

Headquarters Australian Defence Force

ESTABLISHMENT AND SITING OF AN EXPLOSIVES ENVIRONMENTAL TEST FACILITY

By: Mr J. J. Goold, Secretary, Explosives Storage and Transport Committee (ESTC),
Australian Ordnance Council

Mr Ian Kummerow, Technical Staff Officer-Australian Defence Industries, Australian
Ordnance Council/ VADI Ordnance

Mr A. U. Ringer, Technical Staff Officer-Explosives, Australian Ordnance Council

ABSTRACT

The Australian Department of Defence is establishing a new Environmental Test Facility at Port Wakefield, South Australia. This paper outlines the requirement for the Environmental Test Facility, discusses its proposed capabilities and describes the unique problem in siting and establishing an Environmental Test Facility.

INTRODUCTION

1. The capabilities of an Explosives Environmental Test Facility are an inherent requirement to provide evidence to assess the safety and suitability for service (53) of items of explosive ordnance (EO) for use by the Australian Defence Force (ADF). The Australian Ordnance Council (AOC) is the body responsible for the provision of independent ~3 advice to the ADF and was formed in 1975. It soon found that the capability for testing stores to the requirements of Council Proceedings was inadequate in a number of areas.
2. This paper addresses the history of the process required to resolve the inadequacies, details the capabilities of the Australian Explosives Environmental Test Facility and provides some insight into the problems faced, and their resolution, in establishment and siting of a new Explosives Environmental Test Facility.

HISTORICAL BACKGROUND

3. Inadequacies in the explosive ordnance test capability within Australia were becoming clear in the early '80s. The then President of the Australian Ordnance Council (PAOC) tasked an AOC

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subcommittee, the Environmental Requirements Coordination Committee (ERCC) to undertake a study of the capability.

4. The study was conducted in two parts. The first part comprised a description of the facilities and equipment required for the environmental testing of EO, a survey of the existing facilities for such testing and identification of deficiencies in the then current capabilities. The second part comprised an examination of the options for correction of the identified deficiencies and provided a recommended course of action.

5. Part I of the study was completed in October 1982 (Reference A). The conclusion was that serious deficiencies did indeed exist in the current capability. There were ten tests including acoustic vibration, underwater shock, explosive decompression and simulation of the electromagnetic service environment for which no capability existed in Australia. Obsolete, outworn and partially inoperable equipment existed in many areas.

6. Of special note was the geographic distribution of test locations and the necessity to transport stressed ordnance between them for appropriate sequential testing as well as transport to separately located proof ranges for functioning. This imposed a higher than normal level of risk on defence personnel and the general public.

7. Explosive safety regulations were also starting to impose severe constraints as new regulations, which included more stringent quantity-distance rules were to be in force by December 1983. This severely limited all current sites to testing two to six 105 mm HE shell or one or two 155 mm HE shell at a time. There was no capability for environmental testing of large stores or warheads such as bombs or sea mines.

8. Part 2 of the study, completed in May 1983, (Reference B) recommended that the then Departments of Defence and Defence Support take urgent action to rectify the deficiencies and noted that the cost of construction of a comprehensive explosives environmental test centre to be in the order of \$26.5 M (November 1982 dollars). The study also recommended that the EETC should be sited at or nearby the Proof and Experimental Establishment Port Wakefield, South Australia. It would then have internal access to proof facilities and technical support from DSTO was relatively close.

9. In November 1983 the Chief of Logistics - Army issued a draft Defence Facilities Brief (DF1). It is noted that at the time defence was split into two departments, the Department of Defence and the Department of Defence Support. It is also noted that the latter was conducting a study into rationalisation of the then existing explosives factories. This, along with further rationalisation and privatisation of ammunition and weapon production facilities in the '90s would have some bearing on the final decision.

10. As a result of the DFI, the Council tasked the ERCC to provide a detailed study into the siting and layout of an EETC in the vicinity of P & EE Port Wakefield. This study (Reference C) recommended that an EETC be constructed, and managed by Army as single service manager. The Council recommended that the ERCC report (Annex A to Ref. C) be used as the user requirement. It was noted that, at the time, the siting of P & EE was under review.

11. In 1985 the AOC recognised that the facilities project was going nowhere and published a further Proceeding (Reference D). It expressed the likelihood that an EETC, now renamed Explosives Environmental Test Facility (EETF) would not be available for use before 1992. It also expressed concern that the capability for environmental testing of EO had deteriorated significantly since the first publications in 1982/83.

12. Reference D updated the earlier reports and made recommendations on providing facilities for EO testing until the EETF became available. A key point was the interim improvement of facilities and provision of further staff at the then AEL Salisbury environmental engineering facility (EEF), even though the report noted that this facility had no official role in explosives testing. The NATO Safety Principles for the Storage of Explosives had emphasised the unsuitability of the majority of existing test centres due to their close proximity to built-up areas, railway lines etc. EEF was best located to accept an increase in facilities and workload although even it was only a short term solution and would meet only part of the requirement. MRL EO testing was being severely limited by the new regulations.

13. Conclusions from discussions on management philosophy and the viability of an environmental test facility solely for EO in the years 1985 to 1988 were that Army should sponsor an ETF which included both EO and non-EO testing at Port Wakefield. However still no real decision was made. In 1989 the Chief Defence Scientist (CDS) reiterated to VCDF that environmental testing was outside the charter of DSTO and started redeploying staff and providing only minimal maintenance of equipment for the EEF. At the same time tests which had been previously conducted by MRL Explosive Ordnance Division were being devolved to EEF.

14. Discussion with Australian Defence Industries (ADI) in 1989 indicated ADI's willingness to take over management of the EEF. The Defence view, agreed at PAOC level at a meeting held in December 1989 was that the facility for EO testing should be retained within Defence. It was believed by the representatives at that meeting that the problems of independent assessment and other issues could not otherwise be addressed. Despite the recommendation of this meeting CGS and VCDF still disagreed as to whether ADI should be encouraged to develop an alternative proposal. It was assumed that VCDF's reason was to protect himself from a challenge by ADI in case they (ADI) felt that they were not given the chance to get involved and (reading 'between the lines') especially if in the future they had to pay highly inflated prices for environmental testing and thus subsidise other Defence testing requirements even on products not produced in country.

15. Perceived inactivity within the system led to some retrenchments and redeployment of staff from EEF as well as further run down of equipment during the first part of 1990. On the 1st June 1990 CDS wrote to VCDF again reiterating that DSTO charter did not include the EEF function. He proposed a number of options which included transfer to Army and a return 'to square one' to readvertise for expressions of interest. "The "System" takes another bite of its tail'.

16. Further discussion between FASSP and DACMAT-A led to a mutually agreed arrangement for the way ahead which met the majority of CDS's concerns. A letter from VCDF to CDS dated 8 Nov 1990 set the agreed policy which included the following points:

- a. The EEF provides a nucleus around which an EETF can be developed.

- b. An EETF must also conduct non-explosive testing.
- c. The EETF should be Defence-owned and operated by Army.
- d. Set up a working group for the transfer to report by 14 Dec 1990.

17. The subsequent hand-over of EEF to Army by DSTO occurred on 22 March 1991 with interim arrangements operating until 1 Jul 1991 when the transfer was complete. The facility was renamed Environmental Test Facility (ETF).

18. On 12 Mar 1991 EDE issued a Defence Facility Brief on Additional Land for Environmental Test Facility Port Wakefield SA. The additional land requirement was for acquisition of 182 ha.

19. After the usual procedures of obtaining land, conducting a limited EIS, and receiving a funding allocation, work on the Environmental Test Facility at Port Wakefield commenced in July 1994.

ENVIRONMENTAL TEST FACILITY (ETF): CAPABILITY

20. The test facility currently at Salisbury, South Australia provides a one-stop-shop service for environmental testing of explosively filled stores. The ETF satisfies the requirements of the Australian Ordnance Council for munitions testing capability.

Testing to National Defence Standards

21. ETF has the capability to perform a wide range of tests and calibrations to meet the requirements of both national and defence standards. The capability extends beyond these, and includes specifications which are special to type for equipment generated locally by manufacturers, by customers or by designers.

22. The following is a list of the more common standards used, but potential customers are advised to discuss their testing requirements with ETF in order to resolve any queries:

DEF(AUST) STANDARDS	:	168, 1000, 5168, 5247
BRITISH DEF STANDARDS	:	00-1, 00-35, 07-55
US MIL STANDARDS	:	108E, 167/1, 167/2, 167B, 202F, 210C, 331A, 454K, 740B, 810D/E, 883C, 901C, 1670A, 5400R, 5422F, 7743E, 164000, 17000N, 21200L
AUSTRALIAN STANDARDS	:	1099, 1180, 1349, 2625, 2660
BRITISH STANDARDS	:	2011, 30-100
INTERNATIONAL ELECTROTECHNICAL COMMISSION SPECIFICATIONS	:	IEC 68 Series

Accreditation

23. Almost all the testing and calibration services performed by the ETF are accredited by the National Association of Testing Authorities (NATA). The NATA registration provides traceability to national standards and ensures high quality testing and reporting is maintained. The list of accreditations is given at Table 1.

NUMBER	FIELD	ITEM OR FUNCTION COVERED
382	Mechanical Testing	Metals and metal products. Lifting gear, welded chain, wire rope and fillings. Springs and energy absorbing devices. Pipes, hoses, valves and fittings. Cylinders and other pressure vessels.
1371	Non-Destructive Testing	Radiographic examination of aluminum alloys. Radiographic examination of other non-metals. Radiographic examination of components and assemblies. Magnetic particle testing. Penetrant testing.
1542	Acoustic and Vibration Testing	Vibration measuring and calibration equipment.
480	Electrical Testing	Environmental tests. Resistors, resistance boxes and potential dividers. Inductors and transformers. Voltage Standards. Precision transfer instruments. Instrument calibrators. Indicating and recording instruments. Bridges, potentiometers and test sets. Frequency and time measuring instruments and standards. Waveform measuring instruments. Power supplies and stabilisers. Signal sources. Electronic components. Communications equipment.

Table 1: ETF NATA Registrations

Accelerometer Calibration Facility

24. The Accelerometer Calibration Facility, (ACF), developed in-house, is a good example of the level of expertise Environmental Engineering has in accelerometer use and calibration. This work is the result of two years development using the latest computer based instrumentation. The lessons learnt during development have increased ETFs knowledge of the effects environment on accelerometers, eg temperature, type of pre-amplifier, stray magnetic field effects and base strain.

25. The facility was specifically developed to meet the ETF need for calibration of piezoelectric accelerometers with a mass range of 2 to 60 grams, with either charge or voltage preamplifiers. It is very suited to the calibration of piezo-resistive and servo accelerometers.

26. The detailed capability of the ACF can be summarised as follows:

Amplitude Range	0.3g to 100g in a 1-3-10 pattern, shaker travel limited to 0.5 inches p-p
Frequency Range	5 to 5 000 Hz, 5 to 2 000 Hz, 5 to 500 Hz
Mass Range	2 to 60 grams full amplitude (greater than 60 grams, reduced amplitude)
Preamplifiers	Voltage or Charge
Accelerometer output range	2 to 1 000 mV/g
Temperature Conditioning Range	-55 to +1 I0°C
IBM PCXT	IEEE 488 bus controller and data storage
Solartron 1254	4 Channel frequency response analyser
HP 7475	Digital plotter
B&K 2650	Precision conditioning amplifier
Unholtz-Dickie	0.5 inch 5-5 000 Hz shaker

Strain Measuring System

27. The Strain Measuring System (S.S.), an in-house development, provides fast, accurate, drift free measurement of strain.

28. The S.S. consists of Analogue Devices master and slave microprocessor controlled

stations. The master station provides data logging on floppy diskette and control of up to 16 slave stations. The slave stations measure up to 256 individual strain gauges (85 rosettes). The software is presently capable of controlling a single slave station, data logging raw data to disk, calculating principal strain (magnitude and direction), calculating principal stress (magnitude and direction) and print-out of results in a tabular form.

29. The S.S. has been developed to a high level with the object of providing a system which is quick and accurate with low drift. The measuring system does not require a temperature controlled laboratory for its operation. Drift of the system over a full day has been reduced to 3 microstrain or about 0.3% of the normal working strain levels in materials.

30. The system is portable and can be used in any work area, providing 240V 50Hz AC is available. The capacity of the system is expandable to 4 096 gauges.

31. Force measurement can also be achieved using the S.S.. Environmental Engineering has many years of experience in the design of specialist load cells which, combined with the S.S., can provide logging of up to 4 096 force measurements.

32. The Environmental Engineering Facility provides a full range of services in strain gauge applications. The use of these facilities by customer organisations can provide a cost effective solution to strain measurement problems and avoid a steep learning curve.

Summary of Capability

33. The overall capability of the ETF is summarised at Table 2.

<u>FIELD</u>	<u>DESCRIPTION</u>	<u>REMARKS</u>
Vibration Testing	Testing of all types of equipment, from components to large assemblies, to MIL, Def and civil standards, including combined environment (temperature)	Physically large items can be accommodated in all axes, and if parts of systems are tested, the parts not under test can be readily accommodated to allow complete system functioning
	Random, transient, fixed and swept sinusoidal testing, in the frequency range 5 to 2000 Hz, levels to 100g dependant on specimen size, displacements to 150 mm	<p>Combined environment, with a temperature range of -60 to +110°C including simulation of aerodynamic heating</p> <p>Response monitoring of up to 16 channels available</p> <p>Special load support systems available, including a fixture for large shock mounted cabinets</p> <p>Items containing explosives can be tested</p> <p>NATA accreditation is held</p>
Climatic Testing	Equipment up to 6m long, 3m wide and/or 3m high can be tested over a temperature range from -80°C to +300°C, with humidity from 5 to 95% at temperatures from 5°C to 60°, and altitudes up to 46 000 m. available.	<ol style="list-style-type: none"> 1. Large specimens can be accommodated. 2. Diurnal, weekly etc cycles can be maintained. 3. Thermal shock facilities 4. Items containing explosives can be tested. 5. Ready access for specimen services (electrical, exhaust gases etc). 6. NATA accreditation is held.

<u>FIELD</u>	<u>DESCRIPTION</u>	<u>REMARKS</u>
Shock, Impact Testing	<p>A wide range of test equipment is available, including:</p> <p>Hi Impact for MIL-S-90IC etc tests. (Light Weight Admiralty design).</p> <p>Shock Testing - Classical shock pulse (eg V2 sine, trapezoidal, sawtooth) using either free fall shock machines or electrodynamic vibrators.</p> <p>Drop Testing to 12m.</p> <p>Conbur Ramp - horizontal impact and classical shock.</p> <p>Impact Force - various specialised facilities.</p> <p>Bump - to 560kg capacity.</p> <p>Bounce - to 1 800kg capacity, various motions available.</p> <p>Topple, stacking, racking etc</p>	<ol style="list-style-type: none"> 1. Items containing explosives can be tested. 2. Responses can be monitored and analysed as required. 3. High speed filming or video is available. 4. NATA accreditation is held.
Pressure Testing	<p>Pneumatic pressure tests to 41 MPa and Hydrostatic pressure tests to 690 MPa.</p> <p>Calibration of industrial and test gauges and transducers to 400 MPa.</p> <p>External Pnpressure tests to 41 MPa, dependant on specimen size.</p>	<ol style="list-style-type: none"> 1. Higher pressures than most facilities 2. Extensive range of high pressure external test vessels. 3. Calibration available in vacuum and low pressure areas. 4. NATA Accreditation is held.

Materials Testing

Torque.

NATA accreditation is held.

FIELD

DESCRIPTION

REMARKS

Accelerometer
Calibration

5Hz to 5kHz, 0.3 to 100g
acceleration at temperatures
between -40°C and 100°C

1. Approx 1 hr cal time
2. 1 to 20Hz at 1g facility
(development advanced)
3. NATA Certification is held.
4. Significant
knowledge base.

Temperature
Calibration

Temperature transducers -70°C to
+150°C in stirred baths. Ambient
to +600°C fluidised sand.
Precision temp measurement
using PRT -70°C to +600°C.

Wide temperature range
Significant experience in
temperature measurement
discipline.

Force

Load cell design, construction
and calibration

Full in-house service from
specification to completed cell

Strain

Strain gauge measurement
system, software written locally
to cater for up to 4096 gauges
(48 currently filled).

High number of channels
possible
Low drift systems. (+ 0.3% of
full scale per day)
Automatic print out of
calculated data in various
formats
Customer adaptable software

<u>FIELD</u>	<u>DESCRIPTION</u>	<u>REMARKS</u>
Field Instrumentation	<p>Measurement of the following parameters:</p> <ol style="list-style-type: none"> 1. acceleration 2. temperature 3. acoustic noise 4. force 5. displacement 6. velocity 7. pressure 8. signal spectral content 9. voltage, current DC & AC 10. resistance 11. shock 	<p>Comprehensive measurement and analysis services available</p> <p>Complex measurement systems can be designed</p> <p>Traceable to national standards</p>
Acceleration	<p>A range of centrifuges exist for steady state acceleration testing of specimens to 27 000g or loads to 45kg.</p> <p>Rotational acceleration - specimens can be rotationally accelerated or decelerated to meet special requirements.</p>	<p>Up to 32 slip rings</p> <p>Can accommodate explosive items</p> <p>Programmable rotating tables</p> <p>NATA accreditation held</p> <p>Temperature conditioning available.</p> <p>Slip rings available</p> <p>Can be combined with steady state acceleration</p>
Structural	<p>A range of platforms and load frames are adaptable for structurally testing most transportable equipment utilising a range of individual hydraulic loading cylinders and static weights</p>	<p>Strain gauging of critical points</p> <p>Deflection measurements (eg dial gauges)</p> <p>Load cells and tensiometers available</p>

<u>FIELD</u>	<u>DESCRIPTION</u>	<u>REMARKS</u>
Lifting Equipment	Deadweight and hydraulic loading of cranes, hoists, beams and slings.	NATA accreditation held Up to 62 tonne capacity NATA accreditation held.
Harsh Environment	Salt Spray and Salt Corrosion Salt Fog Sand & Dust - Swirling - Driving	Large specimens (assemblies, equipment) Material samples and smaller assemblies Specimens to 2.4 x 1.2 x 1.2m Special rigs can be made to accommodate most specimens Rotating tables available
	Drip Proof, Immersion, Sealing	Most specification requirements can be met
	Fluid Contamination	Most fluids can be handled
	Solar Radiation - to 1140w/m ²	NOTE: All above, except Fluid Contamination, are NATA accredited.
NDI	X-Radiography to 420kV	System is transportable Can be used for explosives Fluoroscope available
	Magnetic Flaw Detection	Can be used for explosives
	Dye Penetrant Testing	NATA accreditation held for all above methods

<u>FIELD</u>	<u>DESCRIPTION</u>	<u>REMARKS</u>
Electrical Calibration	Resistance: precision resistors, resistance boxes and conductance boxes in the range 10 ⁻⁶ to 1014 ohms	Wider range and better accuracy than available elsewhere in SA
	Voltage Ratio (DC): Volt ratio boxes and potential on DC, 0 to 50kV	Wider range and better accuracy than available elsewhere in SA Better accuracy than available elsewhere in SA
	Capacitance: two or three terminal capacitors, 3 x 10 ⁻⁵ pF to 100uF	Wider range and better accuracy than available elsewhere in SA
	Inductance: inductors, self and mutual 10 ⁻⁷ to 100H	Measurements not available elsewhere in SA
	Voltage Ratio (AC): ratio transformers	Wider range and better accuracy than available elsewhere in SA
	Voltage (DC): DC voltmeters to 100kV	Wider range and better accuracy than available elsewhere in SA
	Voltage (AC): AC voltmeters to 10kV	Better accuracy than available elsewhere in SA
	Current (DC): DC ammeters to 100A	Measurements not available elsewhere in SA
	Current (AC): AC current to 1 200A	
	Attenuators: attenuation at DC, AC (to 50kHz)	Measurements not available elsewhere in SA
Current Ratio (AC): current transformers, to 1 200 A		

<u>FIELD</u>	<u>DESCRIPTION</u>	<u>REMARKS</u>
	Voltage Standards: standard cells, electronic emf devices	
	AC/DC Transfer: to 1 000 V, 50kHz to 10A, 400Hz	
	Power DC or 50Hz to 1 000V and 5A	
	Bridges, Potentiometers	
	Waveform Measuring Instruments frequency, input, timing and sweep characteristics	
	Power Supplies, Stabilisers	
	Signal Sources: frequency, output, modulation and sweep characteristics	
	Electronic Components: fixed resistors, capacitors	

Table 2: ETF Capability

THE NEW FACILITY: PORT WAKEFIELD ETF

34. Construction of the new facility commenced in July 1994, and is scheduled for completion in December 1995. It will consist of some eleven buildings at the main site, a Drop Test Tower and Control Building at a remote location approximately 14 km to the south, and associated infrastructure; the proposed site layout is shown at Figure 1. The capability will not be diminished by transfer to the new site.

Figure I: Proposed ETF at Port Wakefield, South Australia

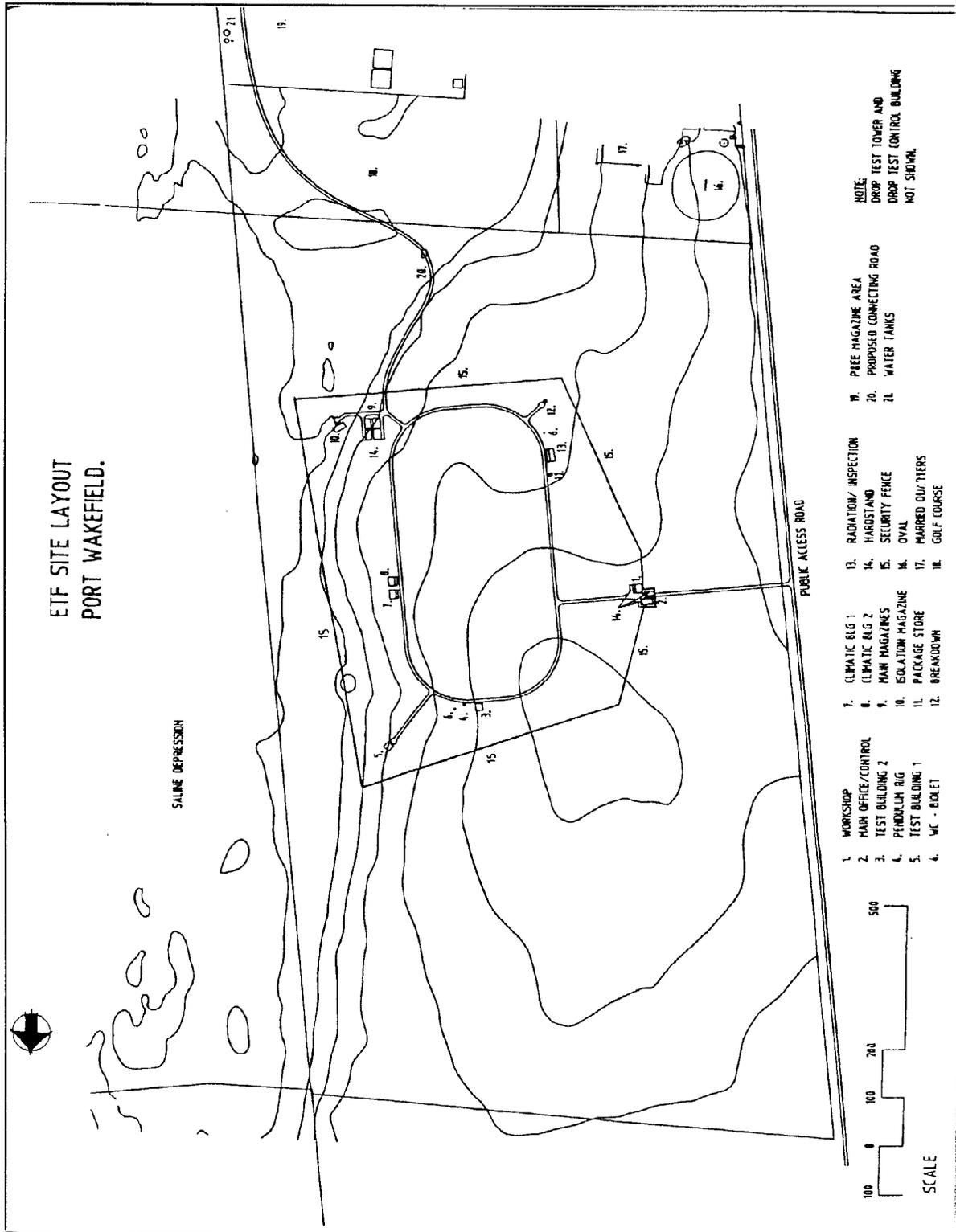


Figure I: Proposed ETF at Port Wakefield, South Australia

Facilities

35. A control/office building at the entrance to the facility. This will allow for remote control of all test and monitoring equipment and CCTV surveillance of tests. Crew room and office accommodation is included.
36. A workshop/store building adjacent to the control building. Minor workshop capability only is planned, as use can be made of facilities at the adjacent proof range or at Salisbury. The store will be used for rigs, fixtures and inert items provided in aid of testing.
37. Test Building 1 will be a hardened building to accommodate a large vibration testing facility. A new 110 kN thrust electrodynamic vibrator with a 50 mm stroke is to be installed. Conditioning equipment to allow combined high or low temperature and vibration or shock testing, including simulation of kinetic heating is included. The vibration controller will allow random, sine, classical shock, sine on random, random on random and shock response spectrum testing.
38. Test Building 2 will be a general purpose rough handling test building and will also be hardened. A small (12 kN thrust) vibrator, temperature conditioning equipment, small drop test machine, bounce machine (2 tonne capacity) and handling shock equipment is included along with a general purpose plinth upon which other test equipment could be mounted as required. A pendulum type shock test rig will be installed externally.
39. A Breakdown Building. This hardened building will include only a bench and monitoring equipment initially, but equipment will be added as required.
40. A hardened Radiography and Inspection Building. The inspection area is a large room fitted with appropriate benches. Currently, it is planned to move the existing 420 kV X-ray machine to this site, but it is hoped to obtain a linear accelerator within a few years. Radiography control and film processing and viewing facilities will be included in this building.
41. Climatic Test Building 1 will be a general purpose climatic test facility with three chambers, plus a Salt Fog and a Solar Radiation Chamber. These chambers will accommodate items up to about 2m x 2m x 2m in size and will have a temperature range of -60°C +100°C; some will have humidity control.
42. Climatic Test Building 2 will house an altitude chamber, approximately 4m long by 3m diameter, capable of simulating in temperature and pressure, altitudes to 30 km (100 000 ft), and a 6m x 3m x 3m climatic chamber with a temperature range of -40°C to +100°C and humidity control.
43. A Drop Test Tower to accommodate loads of 1.5 tonne to a height of 12 m and a separate, hardened Drop Test Control Building.
44. Four small hardened magazines for storage and one isolation magazine. A package store completes the list of facilities.
45. In addition to the above, Fast and Slow Cookoff tests have been conducted within the Proof Range

boundaries and this will continue. DSTO conduct Bullet and Fragment Impact tests within the Proof Range.

FACILITY CONSTRUCTION & SEPARATION DISTANCES

Siting Policy

46. Given the greater probability of an explosives related incident occurring in an Explosives Environmental Test Facility (ETF)¹ compared with a normal ammunition storage facility, it is imperative that facility design agencies are fully aware of both Government and Departmental policy with respect to explosives safety.

47. Reference E is clear in advising that the determination of the acceptability of a hazardous situation that may affect life, is an exercise normally reserved for the Government itself. Reference F advises that the standard of care required of anyone who handles explosives amounts to "practically a guarantee of safety" and warns of the consequences of negligence. This legal advice, along with the recommendations of a Joint Parliamentary Committee of Public Accounts - Reference (3 - resulted in the promulgation of an amended DoD Explosives Safety Policy at Reference H. This policy has been directly approved by the Minister of Defence.

48. Whilst Reference H calls up References I and J for guidance on explosives storage and handling safety, neither of these latter references provides direct guidance on the establishment and operation of high risk testing. However general principles for building construction and appropriate separation distances can be deduced therefrom. It must also be appreciated that the Reference H, I and J guidelines are based on the concept of tolerable risk. What is tolerable depends to some degree on the consequences of an accidental explosion and the frequency with which these occur. For example, major damage to nearby buildings may be tolerable if an accident happened say only every 50 years, but the same damage would certainly not be tolerable if accidents happened frequently.

Facility Construction

49. In an explosive incident, damage to buildings and injury to personnel or equipment usually results from blast over-pressure or from projections (either from ammunition or from buildings and facilities in proximity to the explosion) or from fire. The severity of effects will be dependent on a large number of factors including the type of structure at the potential explosion site (PES) and the exposed site (ES). The design of structures to contain blast or projections is an extremely complicated procedure and unless specifically warranted due to other special circumstances, eg the containment of the explosive effects of very small quantities of explosive, is prohibitive in cost. In practice, designers normally aim to protect exposed sites from the effects of an explosion or limit the effects of that explosion to tolerable levels at the exposed site.

¹ Definitive probabilities of an accident occurring during any mode of explosives handling are extremely difficult to derive, however an examination of the accident literature (eg US Joint Conventional Ammunition Program Coordinating Group Accident/Incident Annual Report, G.S. Biasutti's "History of Accidents in the Explosives Industry", Australian Ordnance Council ESTC Pamphlet No 4 "Accident Log" etc) indicates that accidental explosions are much more likely to occur during testing or transport than they are during benign storage or normal processing.

50. When considering appropriate facility types to be constructed at an ETF, the range of both PES and ES types needs special attention. Also, new and experimental types of ammunition and explosives would routinely undergo assessment for safety and suitability for service under adverse conditions, and service life-expired ammunition could also be tested. Process buildings will often contain unique, expensive (and often irreplaceable in the short term) equipment. Two or more trials may be conducted simultaneously and an explosion involving one experiment may, if the ETF is poorly planned, cause the curtailment of or delay other experiments and possibly precipitate the loss of many man-hours of labour and the forfeiture of considerable intellectual effort.

51. Historically, there have been basically three approaches to explosives facility design:

- a. the use of frangible buildings separated from each other by large distances,
- b. the use of traversed, strengthened or hardened buildings with lesser separation distances, and
- c. a combination of the above, eg a hardened building with deliberately designed weaknesses such as "blow-out" roofs or panels. This type of building has been used in ETh type facilities.

52. Generally, frangible buildings are designed so that they will not produce dangerous projectiles that could initiate explosives in adjacent storehouses. Frangible buildings may be used in a processing area to minimise the amount of harmful projections produced in an explosion. This type of structure provides little resistance to high velocity fragmentation and should be traversed unless large separation distances are used. The lack of a protective roof on most frangible building designs ensures there is no protection against lobbed ammunition² which may explode on impact, thereby initiating further stocks of ammunition or destroying additional facilities and equipment. Consequently large separation distances are required for this type of facility, if a high or even moderate degree of protection is required.³

53. Reference E Part I Paragraphs 408 and 409 provide guidance on alternative levels of protection at an ES for explosives of Hazard Division 1.1 (HD 1.1) (mass detonation hazard) and Hazard Division 1.2 (HD 1.2) (fragmentation hazard). These levels are summarised as follows:

- a. Virtually complete protection against practically instantaneous Drowning (PIP) of explosion by around shock, flame, blast or high velocity projectiles. There are unlikely to be fires or subsequent explosions caused by these effects or by lobbed ammunition. Stocks at the ES are likely to be serviceable. However, ground shock may cause indirect damage and even

explosions

2 Reference J, Leaflet 6 Section 2

3 Reference J, Leaflet 5 Pt 2 Tables

among especially vulnerable types of ammunition or in conditions of saturated soil. These exceptional circumstances require individual assessment rather than the use of separation distances.

- b. A high degree of protection against PIP of explosion by bound shock, flame, blast or high velocity projectiles. There are occasional fires or subsequent explosions caused by these effects or by lobbed ammunition. Most of the stocks at the ES are liable to be serviceable though some may be covered in debris.

A limited degree of protection against PIP of explosion by bound shock, flame and high velocity projectiles. There are likely to be fires or subsequent explosions caused by these effects or by lobbed ammunition. Stocks at the ES are likely to be heavily damaged and rendered unserviceable. This level of protection is not recommended for new construction. ⁴

54. A study of the quantity distance tables in References I and J indicates virtually complete protection cannot be attained for frangible buildings at normal separation distances and to achieve a high degree of protection, traversing or hardening of ES often would be required.

55. In the case of accident or fire involving ammunition or explosives in a magazine or process building, ammunition may be lobbed from any affected PES design but it is least likely to be lobbed from earth covered or igloo type structures (Reference I Part I Para 440.a (2)). These lobbed items may explode on impact and the subsequent fragmentation may initiate exposed stores either in the open or in storage. Certain of the separation distances in Reference I presume that the roof, head-walls and doors of exposed sites of the earth covered or igloo type will arrest high velocity fragmentation⁵ and provide virtually complete protection, but not necessarily from items larger than 155 mm shell.

Separation Distances

56. Generally, explosives of Hazard Division 1.1 require the most stringent separation distances. If a facility is planned to accommodate HD 1.1, it can usually accommodate all other hazard divisions. If there are real estate restrictions, facilities may be grouped and their explosives quantities aggregated, with separation distances being based on the aggregate quantity.

57. There are two kinds of separation or quantity distances that need to be considered. These are: Exterior Quantity Distances to public traffic routes (PTR) and to inhabited buildings (IBD) and Interior Quantity Distances (IQD) which separate magazines and workshops (see References H, I, and J). Neither Reference I nor J, directly provides quantity distance tables for an ETF, but they do provide an indication of what distances should be used.

⁴ Reference I Part I Paragraph 4o8.b.3.

⁵ The 1990 joint AS/UK STACKFRAG4 Trials and the 1991 SPANTECH trials at Woomera support this presumption.

58. In particular, Reference I:

- a. in Part I Section VII, advises expected injury and damage and different levels of protection for Hazard Division 1.1 and the grouping of structures and facilities; and

in Part II Chap 3 Section I Para 301 Sub-para 14 warns of a minimum PTR and IBD of 600 m, in certain circumstances, for stacked shell. Therefore the use of 600 m minimum IBD, instead of the normal 400 m minimum for Hazard Division 1.1, is recommended in storage and processing situations where the levels of risk are greater than those normally accepted from Reference I.

59. Reference J:

- a. "... notes high risk testing attracts process building and inhabited building distances of 2.5 times the normal prescribed value" and for "The extreme case, static (deliberate) firings where the probability of detonation is obviously unity, attracts the absolute safety distance calculated by ... " "or at least the criterion of one tolerable fragment where absolute safety is impracticable."⁶ It is recommended that application of the 2.5 times safety factor should be applied in the design of a local ETF. The increased distance will provide a level of protection against blast and heat approximating the complete protection requirements of Reference I. Ground shock is unlikely to ever be a limiting factor in these circumstances. This increased distance should also attenuate some of the risk from low angle fragmentation. Guidance on deriving safety distances for deliberate detonations, or situations where the testing authority considers an explosion more likely eg 12 m drop tests for new, unproven ammunition; may be found in Annex C to Reference H.
- b. Advises that "Where it is practicable to provide an area for process buildings which is quite separate from a site containing mainly magazines and stacks, consideration should be given to maintaining 300 m as the minimum separation" (of the test site) "from the nearest storage site containing explosives of Hazard Division 1.1." ~ Therefore the application of a 300 m minimum interior quantity distance between process buildings and other PES containing HD 1.1 ammunition and explosives, should be applied.

Summary

60. If there are restrictions on the availability of real estate for development or there are other limitations due to existing construction or facilities, then the use of earth covered or hardened structures for PES at the ETF is recommended. The building design selected will depend on site and economic factors. However irrespective of the design chosen, buildings should be substantial enough (and separated by sufficient distance) to prevent penetration of fragments from projectiles of up to 155 mm calibre and be sited to provide a high level of protection from practically instantaneous propagation of blast effects. If earth covered buildings are used (see Reference I) particular consideration should be given to building orientation and door design. Provided net explosive quantities (NEQ) are limited and enhanced separation distances applied (see

above), fragmentation and lobbing effects from an accident will be the main concern to the structural engineer. The relatively small net

⁶ Reference J Leaflet 5 Part I Sect III Para 70

⁷ Reference J Leaflet 5 Part 2 Sect I Para 69

explosive quantities to be stored or processed within individual ETF PES, should make the use of expensive 7 bar, or even 3 bar, doors unnecessary.

61. Reference K is of interest in reporting how other nations have constructed ETF. Whilst the rationale for design criteria has not been given, it is of note that in nearly all cases, the constructing authorities have opted for the use of strengthened buildings, eg reinforced concrete structures or earth covered buildings. In designing our local facility, we should be careful to avoid generalising on design for the whole range of ETF buildings since an ETF will require a range of buildings with different functions. For example, depending on where they are sited in relation to the rest of the ETF facility, climatic chambers could be cheap, unstrengthened structures.

Example Application of Above Considerations for a Proposed ETF

62. The appendices apply the above considerations to the construction and siting of a proposed ETF adjacent to an existing military facility. Annex A explains how the separation distances were derived for explosives facilities required at this ETF with their appropriate separation distances.

Annex: A. Determination of Facility Separation Distances

References:

- A. AOC Proceeding 7/82 dated 12 Oct 82 "The Australian Capability for Environmental Testing of Explosive Ordnance".
- B. AOC Proceeding 9/83 dated 10 May 83 "The Australian Capability for Environmental Testing of Explosive Ordnance Part 2".
- C. AOC Proceeding 120.85 dated 12 Feb 85 "Siting and Layout of an Explosives Environmental Test Centre".
- D. AOC Proceeding 124.85 dated 10 Sep 85 "The Australian Capability for Environmental Testing of Explosive Ordnance Report by the Environmental Requirements Coordination Committee".
- E. Commonwealth of Australia Attorney General letter M/83/8395 DP of 7 Dec 83
- F. Commonwealth of Australia Crown Solicitor letter M/83/8395/3656 of 12 Dec 83
- G. Parliament of Australia Report 303 Joint Committee of Public Accounts "Review of Auditor General's Efficiency Audits - Department of Defence: Safety Principles for Explosives and RAAF Explosives Ordnance" Nov 89
- H. Australian Department of Defence, Defence Instruction (General) LOG 07-1 ALI of 25 Jul 91
- I. I.NATO Publication "AC/258 Manual on NATO Safety Principles for the Storage of Ammunition and Explosives 1976 Parts I to W" [Corrigenda 20] (Limited Access)
- J. UK ESTC Series 10 Leaflets
- K. Australian Department of Defence Army Office A87/27041 of 31 Jul 91 "Environmental Test Facility Overseas Visit Report" by LTCOL G. Barkley

ANNEX A TO DDESB PAPER ESTABLISHMENT AND SITING OF AN EXPLOSIVES ENVIRONMENTAL TEST FACILITY

DETERMINATION OF FACILITY SEPARATION DISTANCES

1. The method of deriving facility separation distances for structures in the new ETF are discussed below. For this exercise, real estate and existing facility restrictions have resulted in the choice of facilities that generally are of an earth covered or hardened design. Separation distances have been based on the following structural groupings:

- a. A climatic chamber licensed for 1900 kg NEQ mixed hazard division and classifications. Climatic chambers are only sparsely inhabited by facility personnel and are not regarded as high risk test facilities. Light construction is regarded as sufficient which will provide a high level of protection when the climatic chambers are considered as an ES. Climatic chambers could be sited in the same functional area as the magazines.
- b. A multiple magazine area with possibly 4 individual bays to cater for all classification groups - total NEQ 3500 kg (say 900 kg/bay) and an isolation magazine with an NEQ of 500 kg. An explosives unpacking/packing is required if the inspection facility is not used for this task. In a normal storage situation, a frangible brick magazine with light roof would probably suffice for magazines, separation distances permitting. Due to the nature of ETF activities, the effects of an accidental explosion in the magazine area needs additional consideration. The magazine functional area will hold the largest NEQ in the ETF. The probability of an accidental explosion caused by normal activity in the magazine area could, by current guidance, be considered tolerable. However, the greater probability of an accident occurring in the test facility, which then enhances the probability of a potentially explosive projectile being lobbed into the magazine area causing subsequent explosions, must be considered. Additional overhead protection against lobbed ammunition is recommended for the magazine area.
- c. Three test cells each 1000 kg NEQ. These cells are high risk test facilities. They must be hardened as they will be regularly inhabited for long periods by personnel setting up tests.
- d. Radiographic/Inspection - NEQ 320 kg. The radiographic and inspection facilities are not used for high risk testing but will require extensive exposure of personnel and should be treated as process buildings for site planning.
- e. Breakdown Facilities - NEQ 70 kg. This is a facility for extremely high risk operations involving the breakdown of tested items for examination. Breakdown will be by remotely controlled procedures and the breakdown facility will require a special control bunker for operation. The breakdown facility is especially constructed to direct

fragmentation in event of accident into a specially designed receptor area. Protection from blast and heat is to be provided by separation distances.

- f. Workshop/Control Room - These are non explosives buildings used by personnel regarded as explosives workers and as an ES should be treated as process buildings. If sited as part of the test cell group, buildings should be hardened. In this case, the buildings could in special circumstances and perhaps under special restrictions, be used also as PES. If sited in an non-explosives area, they could be built more cheaply.
- g. Box store - non explosive but minor fire risk; no personnel protection required.
- h. 12 m drop tower and crew bunker. This strictly speaking is a range facility and would not normally be sited within an ETF explosives area. However, a 12 m drop tower is required for testing purposes and so guidance is provided on its siting.

General Considerations

2. Ignoring administrative buildings outside the explosives area, there are four basic structural groupings to consider: magazines (which can include low risk climatic conditioning), high risk test centres, the remote breakdown facility and process buildings (radiography, inspection etc). The non-explosive box store could be sited as part of the magazine area but general advice on siting is offered; finally the siting of a 12 m drop facility is considered, though the facility is sited on a range and not within the ETF. In general, the 600 m recommended for 1BD/PTR distances in the main paper is sufficient to meet all basic facility needs, though this distance has been lowered in some cases. The recommended 300 m IQD also meets most facility requirements and in some cases is lowered where facilities are grouped. Breakdown, box store and 12 m drop facilities are special cases and separate advice is offered.

Climatic Chamber

- 3. 1900 kg NEQ:
 - a. PTR/IBD - Use Reference I HD I.1 D13 table x 2.5 - $1900^{1/2} \times 5.5 \times 2.5 = 599$ m however there is a 600 m minimum requirement for fragmentation - see paragraph 58.b. above. Therefore the 600 m PTR/IBD distance should be used for all NEQ 1900 kg and below.
 - b. Internal Quantity Distance (IQD) to magazines/process buildings etc -Use greater of 300 m (main paper para 59.b.) or Reference I HD I.1 D10 table x 2.5. ($1900^{1/3} \times 8 \times 2.5 = 248$ m). As no other facility has an NEQ > 1900 kg, this 300 m IQD may be applied to all PES.
 - c. IQD to workshop - 300 m.

Magazines

4. Assume each magazine holds 900 kg NEQ except the isolation magazine which holds 500 kg NEQ. The magazines may also hold unproven and pre-stressed ammunition awaiting further testing. Therefore use the increased risk criteria discussed above.
 - a. PTR/IBD - 600 m - see main paper para 58.b.
 - b. IQD to other magazines = $2.5 \times$ Reference I HD I.1 D5 table = 35 m
 - c. IQD to other process buildings = $2.5 \times$ Reference I D10 table = 195 m, however a 300 m minimum applies - see main paper para 59.b. and paragraph 3.b. above.
 - d. IQD to workshop - 300 m.

Test Facilities 1-3

5. NEQ each 1000 kg.
 - a. PTRIIBD-600m
 - b. IQD to magazines/climatic chamber/WKSP/CNTRL - 300 m.
 - c. IQD to other test facilities - $2.5 \times$ Reference I HD I.1 D9A table = 106 m (test facilities may be considered grouped)

Radiography/Inspection

6. Lower risk area. NEQ = 320 kg.
 - a. PTR/IBD - 400 m Reference I HD I.1 D12x2.5 = 380 m but apply 400 m minimum.
 - b. IQD to all except breakdown facility - 300 m
 - c. IQD to especially constructed breakdown facility - 85 m. This facility is not used during remote breakdown operations otherwise the minimum separation criteria discussed above will apply. The 85 m distance provides blast, flame and ground shock protection to the radiographic equipment if an accident occurs at the breakdown bay. The assumption here is that radiography/inspection is hardened and is being used as the "control bunker" for breakdown. In this case operations will only be conducted at one facility at a time ie breakdown or inspection but not both together. This limitation may be unacceptable. If operations are to be conducted concurrently, the IQD to breakdown should be increased to 300 m. The use of a separate "bunker" from which to control breakdown should be considered.

Breakdown

7. NEQ = 70 kg. This is a specially constructed facility designed to funnel fragmentation either straight up or into a receptor traverse. This facility has a higher probability of accident therefore NEQ is reduced:

- a. PTR/IBD - 400 m. At this distance, over-pressure effects for an NEQ of 70 kg would be negligible and fragment density (depending on siting of the facility) tolerable.
- b. IQD to all but radiography and box store - 300 m
- c. IQD to radiograph - 85 m, see paragraph 6.c. above.
- d. IQD to box store >100 m fire protection only. An enhanced distance is provided due to the greater probability of accident during breakdown.

Box Store

8. Non explosive store but a fire risk therefore apply 25 m separation to all facilities except Breakdown where 100 m should apply due to the increased probability of hot fragmentation being ejected from the breakdown facility. The box store would normally be sited within the magazine area.

12 m Drop Tower & Tower "Bunker"

9. This is a range facility and is not sited within the ETF. The nominated 1000 kg gross ordnance mass is used as the basis of safety distance calculations. Demolition distances from Reference H should be applied if the hazard envelope is unknown. A distance of 2.59 km to all ES except the "bunker" is required. A bunker with observation ports (ie windows) should be at 1400 m, however it could be sited at 250 m if there are no observation ports and it is hardened against fragmentation.