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TNMA

Guidance on liquid propellant fuelled systems



Warning

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Foreword

Management practices and operational procedures for humanitarian mine action are constantly evolving. Improvements are made, and changes are required, to enhance safety and productivity. Changes may come from the introduction of new technology, in response to a new mine or UXO threat, and from field experience and lessons learned in other mine action projects and programmes. This experience and lessons learned should be shared in a timely manner.

Technical Notes provide a forum to share experience and lessons learned by collecting, collating and publishing technical information on important, topical themes, particularly those relating to safety and productivity. Technical Notes complement the broader issues and principles addressed in International Mine Action Standards (IMAS).

Technical Notes are not formally staffed prior to publication. They draw on practical experience and publicly-available information. Over time, some Technical Notes may be 'promoted' to become full IMAS standards, while others may be withdrawn if no longer relevant or if superseded by more up-to-date information.

Technical Notes are neither legal documents nor IMAS. There is no legal requirement to accept the advice provided in a Technical Note. They are purely advisory and are designed solely to supplement technical knowledge or to provide further guidance on the application of IMAS.

Technical Notes are compiled by the Geneva International Centre for Humanitarian Demining (GICHD) at the request of the United Nations Mine Action Service (UNMAS) in support of the international mine action community. They are published on the IMAS website at www.mineactionstandards.org.

Introduction

There have been recent occasions in Bosnia-Herzegovina¹ and Somalia² involving a requirement to render safe, or certify as safe to move, liquid fuelled missile systems. In addition, a third project is ongoing³, under the auspices of the NATO Partnership for Peace (PfP) programme, for the safe disposal of a liquid bi-propellant in storage.

This Technical Note has been written as an advisory document, to remind, or inform, mine action managers and field staff of the major hazards of liquid fuelled systems. The Technical Note also provides guidance on the establishment of safe operating environments and procedures. **It does NOT provide all of the necessary information for the formulation of a render safe procedure; the appropriate technical advice should always be taken.**

The clearance of liquid fuelled systems should only be undertaken by appropriately qualified EOD personnel or other qualified staff; it is not a task for basic deminers or other field staff.

¹ Clearance of stored liquid bi-propellant from an explosive storage area in Republic Srpska. (NATO SFOR).

² Breakdown and destruction by demolition of fuelled SA2 Guideline Missiles and components, Somalia. (Danish Demining Group). (Further information from www.danishdemininggroup.dk).

³ Clearance of stored liquid bi-propellant compounds from an explosive storage area in Moldova. (As at October 2001). (NATO NAMSA contract)

Guidance on liquid propellant fuelled systems

1. Scope

This Technical Note provides guidance on the identification of inherent hazards, and establishment of safe operating environments and procedures for liquid propellant fuelled systems that may be encountered during demining operations in a permissive post conflict environment. Identification of such systems at an early stage of a programme is essential to ensure a safe environment.

2. References

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

3. Terms and definitions

A complete glossary of all the terms, definitions and abbreviations used in the IMAS series and Technical Notes is given in IMAS 04.10.

In the Technical Notes series, the words 'should' and 'may' are used to indicate the intended degree of compliance. This use is consistent with the language used in International Mine Action Standards (IMAS) and guides.

- a) 'should' is used to indicate the preferred requirements, methods or specifications.
- b) 'may' is used to indicate a possible method or course of action.

4. Background

Recent conflict has seen significant deployment or use of liquid propellant-fuelled systems. The legacy of the use of these munitions remains, and they could become a clearance or disposal task for demining organisations in the future. They potentially pose a significant hazard to the local population and their safe clearance and disposal is a particularly complex technical task. Notwithstanding this, simple procedures can significantly reduce the risk to the local population whilst a clearance and disposal methodology is formulated.

A typical liquid propellant-fuelled system encountered by mine clearance programmes is the Russian SA 2 GUIDELINE Sustain Motor. (The parent system is shown on the front cover). Other systems recently encountered in post-conflict environments have been SS1-SCUD and variants, HY-2 SILKWORM, STYX and AS-9 KYLE.

Demining organisations might encounter hazardous fumes, vapour or residue from liquid bi-propellant systems by:

- a) being downwind of the results of an armed strike against targets where the fuels and chemicals in the system were released, and continue to be slowly released, into the atmosphere;
- b) participating in helicopter movement on, near or over the hazards; or
- c) physical contact during explosive ordnance reconnaissance or clearance activities.

5. Reasons for liquid propellant fuelled system hazard clearance

There are numerous reasons why the clearance of liquid propellant-fuelled system hazards may be desirable in a post conflict situation. These include:

- a) to reduce risk to human health;

- b) to allow destruction of unserviceable or unstable ammunition;
- c) to safeguard the environment; or
- d) to permit environmental clearance of the area.

6. Liquid propellants

Liquid propellants are still used in some rocket motors, and are divided into **monopropellants** and **bipropellants**. Monopropellants consist of a single compound, although some may require the action of a catalyst. They have a low specific impulse⁴ and tend to be used mainly in small rocket motors, such as thrusters, or in gas generators. They are unsuitable as a main propulsive source in a munition, and therefore they are not discussed further.

Bipropellants contain a separate fuel and oxidiser.

NATO munitions containing liquid propellants are often marked **LPA** - Liquid Propellant Activated.

6.1 Liquid bipropellants

Bipropellants use a combination of a liquid **fuel** and a liquid **oxidiser**. They are stored in separate tanks within the munition and injected into a combustion chamber where they come into contact and violently react, producing hot gas for the purpose of propulsion.

Most military bipropellants ignite spontaneously when mixed; these are known as '**hypergolic**'. Those that require the use of a separate igniter are known as '**non-hypergolic**'.

Bipropellants can be further categorised into '**earth storable**' in which the components are liquid under ambient conditions. '**Space storable**' bipropellants, in which the components have to be cooled to low temperature and then pressurised to force them into their liquid state, are not used in military systems as they cannot be maintained in a state of instant readiness.

6.1.1 Fuels

The most common fuels likely to be encountered in UXO or storage are:

- a) Kerosene (Kero);
- b) Unsymmetrical DiMethyl Hydrazine (UDMH) $((\text{CH}_3)_2\text{N}-\text{NH}_2)$;
- c) MonoMethyl Hydrazine (MMH)⁵ $((\text{CH}_3)\text{NH}-\text{NH}_2)$; and
- d) Triethylamine/Xylidene.⁶

The hydrazines are colourless, oily liquids with ammonia-like or fishy smells.

6.1.2 Oxidisers

The most common oxidisers likely to be encountered in UXO or storage are:

- a) Red Fuming Nitric Acid (RFNA);
- b) Inhibited Red Fuming Nitric Acid (IRFNA)⁷;

⁴ This can be defined as the thrust per unit mass rate of burning of the propellant. Ideally it should be a constant for a given propellant. It is an important performance parameter.

⁵ Used with DiNitrogen Tetroxide.

⁶ Commonly referred to as TONKA fuel.

- c) DiNitrogen Tetroxide;

WARNING 1: The inhibitor in IRFNA is Hydrofluoric Acid and is designed to protect the container against corrosion caused by the Red Fuming Nitric Acid (RFNA). In some systems, this inhibitor is not present; these systems then become even more hazardous during long-term storage when fuelled.

7. Hazards

The hazards posed by liquid bipropellant systems are wide-ranging and complex. A summary of them is included at Annex B for reference. The missile itself will also pose major explosive hazards if the warhead is still intact.

8. Clearance methodology

The more technical issues of clearance methodology are at Annex C.

The minimum action that should be taken by a mine action programme manager to protect the workforce and the community from the potential effects, when a missile with a liquid propellant filling has been identified, is as follows.

- a) report the matter to the programme manager, who will brief staff accordingly;
- b) warn own staff, the mine awareness staff (MRE staff) and the National Mine Action Authority of the presence of this type of hazard;
- c) using staff wearing protective clothing as outlined in paragraph 9 below, mark the area at a radius of 100m around the missile, fence it and report it;
- d) evaluate the potential worse case downwind hazard area. (A computer model capable of this can be obtained from companies such as Bruhn Newtech (<http://www.bruhn-newtech.com>));
- e) do not touch the system unless the programme has appropriately qualified staff deployed⁸, and warn all staff that the fuze sensors in the nose or on the flanks of the warhead may still respond to a radar or infra-red target such as a small vehicle;
- f) if no appropriately qualified staff are available, then identify the location of such staff and request their assistance through UNMAS; and
- g) once appropriately-trained staff are available, develop an appropriate clearance and disposal methodology in close co-operation with these qualified staff.

9. Equipment

9.1 Personal Protective Equipment (PPE)⁹

The following PPE should be the minimum used by staff marking off the missile, and by the EOD technician or qualified staff member during the close reconnaissance phase until the presence of liquid bipropellant can be positively discounted:

- a) inner cotton gloves;
- b) outer heavy PVC gloves of industrial quality;

⁷ On occasions, it is possible that a derivative of IRFNA known as 'Melange' may be referred to.

⁸ Advice can be obtained from UNMAS or the GICHD on what formal qualifications or experience would be desirable in such cases.

⁹ This PPE is additional to the PPE requirements contained within IMAS 10.30.

- c) respirator; and
- d) gas and liquid resistant protective oversuit and overboots.

WARNING 2: This level of protection is for a visual look at the problem only. It will not provide complete protection from any contact with the liquid bipropellant.

The aim of this PPE should be to provide complete overall protection from inhaled or skin-contact vapour. Managers unable to obtain military equipment should use the best materials, and ingenuity, to achieve this requirement.

Should liquid bi-propellant be confirmed from the beginning, or physical operations on the munition or storage tank be intended, then Self Container Breathing Apparatus (SCBA) and Gas Tight Suits (GTS) should be worn.

9.2 Respirator

The eyes are particularly sensitive to chemical attack and the presence of any toxic or irritant vapours, fumes or mists will necessitate adequate eye protection being available. There are many commercial personal respirators on the market that provide adequate protection against particulate contamination, BUT may well not be suitable for protection against vapours, fumes and mists.

Some respirators fitted with activated charcoal filters may also provide protection against toxic vapours. However, in the case of liquid bipropellants it is strongly recommended that closed circuit or self contained breathing apparatus is used for ALL work in liquid bipropellant contaminated areas. Such systems should be of a type approved by a national health and safety organisation.

10. Safety brief

Demining organisations should ensure that all of their managerial, demining, administrative and support staff are briefed as to the hazards of liquid fuelled systems if they have to move in a potentially hazardous environment. (Their EOD or specially qualified personnel should already be trained in the hazards of liquid fuels).

The following safety brief should be made available to such personnel:

You should be aware that it will not be possible, without special instruments, to detect whether a damaged liquid fuelled system is leaking. The following precautions should be taken.

- a) *do not enter or climb onto a damaged liquid fuelled system, or loiter within 100 metres, unless you are working in co-operation with an EOD technician;*
- b) *if your work requires you to work within 100 metres, wear a facemask and gloves, and roll your sleeves down. Cover any cuts and abrasions with waterproof dressings. Spend as little time as practicable on the task. Do not enter the downwind hazard area or approach within 50 metres of the suspect system;*
- c) *do not eat, drink or smoke near the damaged liquid fuelled system. After completing your task, wash and shower as soon as practicable. Remove your outer clothing and, if feasible, replace it. Otherwise, have it laundered. Do not eat, drink or smoke until you have done so; and*
- d) *if you suspect you have been exposed to the liquid propellants, inform your medical support team.*

11. Recommendations

11.1 National mine action authority

The National Mine Action Authority is responsible for identifying and warning all mine action agencies of any history of the use of liquid fuelled systems, and should be made aware of the hazards presented by such systems. The Authority should be urged to obtain as much information as possible from former warring factions. The Authority should be aware of these Notes, and make copies available, through the National Mine Action Centre, to all mine action agencies, including those involved in Mine Risk Education.

11.2 Demining organisations

The manager of any mine action team should also be aware of these notes, and if the use of liquid fuelled systems is suspected or proved, should include the recommendations of these notes in SOPs. The manager is also responsible for ensuring the presence of a trained EOD staff member, or for sending a staff member for specific training in liquid fuelled system hazards. Where a National Mine Action Authority of Mine Action Centre have not been established, managers are responsible for establishing amongst themselves a code of practice to ensure the safety of mine action staff and locals.

11.3 Demining personnel

All mine action staff working in areas of potential liquid propellant contamination, should make every effort to keep themselves free from the hazard by conscientious use of protective equipment, and strict observation to SOPs and the dictates of common sense.

Annex A (Normative) References

The following documents when referred to in the text of this Technical Note, form part of the provisions of this guide.

- a) IMAS 04.10. Glossary of demining terms.

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

The latest version/edition of the Technical Notes can be accessed via the IMAS website at www.mineactionstandards.org

Annex B (Informative) Hazards

B.1 General EOD hazards

- a) liquid propellants are particularly dangerous in unexploded munitions, where damage or poor maintenance may lead to leakage. This may also result in a downwind vapour hazard;
- b) the Boiling Point of UDMH is only 63⁰C. This may be a significant factor in very hot climates;
- c) to avoid homing sensors and proximity fuzes, unexploded missiles should not be approached from the front. Similarly lateral proximity sensors should be identified and avoided;
- d) impact fuzes may be located externally, for example, on the leading edge of fins;
- e) consider the presence of HEAT effect warheads and directional fragmentation systems;
- f) the venturi of the rocket motor should be a major consideration during destruction by demolition. Unless it too is destroyed there is a risk of the missile going propulsive, albeit in a ballistically unstable fashion; and/or
- g) thermal battery assemblies may contain gas under high pressure or propellant.

B.2 Toxicity ¹⁰

B.2.1 General

In addition to the significant risk from spontaneous combustion or explosion, many liquid propellants are highly toxic or corrosive. Protective clothing and breathing apparatus are required when working near Hydrazine, UDMH, IRFNA or Hydrogen Peroxide in concentrations as low as 5 parts per million (ppm).

For any given substance the toxic risk depends on:

- a) toxicity of the substance;
- b) duration of exposure; and
- c) intensity of exposure.

Whilst the main routes by which a toxic substance may enter the body are:

- a) ingestion ¹¹;
- b) percutaneous ¹²;
- c) eye; and/or
- d) inhalation.

¹⁰ Toxicity can be defined as “**the ability of a substance to cause damage to a target organ**”.

¹¹ Entry into the body by eating or swallowing.

¹² The penetration of substances through the skin.

B.2.2 Toxicity and risk level

The toxicity alone of a compound is not necessarily a good guide to the level of risk it may induce during EOD operations. In the case of contaminant vapours, the volatility of the parent compound must be considered.

In practice, a compound with a higher volatility may pose a greater hazard than a more toxic compound with lower volatility. This is because there will be more of the higher volatility compound present in the local atmosphere at a given ambient temperature.

There is not a universally recognised method to quantify risk on the basis of both volatility and toxicity, but one simple method uses the "Hazard Index":

$$\text{Hazard Index (HI)} = \text{Volatility} / \text{Toxic Dose}$$

To illustrate the relationship between toxicity, volatility and risk a comparison has been made between UDMH and MMH:

Compound	Vapour Pressure @ 25 ^o C (mm Hg)	Toxicity ¹³ index	Hazard Index
Monomethylhydrazine (MMH)	49.6	74	0.67
Unsymmetrical dimethylhydrazine (UDMH)	156.8	252	0.62

UDMH is nearly a factor of 4 times less toxic (see note 11 below) than MMH, but because of its higher volatility, (caused by much higher vapour pressure), the Hazard Index is about the same.

WARNING 3: It is emphasised that the Hazard Index is not a universally agreed concept, but it does present a rough guide that can be used operationally to assess the relative risk posed by different chemical substances.

B.3 Hydrazines

The hydrazine derivatives (MMH and UDMH) tend to be local irritants, convulsants and blood-destroying agents¹⁴ that are absorbed by all routes of administration to the body. They are almost all suspected of causing cancer in humans.

Hydrazine itself is a strong skin and mucous membrane irritant and a moderate blood destroying agent. It can be absorbed through **intact** skin. Exposure to the vapour results in:

- eye irritation;
- lung congestion; and
- nervous system convulsions.

Similar effects are exhibited by UDMH contamination, but it is less irritating to the skin, with reduced toxicity through the skin. It has a lower oral toxicity than Hydrazine, but its acute vapour toxicity is greater. **It is therefore a greater risk in cases of localised atmospheric contamination.**

¹³ The LC₅₀ Limit is "the concentration of substance, which under defined conditions, is lethal to 50% of those exposed". In this case the LC₅₀ limit is for a 4 hour period.

¹⁴ Agents that can attack, and contribute to the destruction, of the red blood cells.

The American Conference of Governmental Occupational Hygienists (ACGIH) is an advisory body that sets standards for Threshold Limit Values (TLV)¹⁵. These standards are similar to the UK Health and Safety Executive Occupational Exposure Limits (OEL), which although are internationally preferred, do not publish limits for UDMH and MMH. Therefore, TLVs have to be used:

COMPOUND	TLV		REMARKS
	ppm	mg.m ⁻³	
Hydrazine	0.1	0.10	UK HSE OEL = 0.10 mg.m ⁻³ . Same as TLV.
MMH	0.2	0.35	
UDMH	0.5	1.00	

B.4 Hazard reduction

The reduction of hazard when working in liquid bipropellant contaminated environments does not consist solely in adopting the appropriate operating procedures and the provision of suitable personal protective equipment. The following measures are also essential;

- education of employees;
- regular monitoring of the working environment;
- emergency contingency planning;
- management of work schedules to reduce exposure; and
- frequent medical monitoring of worker health.

B.5 Advice and International Responsibilities

Advice on safety and on the disposal of chemical waste can be obtained from either:

United Nations Environmental Programme (UNEP)
Emergency Response Unit
United Nations Avenue, Gigiri
PO Box 30552,
Nairobi
Kenya

Tel: (254-2) 621234
Fax: (254-2) 624489/90
Email: UNEP_Webmaster
http://www.unep.org/PolicyDivision/emergency_response.html

World Health Organisation (WHO)
Avenue Appia 20
1211 Geneva 27
Switzerland

Tel: (+41) (22) 791 2599
Fax: (+41) (22) 791 3111
E-Mail: inf@who.int
<http://www.who.int/m/healthtopics-a-z/en/index.html>

¹⁵ TLV is the "maximum concentration levels of a toxic substance in air, which, under certain conditions, is considered acceptable for the exposure of industrial workers".

Annex C (Informative) Clearance methodology

C.1 Detection of liquid bipropellant contamination

Commercial pump ¹⁶ and sampling systems, monitors and detectors have the capability to indicate the presence of bi-propellant fumes and vapours.

For fuels the following companies ¹⁷ can supply suitable systems:

- a) Casella Limited. (www.casella.co.uk/) (With Tennax ¹⁸ tubes).
- b) Dräger ¹⁹

For oxidisers the Dräger is again a very suitable system.

C.2 Personal protection

C.2.1 Medical team

An appropriately equipped and qualified medical team is to be present during operations in all suspected liquid bipropellant contaminated areas.

C.2.2 Casualties

The appropriate medical authorities are to be informed of any casualties that occur whilst in a liquid bipropellant contaminated area.

C.2.3 Safe working time

Personnel working in GTS and SCBA should be limited to 30 minutes working time to protect against heat exhaustion.

C.3 Detection, sampling and disposal

WARNING 4: The methodology for operating in such hazardous environments will be dependent on the training of the team leader and team. This is one proposed methodology based on past operations. Any operations planned in such hazardous environments should be physically rehearsed prior to the live operation. This methodology does not negate the need for detailed standing operating procedures to be developed and applied.

C.3.1 Detection

An incident control point (ICP) should be established in an area upwind of the suspected location. On arrival, an air sample should be taken using appropriate test equipment.

¹⁶ Military systems such as the Chemical Agent Monitor (CAM) used by some NATO countries will detect IRFNA and give very strong readings. Unfortunately the IRFNA will allegedly damage sensitive internal components if in the vicinity of the CAM for more than a few seconds. Therefore this system is unsuitable for use, unless in a real emergency.

¹⁷ These companies are included for illustrative purposes only. The UN or the GICHD are neither recommending nor endorsing their products by mentioning them in this Technical Notes. The national mine action authority should procure such systems in accordance with its own national guidelines.

¹⁸ <http://www.skinc.com/tubes/tenax.html>

¹⁹ An internet search will provide numerous suppliers of Dräger equipment.

If the result is clear, then a downwind hazard prediction should be made using suitable methodology. (A computer model capable of this can be obtained from companies such as Bruhn Newtech (www.bruhn-newtech.com/)).

Should conditions be favourable, then operations can commence, but all assets are to remain upwind of the suspect location at all times and the predicted downwind hazard area should be evacuated.

A "Hot Line" should be established at the ICP and be clearly marked. No personnel are then to cross the "Hot Line" unless in full GTS with SCBA.

A Decontamination Station (DS) is to be established on the live side of the Hot Line. In addition to the decontamination team, this is to be staffed by at least 2 persons part dressed in GTS and SCBA in order to assist the work party during an emergency evaluation.

The work party should consist of a minimum of three persons at any time. The detection or sampling operator is to be closely monitored by another team member at any time. The third team member should act as the Safety Supervisor at a safe distance from the working area.

The Safety Supervisor should be in a position to monitor all other team members and have constant communication with the ICP. Should communications be lost then all team members should return to the ICP.

All personnel returning to the ICP are to pass through a footbath and are to be decontaminated by the DS before recrossing the Hot Line into the ICP safe area.

WARNING 5: No equipment or clothing used in the detection or sampling of the fuel is to be used in the detection or sampling operation for the oxidiser, and vice versa. Contact between both sets of equipment and clothing should be avoided as there is a risk of a hypergolic reaction taking place.

C.3.2 Sampling of air

The appropriate sampling methodology for the equipment should be conducted.

C.3.3 Sampling of liquids

This is a highly complex task that should only be undertaken by specially trained personnel. It is highly recommended that this be sub-contracted to an experienced hazardous and toxic waste management company.

C.3.4 Disposal

This is a highly complex task that should only be undertaken by specially trained personnel. It is highly recommended that this be sub-contracted to an experienced hazardous and toxic waste management company.

During the area clearance of Kuwait in 1991 - 1992 some organisations disposed of liquid bi-propellant systems by deflagration or detonation. This should only be considered as an emergency measure and used as a last resort. The following factors should be considered:

- a) sufficient donor explosive or fuel should be used to ensure "massive overkill" conditions apply;
- b) a hazardous downwind vapour hazard is still likely to apply, therefore downwind hazard predictions and precautions should be made; and
- c) the site, after all explosions and burning have finished, could still be toxic. Therefore the requirement to wear GTS and SCBA for final clearance is not negated.

Amendment record

Management of Technical Notes amendments

Technical Notes (TN) are subject to review on an 'as required' basis. As amendments are made to this TN they will be given a number, and the date and general details of the amendment shown in the table below. The amendment will also be shown on the cover page of the TN by the inclusion under the version date of the phrase *'incorporating amendment number(s) 1 etc.'*

As reviews of TN are made new versions may be issued. Amendments up to the date of the new version will be incorporated into the new version and the amendment record table cleared. Recording of amendments will then start again until a further version is produced.

The most recently amended TN will be the versions that are posted on the IMAS website at www.mineactionstandards.org.

Number	Date	Amendment Details
01	01 Jul 2013	<ol style="list-style-type: none">1. Inclusion of amendment No, date in the title and header.2. Updated links and email addresses.3. Removal of Annex B.4. Inclusion of Amendment record.5. Minor text changes in fifth paragraph of foreword.6. Annexes B and C, relabelled.