD 2191, Engineering Development Establishment, Department of Defence, Australia.

11 DI(G) LOG 07-10 (1993), *Insensitive Munitions*, Department of Defence, Australia.

12 United Nations *Recommendations on the Transport of Dangerous Goods* (1993).

13 AOC Proceeding 82.83 (1983), *Effects of Solar Radiation on Ammunition*, Australian Ordnance Council, Department of Defence, Australia.

14 AOC Proceeding 100.84 (1984), *Effects of Solar Radiation on Ammunition Part 2*, Australian Ordnance Council, Department of Defence, Australia.

15 UK Ordnance Board private communications.

16 AMCP 706-196 Engineering Design Handbook, *Development Guide for Reliability Part 2. Design for Reliability*, Headquarters, US Army Materiel Command (1976).

17 STANAG 2895, *Climatic Environmental Conditions Affecting the Design of Materiel for use by NATO Forces,* North Atlantic Treaty Organisation.

The following, although not referred to specifically, are suggested as sources of further information.

18 Ordnance Board Proceeding 41779 (1977), *Introduction of New Explosives to Service,* Ministry of Defence, UK.

19 Ordnance Board Proceeding 41849 (1977), *Climatic Environmental Conditions,* Ministry of Defence, UK.

20 Ordnance Board Proceeding 41885 (1978), *Life Assessment of Armament Stores,* Ministry of Defence, UK.

21 Ordnance Board Proceeding 42496 (1987), *Life Assessment of Munitions,* Ministry of Defence, UK.

22 Ordnance Board Proceeding 42657 (1990), *Insensitive Munitions* , Ministry of Defence, UK.

23 AOC Proceeding 188.91 (1991), *Insensitive Munitions Recommended Australian Defence Force Policy,* Australian Ordnance Council, Department of Defence, Australia.

24 AOC Proceeding 218.93 (1993), *The Qualification of Explosives for Service Use,* Australian Ordnance Council, Department of Defence, Australia.

25 MIL-STD-2105B (1994), *Hazard Assessment Tests for Non-Nuclear Munitions,* US Department of Defense.

Appendix A

Some Common Life Cycle Stages, and Likely Associated Environmental Stresses

Road and rail transport (all services) (can occur at several stages, eg manufacturer to depot, depot to unit)

Vibration (dependent on road condition, vehicle type, packaging and degree of restraint)
Bump and bounce (dependence as for vibration)
Handling shock (drops, overturning)
High temperature (can be in excess of 30°C above ambient temperature for loads under unventilated covers and exposed to solar radiation)
Low temperature
High humidity
Dust (unsealed roads)

Sea transport or storage on supply ships (all services)

Ship vibration
Handling shock (drops from considerable heights, overturning)
Temperatures of relevant marine climatic zones (M1, M2, M3 of STANAG 2895) (dependent on stowage location)

Air transport (all services)

In flight vibration
Low pressure
Rapid decompression
Shock (air dropped, helicopter delivery, handling shock)

Depot storage (all services and including any storage by manufacturer)

Temperature dependent on nature of storehouse and location.
(In good quality storehouses temperatures will follow seasonal averages. In thin walled storehouses temperatures could range from DEF AUST 5168 "Operational" to in excess of "Storage" conditions, depending on the adequacy of ventilation.)
Humidity (dependent on location)
Fungus growth

Unit storage (land/air service)

As for depot storage above, plus:

High temperature (can be in excess of 30°C above ambient temperature for loads under unventilated covers and exposed to solar radiation)
Solar radiation
Rain
Dust/sand

Deployment on gun, launcher or other weapon system (all services)

Vibration
Shock
Temperature extremes
Humidity
Dust/sand
Salt spray
Rain/water immersion
Solar radiation

Field deployment (land service)

High temperature (from unventilated or unprotected storage or stowage in hot locations in vehicles)
Humidity
Fungus
Low temperature
Solar radiation
Rain/water immersion
Dust, sand, mud
Vibration (wheeled and tracked vehicles)
Shock (handling, drops, weapon firing, mine blast)

Combat vessel deployment (maritime service)

Ship vibration
Possible storage in exposed positions (Solar radiation, poor ventilation, high temperature)
High humidity
Salt spray (dependent on stowage location)
Underwater shock/gun blast (dependent on stowage location)
Handling shocks (drops, overturning, helicopter delivery)
Possible water immersion (during transfers)

Combat aircraft deployment (air service)

High temperature (affected by unventilated storage during standby, altitude, aerodynamic heating, installation in hot locations in aircraft)
Humidity

Vibration (in-flight, runway induced, weapon firing)
Shock (handling, drop, weapon firing)
Low pressure
Salt spray
Dust/sand
Rain

Abnormal hazards or events

Fire (direct eg liquid fuel, adjacent)
Impact/shock (bullet/fragment, blast, shaped charge, sympathetic detonation)
Premature functioning of adjacent store(s)
Nuclear radiation
Electromagnetic environment

Appendix B

An Example of a Tabulated Life Cycle

Serial	Para.	Stage	Duration	Store state	Significant environmental conditions
1	9	Surface transportation	16 days, 8 hours/day	Palletised ammunition boxes	Vibration, shock, rough handling, climatic categories A2 "storage" and CO(A)
2	14	Air transport	72 hours (10 flights)	Palletised ammunition boxes	Vibration, altitude (low pressure) to 3000 m
3	15	Ship transport	6 weeks	Palletised ammunition boxes	Shipboard vibration, underwater shock, no temperature extremes (large hold), possibly high humidity
4	16	Depot storage	12 years	Ammunition boxes, usually palletised	Climatic categories A2 ,B1(A), B2, CO(A), "operational" conditions
5	18	Supply ship transfer	Few hours	Ammunition boxes, usually palletised, may be loose in cargo nets	Open exposure of boxes to solar radiation, wet, cold. Risk of 18 m drop, other rough handling
6	19	Storage in supply ship	3 years	Ammunition boxes, usually palletised	As for serial 3
7	21	Combat ship transfer	Few hours	Palletised ammunition boxes	As for serial 5, plus risk of sea water immersion
8	23	Storage in combat ship	6 years	Ammunition boxes	Temperature controlled magazine (20 - 25°C), possibly high humidity, vibration, risk of fire
9	25	Ready use locker transfer	1 hour	Ammunition boxes	Rough handling, risk of 3 m drop
10	26	Storage in ready use locker	12 weeks	Ammunition boxes	Marine hot wet (M2) and cold (M3) "operational" conditions, vibration
11	28	Weapon system transfer	20 minutes	Unpackaged	Risk of 1.5 m drop, solar radiation, rain, salt spray
12	31	Standby in weapon system	12 weeks	Unpackaged	Marine cold and A2 "storage" conditions, rain, salt spray, solar radiation, risk of fire
13	36	Operation of weapon	Short	Unpackaged	High acceleration, vibration, shock
14	37	Removal of unfired rounds	20 minutes	Unpackaged	As for serial 11

Appendix C

Effects of Common Environmental Stresses

Table 1 Some of the Principal Effects of Environmental Stresses

(Adapted from Engineering Design Handbook AMCP 706-196 [16])

ENVIRONMENTAL FACTOR	PRINCIPAL EFFECTS	TYPICAL FAILURES INDUCED
High temperature	More rapid ageing (material degradation). Softening, melting, sublimation. Physical expansion.	Altered performance and hazard properties. Loss of mechanical strength of explosives. Failure of seals. Exudation, increased hazard.
Low temperature	Hardening, embrittlement. Physical contraction	Altered performance. Failure of seals. Loss of mechanical strength, cracking, breakup of charges.
High relative humidity	Accelerated deterioration. Moisture absorption. Corrosion. Mould growth.	Altered performance or failure to function. Swelling, loss of mechanical strength.
Low relative humidity	Embrittlement.	Altered performance, increased sensitivity.
Cyclic temperature changes	Effects of high & low temperature plus moisture ingress, growth, stress.	Effects of high & low temperature plus altered performance, hazard properties. Failure of seals, bonds.
Altitude/Low pressure	Expansion, outgassing.	Permanent change in performance of some compositions.
Solar radiation	Accelerated deterioration reactions, embrittlement. Increased thermal stress.	As for high temperature. (Bare explosives must never be exposed to direct solar radiation).
Salt spray	Corrosion	Interference with function.
Sand and dust	Abrasion, clogging.	Increased wear. Interference with function.
Rain	Water absorption, corrosion. Physical stress.	Interference with function.
Ice, hail, snow	Abrasion, clogging.	Interference with function.

Table 1 Some of the Principal Effects of Environmental Stresses (Continued)

ENVIRONMENTAL FACTOR	PRINCIPAL EFFECTS	TYPICAL FAILURES INDUCED
Thermal shock	Mechanical stress.	Failure of seals, bonds. Loss of mechanical integrity.
Vibration	Mechanical stress, wear, fatigue.	Failure of seals, bonds. Interference with function. Loss of mechanical integrity.
Acceleration	Mechanical stress.	Failure of seals, bonds. Interference with function. Loss of mechanical integrity.
Shock	Severe mechanical stress.	Failure of seals, bonds. Interference with function. Loss of mechanical integrity. Increased hazard.

Table 2 The Effects of Common Combinations of Environmental Pairs

(Adapted from Engineering Design Handbook AMCP 706-196 [16])

FACTOR A	FACTOR B	EFFECT OF COMBINATION
High temperature	Vibration, shock, acceleration.	Intensification of the effects of each. Plastics and polymers are particularly susceptible.
	Humidity	Increased rate of moisture penetration. General increase in the effects of each.
	Salt spray	Increases rate of corrosion.
	Fungus	Micro organisms require warmth to grow. Above about 70°C they cannot develop.
	Solar radiation	Intensifies effects on organic materials.
Low temperature	Vibration, shock, acceleration.	Can intensify effects on polymers (especially seals) at temperatures low enough to cause hardening/embrittlement.
	Humidity	May induce condensation.
	Salt spray	Reduces rate of corrosion.
	Fungus	Reduces or prevents growth.
	Solar radiation	Each reduces the effect of the other.
High humidity	Salt spray	May dilute the salt concentration, but has no effect on the corrosive effects of the salt.
	Fungus	Promotes growth of micro organisms.
	Solar radiation	Intensifies effects of solar radiation on organic materials.

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Appendix D

Example of Service Life Prediction Calculation

(Based on information provided by UK Ordnance Board [15])

Requirement

For a hypothetical item of explosive ordnance it will be assumed that the required life is 7 years in a region classed as climatic category B3. (STANAG 2895 [17]). This is characterised by moderately high temperatures accompanied by high humidity and high levels of solar radiation.
Six years will be storage under "good" conditions (at the worst a thin walled storehouse with adequate ventilation). In this type of storage the conditions would be expected to follow but not exceed the temperature and humidity of the B3 "operational" condition (a maximum of 41°C at the hottest time of the year).
One year will be under field storage conditions, which would approximate to the unventilated "storage" condition, with a maximum temperature of 71°C. In both conditions it is assumed that the stores are not exposed to direct solar radiation for any significant period, although the heating effect of solar radiation on enclosures is included in the "storage" condition.

Under the above conditions of cyclic high temperature and humidity, degradation may occur via ingress of moisture and subsequent reaction with some components of the filling, such as a composition in the ignition system, or by a material degradation accelerated by the high temperatures.

Selection of trial conditions.

Based on the above assumptions, a suitable trial should include both high temperature and high humidity, with cycling to reveal thermomechanical failures. The most severe condition likely to be experienced in service is the B3 storage condition. The proposed test condition is the diurnal cycle representing the maximum temperature and associated humidity profile recommended in Table 11 of STANAG 2895 as design criteria for explosives exposed to the B3 storage conditions.

Selection of trial duration.

Acceleration of degradation is achieved by performance of the trial at a mean temperature higher than the mean temperature experienced by the store during its service life. For simple first order reactions the relative reaction rate between two temperatures is given by:

$$f = \frac{K_2}{K_1} = \exp\left[\frac{-E}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right]$$

Where f = Accelerated ageing factor
K_1 and K_2 = reaction rates at temperatures T_1 and T_2
E = Activation energy
R = Gas constant = 8.314
T_1 = Mean temperature in storage (Kelvin)
T_2 = Mean temperature of trial (Kelvin)

For this example it is assumed that the rate determining step is diffusion of water vapour through a polymeric seal, for which an activation energy of 70 kJ per mole is typical. As the relation between reaction rate and temperature is highly dependent on the activation energy, selection of a low activation energy will give a conservative estimate of the acceleration in degradation achieved by a trial at an elevated temperature.

It is then necessary to determine the constant temperature which would give the same amount of degradation as one year of each of the selected service conditions. This can be calculated from the data given in STANAG 2895 , where for each climatic condition the number of hours in each year for which a given temperature is reached or exceeded is graphed. The relevant figures are Fig 45 for the B3 operational condition, and Fig 47 for the B3 storage condition.

As these figures show the number of days for which a given temperature is exceeded, the total period (1 year) can be divided into intervals during which the temperature is within a selected range. The amount of degradation occurring during each period can then be calculated, and the amounts added to give the total degradation for the period. From this the effective temperature can be calculated.

This "effective" temperature is given by:

$$T_e = \frac{-E}{R}\left\{\ln\left[\frac{1}{P}\sum_i \exp\left(\frac{-E}{RT_i}\right) \times t_i\right]\right\}^{-1}$$

Where T_e = The "effective" temperature (Kelvin)
T_i = The average temperature of each temperature increment (Kelvin)
P = Total period ie Σt_i (hours)
t_i = Duration of each temperature increment (hours)

For calculation of the effective temperature of each service condition, the temperature range is divided into convenient intervals, and the corresponding time intervals read from the graphs. The data and calculations for B3 operational and B3 storage are shown below. The column headed exponent is:

$$\exp\left(\frac{-E}{RT_i}\right) \times t_i$$

For the B3 operational condition (from Fig. 45):

Temperature (°C)	Time (hours)	Time Interval t_i	Exponent
41.0	24	24	5.43x10^{-11}
37.5	460	436	7.30x10^{-10}
32.5	1630	1171	1.26x10^{-9}
27.5	4000	2369	1.61x10^{-9}
22.5	6310	2310	9.76x10^{-10}
17.5	8414	2104	5.44x10^{-10}
13.5	8760	346	5.97x10^{-11}
		$\Sigma t_i = 8760$	Σexp = 5.23x10^{-9}

From this, $T_e = \frac{-70 \times 10^3}{8.314}\left[\ln\left(\frac{1}{8760} \times 5.23 \times 10^{-9}\right)\right]^{-1}$

= 299 Kelvin (26°C)

For the B3 storage condition (from Fig. 47):

Temperature (°C)	Time (hours)	Time Interval t_i	Exponent
70.5	10	10	2.26x10^{-10}
65	400	390	5.93x10^{-9}
55	1190	790	5.62x10^{-9}
45	2500	1310	4.16x10^{-9}
35	4000	1500	2.01x10^{-9}
25	5800	1800	9.66x10^{-10}
15	7300	1500	3.02x10^{-10}
5	8760	1460	1.03x10^{-10}
		$\Sigma t_i = 8760$	Σexp = 1.93x10^{-8}

From this, $T_e = \frac{-70 \times 10^3}{8.314}\left[\ln\left(\frac{1}{8760} \times 1.93 \times 10^{-8}\right)\right]^{-1}$

= 314 Kelvin (41°C)

Similarly, the effective temperature for the selected trial cycle can be calculated from the data in Table 11 of STANAG 2895:

Temperature (°C)	Time (hours)	Time Interval t_i	Exponent
34	3	3	3.69×10^{-12}
33	6	3	3.37×10^{-12}
44	9	3	8.75×10^{-12}
63	12	3	3.93×10^{-11}
71	15	3	7.04×10^{-11}
63	18	3	3.93×10^{-11}
41	21	3	6.79×10^{-12}
35	24	3	4.03×10^{-12}
		$\Sigma t_i = 24$	$\Sigma \exp = 1.76 \times 10^{-10}$

From this, $$T_e = \frac{-70 \times 10^3}{8.314}\left[\ln\left(\frac{1}{24} \times 1.76 \times 10^{-10}\right)\right]^{-1}$$

$$= 328 \text{ Kelvin } (55^{\circ}\text{C})$$

It is now possible to calculate the acceleration factor achieved by the trial relative to each service condition, and hence the length of trial needed to simulate the time the store is expected to be in that condition.

For the B3 operational condition :

$$f = \exp\left[\frac{-70 \times 10^3}{8.314}\left(\frac{1}{328} - \frac{1}{299}\right)\right] \approx 12$$

Hence, for a 6 year period, the trial duration would be:

$$\frac{6 \times 52}{12} = 26 \text{ weeks}$$

For the B3 storage condition

$$f = \exp\left[\frac{-70 \times 10^3}{8.314}\left(\frac{1}{328} - \frac{1}{314}\right)\right] \approx 3$$

Hence, for a 1 year period, the trial duration would be:

$$\frac{52}{3} = 17 \text{ weeks}$$

Thus the total trial duration to simulate the expected service life is 43 weeks.

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Guidance for preparation of a life cycle environment profile and environmental test plan for qualification of explosive ordnance

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ABSTRACT

This report outlines a suggested approach to the preparation of a life cycle environmental profile and the consequent program of environmental tests required before an item of explosive ordnance can be accepted as safe and suitable for service with the Australian Defence Force. Likely environmental stresses and their effects, and a procedure for calculating the duration of accelerated ageing trials are included as appendices.

Guidance for Preparation of a Life Cycle Environmental Profile and Environmental Test Plan for Qualification of Explosive Ordnance

John Pisani

DSTO-GD-0032

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