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Guide for the destruction of stockpiled anti-personnel mines

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Foreword

International standards for humanitarian mine clearance programmes were first proposed by working groups at an international technical conference in Denmark, in July 1996. Criteria were prescribed for all aspects of mine clearance, standards were recommended and a new universal definition of 'clearance' was agreed. In late 1996, the principles proposed in Denmark were developed by a UN-led working group and the International Standards for Humanitarian Mine Clearance Operations were developed. A first edition was issued by the UN Mine Action Service (UNMAS) in March 1997.

The scope of these original standards has since been expanded to include the other components of mine action and to reflect changes to operational procedures, practices and norms. The standards were re-developed and renamed as International Mine Action Standards (IMAS).

The United Nations has a general responsibility for enabling and encouraging the effective management of mine action programmes, including the development and maintenance of standards. UNMAS, therefore, is the office within the United Nations responsible for the development and maintenance of IMAS. IMAS are produced with the assistance of the Geneva International Centre for Humanitarian Demining.

The work of preparing, reviewing and revising IMAS is conducted by technical committees, with the support of international, governmental and non-governmental organisations. The latest version of each standard, together with information on the work of the technical committees, can be found at <http://www.mineactionstandards.org/>. Individual IMAS are reviewed at least every three years to reflect developing mine action norms and practices and to incorporate changes to international regulations and requirements.

Introduction

Article 4 of the Anti-Personnel Mine Ban Convention (APMBC) (MBT) requires that signatories undertake to destroy or ensure the destruction of all stockpiled anti-personnel mines it owns or possesses, or that are under its jurisdiction or control, as soon as possible but not later than four years after the entry into force of the MBT for that State Party. The existing APM stockpiles tend to be large in quantity, but relatively small in terms of weight and Net Explosive Content (NEC); however, the destruction of these stockpiles can be a complex logistic operation.

The physical destruction techniques available range from the relatively simple Open Burning and Open Detonation (OBOD) techniques to highly sophisticated industrial processes. This IMAS seeks to inform national authorities only of the technical and logistic issues involved in Ant-Personnel Mine (APM) stockpile destruction. There are so many inter-relational factors involved in APM stockpile destruction that it is not possible to provide 'template solutions'.

The selection of the most suitable technique or technology by a national authority will depend primarily on the resources available, the physical condition and quantity of the stockpile, the national capacity and the applicable environmental and explosives legislation. The most influential factor is likely to be economies of scale, in that the more APM that are requiring destruction, the larger the economies of scale, and therefore the wider range of available technology. Consequently, national authorities may wish to consider APM destruction on a regional basis in order to achieve the large economies of scale.

Guide for the destruction of stockpiled anti-personnel mines

1. Scope

The purpose of this IMAS is to explain the background to the stockpile destruction of Anti-Personnel Mines (APM), explain UN policy, identify the technical factors of stockpile destruction and the available technology in order that informed decisions for the disposal of the stockpile elements can be made.

Although this IMAS provides guidance for the destruction of national stockpiles of APM, it does not cover the destruction of field stocks of APM that have arisen as a direct result of demining operations; these should be destroyed in accordance with the principles contained in IMAS 09.30.

This IMAS should be read in conjunction with IMAS 04.10, 09.30, 10.10, 10.50 and 11.20:

- a) IMAS 04.10 provides a complete glossary of all the terms, definitions and abbreviations used in the IMAS series of standards.
- b) IMAS 09.30 provides specifications and guidance for Explosive Ordnance Disposal (EOD).
- c) IMAS 10.10 covers the general requirements of Safety and Occupational Health (S&OH). These apply as equally to demilitarization operations as they do to demining operations.
- d) IMAS 10.50 provides specifications and guidance for the storage, transportation and handling of explosives.
- e) IMAS 11.20 covers the principles and procedures to be adopted for Open Burning and Open Detonation (OBOD) APM stockpile destruction operations.

2. References

A list of normative references is given in Annex A. Normative references are important documents to which reference is made in this standard and which form part of the provisions of this guide.

3. Terms, definitions and abbreviations

The subject of stockpile destruction can be technically complex and it is important to understand the terminology in current use. Often terms are used interchangeably, which leads to confusion.

Note: As an extreme example, but to make the point, the logistic disposal of APM does not necessarily mean that they have been destroyed; they could have been gifted from one non-signatory nation to another. The donor nation has then disposed of the ammunition, whilst not destroying it.

A list of terms, definitions and abbreviations used in this standard is given in Annex B. A complete glossary of all the terms, definitions and abbreviations used in the IMAS series of standards is given in IMAS 04.10.

4. Background

4.1. General

Stockpiled APM will rarely pose an immediate threat to human life, but they do provide the capability for the deployment of new minefields. The removal of this capability is therefore an important factor for the continuing success of the Anti-Personnel Mine Ban Convention (APMBC), and the reduction of the threat from landmines world-wide.

Note: Only in those circumstances where there is significant chemical instability of the explosive filling or a major fault in the fuzing mechanism will stockpiled APM pose an immediate threat to human life. Notwithstanding, they of course remain a hazard and must be stored and transported in accordance with international safety standards in order to reduce the risk of an undesired explosive event.

4.2. Core component of mine action

It was agreed at a meeting of the UN Inter-agency Co-ordination Group for Mine Action on 17 August 2000, that stockpile destruction be formerly incorporated as the fifth core component of mine action.

4.3. Legislation

4.3.1. Anti-Personnel Mine Ban Convention (APMBC) (MBT)

Within the APMBC there are specific requirements applicable to the State Parties for the destruction of stockpiled APM. The specific articles are reproduced below for ease of reference:

Note: Also referred to as the Ottawa Treaty, Ottawa Convention etc. The full treaty title to which these refer is the 'Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Landmines and their Destruction, Ottawa Convention, 03 December 1997'.

4.3.1.1. Article 4 – Destruction of stockpiled Anti-Personnel Mines (APM)

Except as provided for in Article 3, each State Party undertakes to destroy or ensure the destruction of all stockpiled anti-personnel mines it owns or possesses, or that are under its jurisdiction or control, as soon as possible but not later than four years after the entry into force of this convention for that State Party.

Note: Article 3 relates to the retention of APM for training in, and the development of, mine clearance techniques.

4.3.1.2. Article 6 – International cooperation and assistance

6(1) *In fulfilling its obligation under this convention, each State Party has the right to seek and receive assistance, where feasible, from other States Parties to the extent possible.*

6(2) *Each State Party undertakes to facilitate and shall have the right to participate in the fullest possible exchange of equipment, material and scientific and technological information concerning the implementation of this Convention. The States Parties shall not impose undue restrictions on the provision of mine clearance equipment and related technological information for humanitarian purposes.*

6(5) *Each State Party in a position to do so shall provide assistance for the destruction of stockpiled anti-personnel landmines.*

4.3.1.3. Non-signatory nations

Notwithstanding the provisions of the APMBC, there may be cases where non-signatory countries seek assistance from the UN with stockpile destruction, and it is appropriate for this to occur. There are already examples of non-signatory nations receiving bi-lateral assistance in this area.

4.3.2. International legislation

At the United Nations level, all work related to the transport of dangerous goods is co-ordinated by the Economic and Social Council (ECOSOC) Committee of Experts on the Transport of Dangerous Goods, which produces the 'Recommendations on the Transport of Dangerous Goods', also called the 'Orange Book'.

These Recommendations and Regulations are addressed not only to all Governments for the development of their national requirements for the domestic transport of dangerous goods, but also to other interested international organisations, (see below).

4.3.2.1. International Standards Organisation (ISO) Series 4200

The ISO 4200 series, whilst not specifically legislation, lays down internationally accepted standards for the determination and measurement of air pollution from industrial processes. These standards will apply to any pollution control systems used during industrial demilitarization operations (<http://www.iso.ch/>), but only in terms of the measurement of emissions as the standards do not provide any guidance on what the overall emission limits should be; this remains the responsibility of the national authority.

The only supra-national legislation that covers emissions into the atmosphere from the incineration of hazardous waste is the European Union Council Directive 91/689/EEC of 12 December 1991 on hazardous waste. These provide a comprehensive standard and are in use by all European Union countries and those countries with associate status. Further information on the background and contents of this directive may be found on the EU website at <http://europa.eu.int/scadplus/leg/en/lvb/l21199.htm>.

4.3.2.2. ISO 9612 (1997) - Acoustics

ISO 9612:1997 - 'Guidelines for the measurement and assessment of exposure to noise in a working environment' could be applied to open detonation destruction operations.

4.3.2.3. Movement of APM by sea or air

There are three major international regulations or codes of practice that relate to the movement of APM across international borders by sea or air:

- a) International Maritime Organisation (IMO), International Maritime Dangerous Goods (IMDG) Code. (<http://hazmat.dot.gov/imdg.htm>).
- b) International Air Transport Association (IATA) Dangerous Goods Regulations. (<http://www.iata.org/cargo/dg/>).
- c) International Civil Aviation Organisation Technical Instructions, Part 4, Chapter 1. (<http://www.icao.int/index.html>).

4.3.3. Movement of APM by road

The movement by road of APM is a complex issue dependent on what area of the world the demilitarization operation is to take place. In Europe, for example, the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) applies. A summary of this treaty, which illustrates the dangers and risk reduction measures to be implemented can be found at <http://www.unece.org/trans/danger/publi/adr/intro.htm>.

The UN have issued United Nations Recommendations on the Transport of Dangerous Goods Model Regulations (*Eleventh revised edition*). Details of how to obtain this publication can be found at <http://www.unece.org/trans/danger/publi/unrec/pubdet.htm>.

4.3.3.1. Storage of APM

There are no specific international regulations or codes of practice that relate directly to the safe storage of ammunition and explosives, this is a national responsibility.

However, international alliances do have consolidated literature that covers this technical area. An excellent example is the NATO Allied Ammunition Storage and Transportation Publications 2 (AASTP 2) - Safety Principles for the Storage and Transport of Military Ammunition and Explosives.

A system for the classification of explosives for storage and transportation is included in Annex G to IMAS 10.50 – Storage, transportation and handling of explosives.

4.3.4. National legislation

The safe movement of dangerous goods, such as APM, within national borders is a national responsibility and national legislation will apply. A good example of such legislation, which those responsible for the movement of APM may wish to consult for information purposes, is the United States Department of Transport Code of Federal Regulation 49 (49CFR). (<http://www.dot.gov/rules.htm>).

4.4. Technical considerations

In terms of stockpile destruction, APM are no different to other types of munitions. They all contain fuze systems and high explosives, so the inherent dangers present during transport, storage, processing and destruction are the same. For this reason, it is recommended that the stockpile destruction of APMs should not be looked at in isolation. The technical factors are the same for the destruction of all types of ammunition, therefore, where appropriate, consideration should be given for the destruction of these different types in parallel to APM; it may prove to be beneficial in some cases. The supporting logistic and support services will remain similar for all ammunition types.

Note: For example, the destruction of APM could be done in conjunction with the disposal of large calibre artillery shells. These can then act as donor charges for the APM, thereby reducing the costs of serviceable explosives during Open Detonation (OD) disposal operations.

There are many differing techniques and technologies available for APM destruction. The selection of the most suitable technique/technology will depend primarily on available finance, the condition of the stockpile, the in-country capacity and the extant environmental legislation of the State concerned. In Europe, many nations have banned OBOD of all munitions, unless there is no alternative and that can only be justified on safety grounds. This has necessitated the construction of expensive demilitarization facilities, hence the requirement for the disposal of ammunition types other than APM and the necessity for economies of scale if pursuing this option. The argument as to the environmental effect of OBOD is still ongoing, and sound scientific evidence has been developed to support a case that OBOD of certain APM types may not be all that damaging to the environment. This means that OBOD still remains a viable destruction option for APM, and may well be the most suitable option for those areas of the world, such as Africa and Asia, with virtually no industrialised demilitarization capacities.

Note: There is often spare demilitarization capacity with commercial companies in Europe and the USA. The NATO Maintenance and Supply Agency (NAMSA) can advise on this disposal option. The costs of demilitarization of APM range from US\$2 to US\$4 each, dependent on the type.

4.5. Advantages and disadvantages of industrial demilitarization

Industrial scale demilitarization has many advantages; mechanical disassembly, incineration in environmentally controlled systems and the ability to operate 24 hours a day, 365 days a year. Their major disadvantage is the high capital set up costs of design, project management, construction and commissioning. Their operating costs are generally lower than OBOD (once amortisation of the development capital is discounted); but it should not be forgotten that the high labour costs in developed countries accounts for a large percentage of the OBOD costs. Notwithstanding this, OBOD can be a cheaper option dependent on the economy of scale. In the US, for example, average OBOD costs are \$US 850 per tonne, whilst industrial demilitarization is \$US1180 per tonne; but it must be recognised that these costs are for all ammunition types, not just APM.

In many cases the development of such purpose built demilitarization facilities to enable State Parties to fulfil their obligation for stockpile destruction will be well beyond available resources and therefore may not be a practical option. Factors such as cost, location and safety may mean that OBOD is the only pragmatic and feasible option. The advantages, disadvantages and environmental implications of OBOD are discussed in Annex G.

4.6. Traditional disposal options for ammunition

There were traditionally five options for the logistic disposal of ammunition and explosives, however, in the case of APM four of these options are banned by international treaty. The MBT itself precludes sale, gift or increased use of APM at training whilst the Oslo Convention now bans deep sea dumping. Therefore, the international community is now left with destruction as the only available option for the disposal of APM.

5. The demilitarization cycle

It must be remembered that the physical destruction process of APM is only one process of the complete demilitarization cycle. The processes in this cycle must be considered in parallel with the technical factors, (see clause 6), before a final disposal solution is produced. The demilitarization cycle is complex, comprehensive, wide-ranging and includes activities such as transportation and storage, processing operations, equipment maintenance, staff training and accounting. The full demilitarization cycle is shown schematically at Annex C.

6. Technical factors

The following factors should be considered before determining the most suitable destruction technique or system to be used for a particular nations' stockpile:

6.1. National legislation

Details of applicable legislation can be found in clause 4.3. Environmental legislation will dictate the emission levels to be met, which will in turn dictate the type of technology required to meet these emission levels. Should this technology be too expensive, then agreement needs to be reached with the environmental authorities for an exemption.

6.2. Chemistry of explosives

The stability in storage and degradation or deterioration rates of the explosive content will influence the degree of urgency for disposal, type of transport that can safely be used and destruction methodology.

6.3. Knowledge of munition design

A detailed knowledge of the munition design is essential to the formulation of a safe destruction plan. This knowledge should also include the type and rate of evolution of gases should a thermal destruction technique be under consideration.

6.4. Quantity for disposal

The most influential factor is likely to be economies of scale, in that the more APM that are requiring destruction, the larger the economies of scale and therefore, the wider range of available technology at an affordable price. Consequently, national authorities may wish to examine the problem of APM destruction on a regional basis in order to achieve the large economies of scale.

6.5. Available technology

Annex D contains a synopsis of current industrial demilitarization technologies, whilst Annex G addresses the issue of OBOD.

6.6. Safe systems of work

Safe systems of work are a pre-requisite when handling and processing any types of ammunition and explosives. IMAS 10.10 - Safety and occupational health - General requirements should be followed by all APM destruction implementing agencies.

6.7. Production rates

The requirement within the MBT for a signatory to destroy its stockpile of APM within four years of ratification will dictate the production rates that have to be achieved.

6.8. Security

Stockpile security is obviously an important issue. Every effort must be taken to ensure the physical security of APM during storage, transportation and processing.

6.9. Logistics

It can be argued that stockpile destruction is primarily a logistics problem. The technology exists to destroy the vast majority of APM, yet the major phases of the demilitarization cycle involve logistics. The destruction methodology will be dependent on logistic factors such as 1) the availability of suitably qualified and trained manpower; 2) location and type of ranges and demolition grounds; 3) the availability of transport and; 4) the availability of water supply, power etc.

6.10. Commercial versus military disposal method

Traditionally the military are usually responsible for the destruction of APM using OBOD techniques, whilst civilian companies utilise the industrial demilitarization option. The availability, or not, of qualified manpower may have a significant influence on the destruction technique to be used.

6.11. Transparency and accounting

The transparency of the destruction programme is an important security and confidence building measure. International organisations, national ambassadors, media and non-governmental organisations (NGO) should be invited to witness the destruction process. They should also be given access to the ammunition account for APM in order that they can verify the APM destroyed against the declared stockpile levels.

6.12. Disposal of residue

Certain destruction techniques result in the production of 'special' or 'hazardous' waste, which itself requires destruction or disposal in an environmentally benign manner. This is usually done by a specialist environmental disposal company.

6.13. Scrap salvage

The salvage of metallic scrap, or explosive waste, can result in an income stream. Some explosive fillings of APM may be useful to the commercial explosive industry, whilst scrap steel is always in demand.

6.14. The requirement for destruction with other ammunition types

Consideration should be given to the destruction of other ammunition types in parallel to the APM; it may prove to be beneficial in some cases, (see clause 4.4). The supporting logistic and support services remain similar for all ammunition types. Major costs savings could be made if this approach was explored, and there are the obvious security and confidence building advantages to be considered.

6.15. Financial factors

This is probably the most important factor, 'how much is a government prepared to spend to ensure the environmentally benign and safe destruction of its APM stockpile?'

7. World demilitarization capability

Industrial demilitarization activity for the full range of ammunition natures is taking place in many countries throughout the world, whilst some examples of OBOD operations exist in developing countries.

It would not be appropriate to include contact details of these, mainly commercial organisations, in this IMAS, however contact details and a indication of the capabilities of known enterprises are included in the UN Stockpile Destruction website at <http://www.mineaction.org/>. It must be emphasised that the inclusion of a specific company's details in this website is not an endorsement of their capability by the UN. Details are included in the website to enable State Parties to have access to the widest possible range of advice and options for stockpile destruction during the preparation of their destruction plan.

Note: The authors of the UN Stockpile Destruction website do not claim that this is necessarily an exhaustive list of all demilitarization companies. It has been compiled from consultation and an extensive literature search. The details will be continually updated and other demilitarization organisations should contact the Webmaster to ensure that they are included

The website covers four main groups of demilitarization expertise that can be consulted by national authorities for advice:

- a) international organisations;
- b) demilitarization advice and consultancy;
- c) demilitarization equipment manufacturers; and
- d) operational demilitarization facilities.

8. Policy and responsibilities

8.1. UN organisations

8.1.1. UNMAS responsibilities

The UNMAS is the focal point within the UN system for all mine-related activities. In this capacity, it is responsible for ensuring an effective, proactive and co-ordinated UN response to stockpile destruction. UNMAS, in consultation with other partners, can provide the following assistance in this area:

- a) establish priorities for assessment missions;
- b) facilitate a coherent and constructive dialogue with the donor and international communities on the issue;
- c) co-ordinate the mobilisation of resources;
- d) the development, maintenance and promotion of technical and safety standards;
- e) technical advice;
- f) training; and
- g) The maintenance of a demilitarization technology database.
<http://www.mineaction.org/>

8.1.2. UNDP responsibilities

The UNDP Mine Action Policy Statement (dated 18 December 1998) requires *'the development of integrated, sustainable national/local mine action programmes'*. The main principles of the policy statement relate as equally to stockpile destruction as they do to all other aspects of mine action. UNDP could assist in the development of national capacities and capabilities for stockpile destruction. Such assistance could take the form of:

- a) the development of national capacities for stockpile destruction;
- b) provision of support to sustainable stockpile destruction initiatives or programmes; and
- c) resource mobilisation and donor co-ordination for UNDP initiatives under sub-clauses a) and b) above.

8.2. National authorities

The national authority is ultimately responsible for all aspects of the safety and security of the APM whilst in the national stockpile. They should ensure that effective management and physical security processes are in place to safeguard the APM stockpile.

They should ensure that the proposed demilitarization implementing agency comply with all appropriate national (and where applicable, international) legislation for the storage, transport and handling of explosives.

The national authority is responsible for all aspects of APM stockpile management, and therefore shall fulfil the management function of stockpile destruction planning. This shall include recognised procedures for the transfer of safety and security responsibility (but not APM ownership) to the destruction implementing agency.

The national authority should be content that the selected destruction technique is as environmentally benign as is reasonably practicable.

8.3. Donors

Donor agencies are part of the management process, and as such have some responsibility for ensuring that the projects they are funding are managed effectively, and in accordance with international standards. This may involve strict attention to the writing of contract documents, and ensuring that the demilitarization organisations chosen to carry out such contracts meet the accreditation criteria within their parent country. This responsibility and accountability is even greater when the national authority is inexperienced in demilitarization operations.

8.4. Implementing agencies

The implementing agency assumes responsibility for all aspects of the safety and security of the APM stockpile on arrival at the agency's storage location. They should demonstrate this to the national authority, and apply it throughout the destruction project.

Note: Safety and security on route from a national to an implementing agency storage location is a national responsibility.

The implementing agency should provide timely and accurate information to the national authority throughout the project as to the destruction rate being achieved.

The implementing agency is responsible for explosive safety during all phases of the demilitarization cycle, (less transport from the national base depot to their own storage location). They shall demonstrate that they have planned and subsequently practice safe systems of work in order to reduce the risk to the work force to as low as is reasonably practicable. In doing so, they should comply with all relevant national explosive safety and environmental legislation.

The implementing agency shall recruit, train and maintain the appropriate staff to conduct AP demilitarization and destruction operations.

Annex A (Normative) References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this part of the standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of the standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid ISO or EN:

- a) IMAS 04.10 Glossary of mine action terms, definitions and abbreviations;
- b) IMAS 09.30 Explosive ordnance disposal;
- c) IMAS 10.10 S&OH - General requirements;
- d) IMAS 10.50 S&OH - Storage, transportation and handling of explosives;
- e) IMAS 11.20 Principles and procedures for OBOD operations; and
- f) IMAS 11.30 National planning guidelines for stockpile destruction.

The latest version/edition of these references should be used. GICHD hold copies of all references used in this standard. A register of the latest version/edition of the IMAS standards, guides and references is maintained by GICHD, and can be read on the IMAS website: (See www.mineactionstandards.org). NMAA, employers and other interested bodies and organisations should obtain copies before commencing mine action programmes.

Annex B (Informative) **Terms, definitions and abbreviations**

B.1.

demilitarization

the process that renders munitions unfit for their originally intended purpose.

Note: Definition from NATO Maintenance and Supply Agency (NAMSA), Peter Courtney-Green, May 2000.

B.2.

destruction

the process of final conversion of munitions and explosives into an inert state whereby they can no longer function as designed.

B.3.

Explosive Ordnance Disposal (EOD)

the detection, identification, evaluation, render safe, recovery and disposal of Explosive Ordnance (EO). EOD may be undertaken:

- a) as a routine part of mine clearance operations, upon discovery of the UXO.
- b) to dispose of UXO discovered outside mined areas, (this may be a single UXO, or a larger number inside a specific area).
- c) to dispose of EO which has become hazardous by deterioration, damage or attempted destruction.

B.4.

logistic disposal

in the context of mine action, the term refers to the removal of munitions and explosives from a stockpile utilising a variety of methods, (that may not necessarily involve destruction). Logistic disposal may or may not require the use of RSP.

B.5.

Render Safe Procedure (RSP)

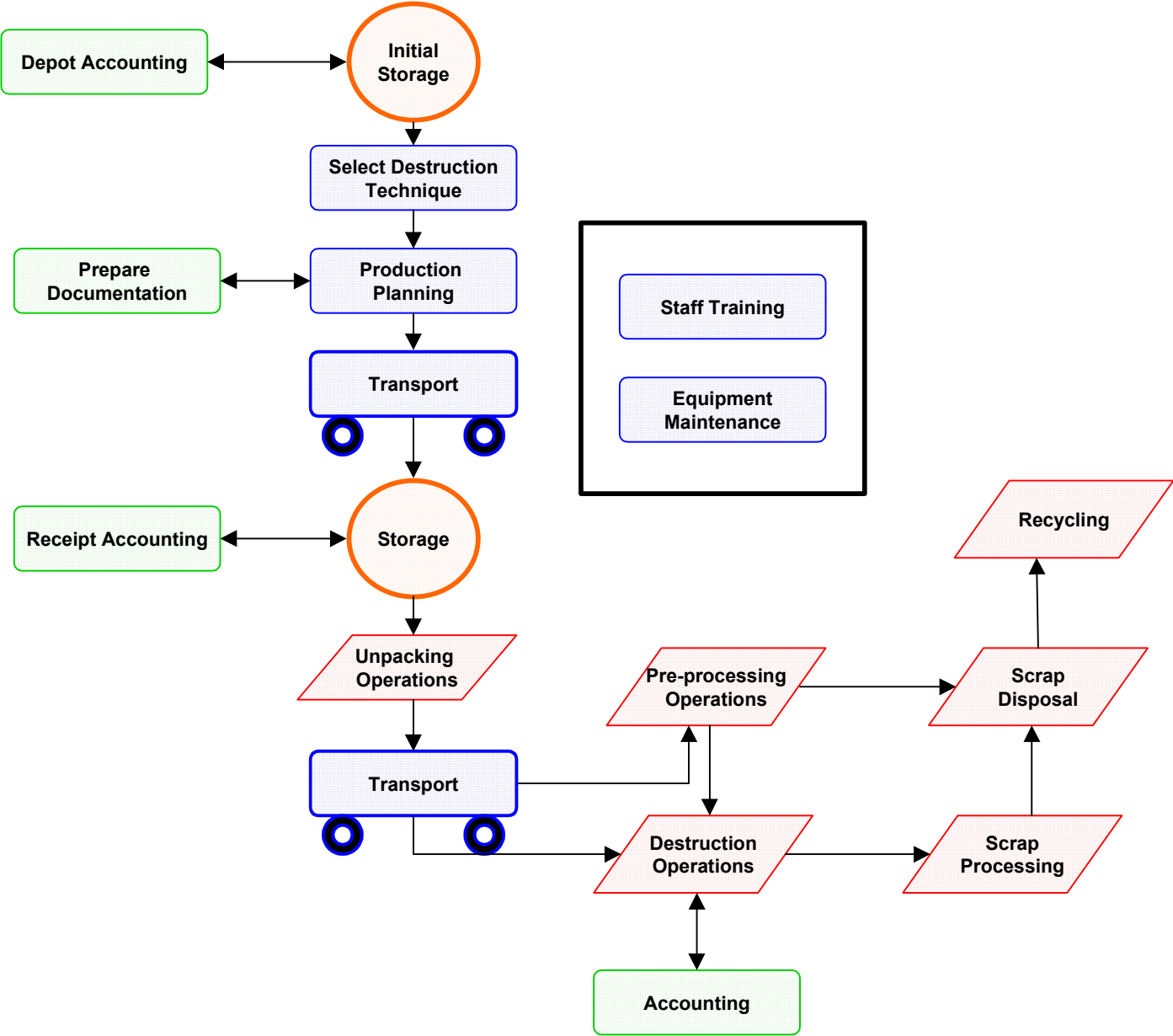
the application of special EOD methods and tools to provide for the interruption of functions or separation of essential components to prevent an unacceptable detonation.

B.6.

Unexploded Ordnance (UXO)

EO that has been primed, fuzed, armed or otherwise prepared for use or used. It may have been dropped, fired, launched or projected yet remains unexploded either by malfunction or design or for any other reason.

Annex C (Informative) The demilitarization cycle



Annex D (Informative) Industrial demilitarization technologies

D.1. Pre-processing operations

D.1.1. General

It may be necessary to disassemble or breakdown APM prior to the destruction process. This is necessary because of limitations on the amount of contained explosive that can be incinerated, the APM design or the requirement for different components to have separate destruction methods. All of these methods require the movement of exposed bare explosive to the final destruction facility.

Note: There are numerous other pre-processing technologies available, or under development, in the international industrial demilitarization industry, but these are unsuitable for the pre-processing of APM and have therefore not been included. These technologies include laser cutting and microwave explosive meltout, which are only really suitable for higher calibre munitions.

Available technology includes:

SER	TECHNOLOGY	REMARKS
(a)	(b)	(c)
1	Manual Disassembly	
2	Mechanical Disassembly	Pull Apart, Defuzing and Depriming.
3	Robotic Disassembly	
4	Mechanical Breakdown	Bandsaw, Guillotine, Cracker Mill, Rock Crusher, Punch
5	Cryofracture	
6	Hydro Abrasive Cutting	

D.1.2. Manual disassembly

The use of human resources to physically dismantle APM by manual labour using simple hand tools.

D.1.2.1. Advantages

Limited capital investment required.

D.1.2.2. Disadvantages

Manual disassembly is labour intensive, results in relatively slow production rates and requires well-trained, yet semi-skilled staff.

D.1.3. Mechanical disassembly

The use of mechanically operated systems to dismantle APM. Some of the available technologies are available as shown in the table at clause D.1.1 above, but systems tend to be specifically designed to deal with each different type of munition.

D.1.3.1. Advantages

In contrast to manual disassembly, mechanical disassembly has the advantages of high production rates, it is an efficient system of work and has low staff requirements. It is environmentally friendly for this stage of the demilitarization cycle and the technology is readily available.

D.1.3.2. Disadvantages

A major disadvantage is the requirement for high capital investment. This is further complicated by the need for a wide range of equipment necessary to cope with all pre-processing requirements.

D.1.4. Robotic disassembly

A fully automated disassembly system. Similar advantages and disadvantages to mechanical disassembly, however the initial capital costs are much greater. This system would only be economically efficient for very large production runs due to the high start-up costs.

D.1.5. Mechanical breakdown

This process is mainly concerned with techniques required to expose the explosive fillings of APMs prior to the destruction phase.

D.1.5.1. Advantages

There are low staff requirements for mechanical breakdown, and it is an environmentally friendly operation during this stage of the demilitarization cycle. The technology is now readily available and there is no secondary waste stream, which reduces scrap salvage and disposal costs.

D.1.5.2. Disadvantages

A major disadvantage is the requirement for high capital investment. This is further complicated by the need for a wide range of equipment necessary to cope with all pre-processing requirements. Production rates per machine can be slow and there is always the danger of induced initiation of the target APM during processing.

D.1.6. Cryofracture

This process is used to break down an APM into small enough pieces to be processed through an incineration destruction method. It involves the use of liquid nitrogen to change the mechanical properties of the munition casing to a more brittle phase by cooling it to -130°C . The munition can then be easily shattered using simple mechanical shear or press techniques.

D.1.6.1. Advantages

Cryofracture is an environmentally friendly technique during this stage of the demilitarization cycle with low staff requirements. The technique can also be used for any other type of munition, explosive or propellant with limited pre-preparation of the munition required. There is no secondary waste stream, hence cutting final disposal costs. In financial terms, low capital investment only is required for set up costs. Sensitivity tests have shown that even at -196°C there is little change to the insensitiveness of the munition.

D.1.6.2. Disadvantages

The disadvantage of high operating costs for liquid nitrogen usage must be considered and unfortunately, today there are only one or two proven production systems in place. APMs with metal or aluminium casings are susceptible to embrittlement but variations in the shear forces or pressures are required to fracture the munition casing. Further trials are necessary, as analysis has shown that the failure modes for the munition casings involved a mixture of brittle fracture, plastic deformation and shearing. Results are currently unpredictable and there is an obvious low temperature hazard to personnel.

Notwithstanding these disadvantages, cryofracture is being successfully used in wider scale demilitarization operations with great success.

D.1.7. Hydro Abrasive Cutting (HAC)

The use of water and abrasives at pressures from 240 to 1000 BAR to cut open APM bodies by an erosive process. There are two distinct technologies; 1) 'entrainment' or 2) 'direct injection'. Research has now proven that the direct injection technology should be the preferred option for safety reasons.

D.1.7.1. Advantages

There are low staff requirements for HAC systems and a wide range of target munitions can be attacked. The explosive safety of systems is well proven and it is a cost-effective technique in comparison to other pre-processing methods.

D.1.7.2. Disadvantages

The major disadvantage is the requirement for initial high capital investment for infrastructure. The systems also produce contaminated waste-water, which requires a complex filtration system to clean it up. In terms of post-process operations, the explosive content is 'grit sensitised' and requires careful handling during any further processing or destruction.

D.2. Destruction technology

D.2.1. General

There are a wide range of industrial technologies available for the final destruction of APM. The selection of the most suitable principle depends primarily on the pre-processing techniques to be utilised, and vice versa. The system must be designed to result in efficient production rates.

Note: There are numerous other destruction technologies available, or under development, in the international industrial demilitarization industry, but these are not yet developed to the stage where they are suitable for the destruction of APM and have therefore not been included. These technologies include 'Silver I', biodegradation and molten salt oxidation, which are only really suitable for higher calibre munitions at this stage of their development.

Available technologies include:

SER	TECHNOLOGY	REMARKS
(a)	(b)	(c)
1	Incineration	Open Pit, Rotary Kiln, Hearth Kiln, Car Bottom Furnace, Directly Heated Retort.
2	Plasma Arc	
3	Mechanical	Guillotine
4	Contained Detonation	

D.2.2. Open pit incineration

Waste material is placed on a tiled floor in a purpose built pit equipped with perforated air pipes to supply forced air to the system. A turbulent air current is created above the fire that recirculates the combustion gases and particulates, which assists in full oxidation of the evolving gases. The principle has been tested, but no large-scale trials have yet being conducted.

D.2.3. Rotary kiln incineration

This is perhaps the most common, and certainly most mature demilitarization destruction technology available. Therefore, full details on Rotary Kiln technology can be found at Annex E.

D.2.4. Car bottom furnace

Used to destroy small amounts of explosive or explosive residue left after flush-out pre-processing techniques. It can also be used to destroy explosively contaminated packing material etc.

D.2.5. Directly heated retort

Thin walled and ceramic lined. Feed system uses an auger. Pre-processed by a crusher. Used to process general chemical waste and explosive in solution. A typical production rate of 10,000 tonnes per year.

D.2.6. Plasma arc incineration

A Plasma torch, at temperatures in the region of 4000⁰C to 7000⁰C, is used to heat a container into which waste products are fed. The plasma is an ionised gas at extremely high temperature, which is used to initiate rapid chemical decomposition by the action of this extreme heat. The material is currently fed in a slurry form, although research is ongoing for the destruction of entire munitions. It is a complex production system that has a high power requirement. Full details can be found at Annex F.

D.2.7. Mechanical

The use of high strength and capacity commercial crushing or shredding machines. Only suitable for APMs with a very low net explosive content. Selection of this option would require some statistically significant trials, prior to the development of a formal risk assessment for its suitability for a particular type of APM.

D.2.8. Contained detonation

The destruction of ammunition and explosives by detonation in an enclosed chamber. The evolving gases are then processed by an integral pollution control system.

D.2.8.1. Advantages

Limited pre-processing is required and a wide variety of ammunition natures can be destroyed.

D.2.8.2. Disadvantages

The available systems are currently limited to 15 Kg NEC. There is also a requirement for a donor charge for each detonation, therefore the process is expensive in serviceable ammunition usage.

Note: A Norwegian company has a unique contained detonation system whereby it utilises old mineshafts at depths of 1000 metres. There is no integral pollution control system, but the emissions are filtered by the rock strata and water. Ground pollution is very limited and falls within European Union limits. The permitted explosive limits are high, but such a system relies on the unique geology and geography of Norway and would be difficult to replicate.

D.3. Pollution Control Systems (PCS)

D.3.1. General

There are a number of pollution control technologies available, but an effective system requires a combination of these technologies. The technologies that follow are currently in use in different demilitarization facilities around the world.

All PCS must have the capability to interface with the incineration system and process all gases arising from kilns. They must remove Volatile Organic Compounds (VOC), particulate matter, acid gas, heavy metals and prevent or reduce dioxin formation.

D.3.2. Afterburning

The afterburning process oxidises entrained organic compounds, ash and metal fragments. In order to achieve this, it must operate above 850⁰C for over 2 seconds to destroy VOC; the VOC then burn to CO₂, H₂O and acid gas. All organic particulate is destroyed. The oil consumption rate of 15 kg per hour is a factor when considering operating costs.

D.3.3. Quench cooling

There is a requirement to cool hot gases after the afterburner before they flow into the next stage of the PCS. This is required so as to protect the usually steel structure from heat treatment effects that could weaken it. The system cools the gas flow from 1200⁰C to 500⁰C by the injection, then subsequent evaporation, of water at a rate of 400 litres per hour.

D.3.4. Acid gas adsorption

Sodium Bicarbonate used as the medium. It operates effectively over a wide temperature range and produces a safe and inert solids such as Sodium Chlorate (common salt), Sodium Sulphate and Sodium Nitrate for disposal. It reacts well with NO_x and is readily available.

The Sodium Bicarbonate reacts with the acid gas in the constantly renewing fixed bed formed on the ceramic filtration rods. (See later).

D.3.5. Ammonia injection

Assists in the NO_x reduction and is injected into afterburner.

D.3.6. Activated carbon adsorption

Required for adsorption of Hg. The process gas is drawn through a bed of activated carbon granules for a gas residence time of just less than 3 seconds. The fixed bed requires renewal on a bi-annual basis.

D.3.7. Dry ceramic filtration

Dry ceramic filtration is now regarded as one of the most efficient filtration systems currently available. It has the capability to remove particulate matter down to one micron. The filter also supports a bed of sorbent for gas adsorption. These filters are generally 1.0 m x 0.06 m and there are typically 256 filter elements in a system, giving a filtration area of 48 m².

D.3.8. Baghouses

USA alternative to Dry Ceramic Filtration. It is difficult to achieve either US state or EU pollution legislation levels. Cheap technology, but now very dated.

D.3.9. Fluid bed

The adsorber section of the fluid bed system includes a series of perforated plate adsorption trays. Contaminated process exhaust enters from the bottom, passing upward through the adsorption trays, fluidising the adsorbent and adsorbing the VOCs. VOC saturated adsorbent flows to the bottom of the adsorber vessel, from which it is removed at a slow, steady rate and transferred to the desorber. Meanwhile, regenerated adsorbent is continuously fed into the top of the adsorber vessel, providing counter-current VOC removal.

In the desorber, the temperature of the adsorbent material is increased, causing it to release the VOC contaminants into a low volume, inert carrier gas stream. The cleaned adsorbent material is then returned to the top of the adsorber vessel for reuse.

The concentrated contaminant stream is so small that it can often be easily treated with a simple afterburner or recovered for reuse or disposal through condensation

D.10. On-line monitoring

This must be fully auditable by national authorities. It works on these basic detection principles:

- | | | |
|----|--------------------|------------------------------------------|
| a) | IR absorption | (CO, NO _x , H ₂ O) |
| b) | Tribo-electric | (Particulate) |
| c) | Flame ionisation | (VOC) |
| d) | pH of solution | (HCl, HF) |
| e) | Velocity | (Flow Rate) |
| f) | Zirconia Electrode | (O ₂) |
| g) | Thermocouple | (Temperature) |
| h) | Pressure | (Diaphragm Strain) |

It also requires data processing system to calculate and display emission rates, concentration and history.

D.4. Scrap processing

The final disposal of arisings from any of the above systems will require some form of scrap processing facility. Commercial advice is required in this area to determine the production rates, technical capability and availability of systems.

Industrial scrap processing systems work by crushing, shredding, cracking or compressing the feed material into an easily manageable form for further salvage or recycling processes. There may be a requirement for a combination of techniques for scrap that is difficult to process.

Safe systems of work shall be implemented to ensure that there is no way that explosively contaminated components or scrap can pass into public hands.

Annex E

(Informative)

Rotary kiln technology

E.1. General description

The rotary kiln is an unlined rotary furnace originally designed to destroy small arms and bulk explosives. The kiln is made up of four 1.6 metre long, 1 metre outer diameter retort sections bolted together. The 6 to 8 cm thick walls of the kiln are designed to withstand small detonations. The kiln contains internal spiral flights, which move the waste in an auger-like fashion through the retort as the kiln rotates. The flights also provide charge separation for the in-process materials, and discourage sympathetic detonations and scattering of materials. The kiln is equipped with a variable speed drive, which allows varying rotation speeds and material residence time.

E.2. Construction

E.2.1. Burner

The burner is a combination proportioning burner designed to operate on either fuel oil, natural gas or propane. Combustion air is provided to the burner by a direct drive turbo blower.

E.2.2. Retort and trunnion assembly

The EWI support components consist of the retort, frame, trunnion, feed and discharge systems, and variable speed drive. The retort assembly rests on trunnion assemblies. The trunnion assembly consists of four rollers mounted on shafts, and pillow block bearings bolted to brackets on the frame. Rotation of the retort is accomplished by friction between the kiln flanges and drive rollers. The variable speed rotation drive motor is connected by a shaft and a sprocket/roller chain to the drive rollers. End sections are installed to match with the feed and discharge assemblies. Two thrust roller assemblies restrict the longitudinal travel of the retort on the trunnion assemblies. Thermal expansion is provided for by the gaps between the rotating portion and stationary portions of the rotary kiln.

E.2.3. Frame and feed assembly

The frame assembly is constructed to support the trunnion assemblies, variable speed drive motor, retort assembly, feed and discharge assemblies. The feed assembly is installed on one end of the frame assembly. The feed assembly supports the feed chute, the feed conveyor, and the furnace exhaust stack. Doors in the feed assembly permit interior inspection of the furnace retort and positive feed system charging into the retort. The discharge assembly directs treated materials from the retort assembly onto the discharge conveyor.

E.2.4. Control systems

The main control panel is located in the feed room. The control panel allows for adjustments of kiln and afterburner fuel flow rates, combustion air flow rates, and kiln rotation speeds. The panel also monitors system draft pressures and system temperatures. An Auxiliary Control Panel is located on the support stand near the burner assembly. The Auxiliary Control Panel provides local control of the burner while making initial adjustments as well as during maintenance.

E.2.5. Temperature control

Two thermocouples continuously record furnace temperatures. The first thermocouple, located at the base of the exhaust stack (feed end), provides a reference temperature to the controller to maintain the preset operating temperature. The temperature preset may be changed with each feedstock, if required. The other thermocouple, located immediately above the burner flame, provides a reference temperature at the burner end of the furnace.

A flame detector senses the presence of flame at the burner. Upon flame failure, the sensor causes a flame-safeguard unit in the control panel to close the fuel solenoid valve, shutting off fuel flow to the burner. It also activates visible and audible alarms at the control panel, and signals the local controller of the fault.

E.2.6. Feed systems

Two feed systems can be utilised depending on the anticipated feed streams: the standard feed conveyor and the positive feed system.

E.2.6.1. Standard feed system

The standard feed conveyor system consists of an inclined pan conveyor, which moves items from the feed room through a reinforced concrete barricade wall to an elevated location above the feed chute. Items drop off the conveyor end and slide by gravity down a feed chute into the first section of the rotary kiln. The standard feed conveyor system is simple, rugged, well-controlled, safe and requires little training or maintenance.

E.2.6.2. Positive Feed System (PFS)

The positive feed system feeds bulk granular and powdered explosive materials into the kiln by injecting containers of these materials by use of a ram. The PFS can also be used to feed sheared or punched items if spilling explosives or dust are concerns. Open-top steel pans or consumable boxes can be fed with this system. The PFS eliminates the chance of explosive propagation back to the loading point, and positively controls the feed rate to ensure that only one container may be placed in the furnace at any one retort spiral flight spacing.

E.2.7. Discharge systems

Metal components from configured items or small arms are discharged from the furnace onto the discharge conveyor. The discharge conveyor transports this material through a hole in the reinforced concrete barricade wall to a discharge point outside the wall.

Annex F (Informative) **Plasma arc technology**

F.1. General

Plasma arc technology has been around since the 1960's. The technology was originally developed for and used by the aerospace industry for the simulation of re-entry conditions on space vehicles. The technology was then picked up by the speciality metals business and used for the development of high purity metal components. During the late 1980's, the U.S. Government funded considerable research in applying the technology to the most difficult to treat waste produced by our society. These wastes included nuclear waste, very toxic chemical waste, and excess military ordnance. Elsewhere in the world other governments and organisations were also in the process of applying plasma technology to the treatment of these wastes.

The interest in the technology arises from the high temperatures capable of being produced by the technology. These high temperatures, in the order of 12,000 F, are sufficient to melt any inorganic compound and thoroughly destroy any organic constituents. The effluent streams resulting from a plasma treatment system are also much more benign than currently used technology. The resulting slag has been proven very benign and non-leachable. In addition to the resulting slag, the emissions resulting from plasma arc technology are much less than resulting from a fossil fuel fired system. Plasma technology gas volume emissions, are typically 10% of a comparable fossil fuel fired system and emission have been proven to meet even the most environmental standards and regulations. In addition to the environmental and operational benefits listed, the U.S. Army has also found that the operational cost associated with a plasma system for the destruction of ordnance are comparable to those of the standard 1236 deactivation furnace.

Because of the advantages associated with the technology, the U.S. Army has contracted with MSE to build two separate plasma treatment systems for the disposal of energetics. The first was a fixed facility to be used for the destruction on pyrotechnic devices as well as other materials. This facility will be installed at the Hawthorne Army Depot in Hawthorne Nevada. The second was a transportable system to be used for energetic devices around the DoD complex.

Many people are constantly looking for that elusive 'silver bullet' technology. Plasma technology is not that silver bullet. However, plasma technology represents a good environmentally friendly and cost competitive alternative technology for the destruction of energetics and energetic devices. As with other incineration technologies, Plasma is not a blast chamber and is not designed for high order detonations. Therefore, the system is meant to be used in conjunction with other pre-processing technologies, just as the APE 1236 incinerator.

F.2. Performance capabilities

A mobile plasma treatment system can provide the destruction capability in a demil system operation. The system requires pre-processing of some components as any other EWI, however it has the flexibility with proper pre-processing to treat the majority of the items present. With proper pre-processing and operation the system is capable of meeting the following production levels:

SER	NATURE	PRODUCTION RATE
(a)	(b)	(c)
1	TNT	140 kg/hr
2	Fuzes	1000/hr
3	Primers	20,000/hr
4	Bulk Propellant	150 kg/hr
5	Bulk Illuminate	200 kg/hr
6	Bulk Smoke	100 kg/hr

F.3. Plasma technology

F.3.1. System components

The major system components of the Mobile Plasma Treatment System are:

- a) primary chamber;
- b) primary chamber feed system;
- c) plasma arc torch;
- d) secondary combustion chamber; and
- e) pollution control system.

F.3.1.1. Primary chamber

The primary chamber is a sealed vessel in which the plasma treatment process takes place. The vessel consists of a water cooled dome, spool piece, and hearth sections with ports installed in the dome and spool for the plasma torch, process offgas, feed, oxidation air, and viewing cameras. During operation, the plasma torch heats and oxidises the feed material using a high temperature plasma gas, creating a molten pool in the primary chamber hearth. In addition to the torch gas, supplemental oxidation air is supplied to the chamber to help maintain an oxidising atmosphere and keep the oxygen content above stoichiometric conditions. Once the hearth is full, it is tapped and the molten slag pours into drums where it cools into a glassy-ceramic solid.

F.3.1.2. Primary chamber feed system

The primary chamber feed system consists of separate feeders for ordnance and soil. Ordnance devices are fed to the primary chamber using a conveyer belt feeder that dumps the ordnance through a rotary valve into a feed tube. A pneumatically actuated rammer then feeds the ordnance through the side of the primary chamber vessel into the hearth.

The soil and flux materials are fed to the top of the furnace using a flexible screw conveyor and hopper. The material is conveyed to the top of the primary chamber, fed through a valve, and dropped into the plasma hearth.

F.3.1.3. Plasma torch

The plasma arc torch system consists of a 500 kW non-transferred arc torch, a plasma gas supply system, a closed loop deionized cooling water supply system, and a power supply. The torch assembly has four water-cooled circuits; the outer housing or ram, the cathode, the anode, and the ball assembly. Deionized (DI) water kept in a closed loop system is used to cool the plasma torch during operation. The DI water is kept cool using a plate and frame heat exchanger fed by the plant cooling water supply. Because it is easier to ionize than the plasma torch gas, helium is used as the torch gas for ignition. In addition, a small flow of argon is maintained during operation as a shroud gas to keep the tungsten electrode from oxidising. Immediately after ignition, the torch gas is switched from helium to the main torch gas. The torch can be positioned in the primary chamber with a three-axis, electrically powered motion control system. Pinhole cameras installed in the dome and spool sections of the primary chamber allow operators to control torch position and view the plasma arc.

F.3.1.4. Secondary Combustion Chamber (SCC)

Hot combustion gases generated during the plasma treatment process are drawn off the top of the primary chamber and routed to the SCC via a refractory lined pipe. The SCC is a horizontal vessel consisting of two refractory lined chambers.

The first chamber is a mixing section in which combustion gases are mixed and heated to over 2000 °F. A diesel/air fired burner is mounted on the inlet end of the mixing section with the burner flame directed horizontally into the chamber. Combustion gases, from the primary chamber, enter the mixing section tangentially to the burner flame to provide a turbulent atmosphere for mixing. The combustion gases and diesel/air products then enter a plug flow section designed to ensure a two-second residence time through the SCC. The combination of high temperature and residence time in the SCC ensures complete combustion of any remaining organic material or products of incomplete combustion (PICs).

Annex G (Informative) **Open Burning and Open Detonation (OBOD)**

G.1. Open Burning (OB)

G.1.1. General

There are a variety of OB techniques available to destroy APM with a low risk of detonation; deflagration is generally considered to be an open detonation (OD) technique. They include the use of small scale burning boxes, large scale burning cages and the use of suitable thermitic compounds. This technique could be defined as a technique where the combustion air is not controlled.

G.1.2. Advantages

OB has the advantages of high production rates combined with low operating costs. It is probably the cheapest destruction option for most economies of scale.

G.1.3. Disadvantages

The products of combustion produce a degree of air and ground pollution, but the VOCs are destroyed if burn temperatures in excess of 850^oC are produced. Particulate matter is introduced into the atmosphere, but the toxicity of this is dependent on the raw materials used in the APM design. OB is legislated against in some countries, but acceptable in others if a supportive environmental impact assessment is formulated.

OB can be a dangerous operation if the design of the target ammunition is not fully understood. There can also be FFE certification problems after burn.

Large danger areas are required and the process is staff intensive. It requires a co-located preparation site due to restrictions on the transport of non UN classified explosive waste.

For safety reasons, OB operations are restricted to daylight hours.

G.1.4. Technology

a) thermite. The use of thermitic compounds to induce a burn of the explosive filling of the APM;

b) 'pandora's box';

Note: This is a technique developed by the UK Demilitarization Facility at DERA Shoeburyness, UK that involves the use of a 5 metre square burning cage. It is highly efficient, although only suited to the destruction of certain plastic-bodied APM

c) burning tanks; and

d) it is recommended that an Infra Red Pyrometer is used to measure external radiated heat. This can then be used to support the environmental assessment, as it means that the burn temperature can be measured to ensure that it is above the 850^oC threshold.

G.2. Open Detonation (OD)

G.2.1. General

The use of serviceable HE or HE filled munitions to destroy APM. OD takes place by the initiation of the target APMs by an external HE donor charge.

G.2.2. Advantages

There are many technical advantages to OD as a destruction technique. High production rates are achievable, (at a logistic cost) that result in relatively low cost per APM destroyed. The products of detonation are generally well known, therefore the environmental impact assessment is a straight-forward process.

It is possible to safely use Radio Control (RC) initiation thereby improving operational effectiveness; (cable cutting is no longer an issue).

The final waste product, if any, requires minimum processing.

G.2.3. Disadvantages

The major disadvantage of OD is the potential effect on the environment if the process is not managed correctly and responsibly. It does result in a degree of air and ground pollution and has been banned in some EU countries and US states, but is accepted in others after the development of a full environmental system model for the target munition. Noise pollution is a major issue, but suppression techniques and sophisticated monitoring systems can, and are being, used in to negate this issue.

Irresponsible management and control can lead to unacceptable ground pollution, with the associated resultant remediation costs.

Sound technical training and judgement is necessary to reduce the risk of detonation transfer problems for certain APMs due to incorrect layout or low detonation pressures of unsuitable donor explosives. The technique can be dangerous if multi-item demolition techniques are not understood as there is the potential for UXO contamination of the demolition area.

Large danger areas are required which, when combined with the high labour requirement and the cost of donor explosives, means that operating costs can be high if economies of scale are not achieved. Operations are also restricted to daylight hours.

If operations are not conducted properly there is a real risk of APM being ejected ('kicked out') of the demolition pit, where they will then pose a significant hazard and threat to unsuspecting personnel at a later date.

G.2.4. Technology

G.2.4.1. Donor charge

Selection of the correct donor charge is essential to the success of the operation. The detonation pressure, (a function of the density and velocity of detonation of the explosive), dictates whether or not the target munition is destroyed by the donor charge. High performance military plastic explosive is expensive, but will always do the job. Lower level commercial explosive, such as Ammonium Nitrate / Fuel Oil (ANFO), may not always be suitable due to its lower detonation pressure.

G.2.4.2. Tamping

Tamping options to reduce noise pollution include 'one tonne' builders' sandbags or the use of water suppression techniques.

G.2.4.3. Acoustic monitoring

There are sophisticated acoustic monitoring systems available based on a PC. These can be used to both measure and predict noise levels at different locations. This not only means that a record of real acoustic levels can be maintained, but also that operations can be suspended if estimated noise levels are going to be above the accepted threshold of 110 dB at certain locations.

G.3. Basic principles and procedures of OBOD operations

The basic principles and procedures for OBOD operations (including information for selection and siting of demolition grounds) are contained in IMAS 11.20 - Principles and procedures for OBOD operations.

