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GUIDELINE FOR EMERGENCY RESPONSE TO CRYOGENIC LIQUID RELEASES

FIRST EDITION

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1 Purpose

This publication provides guidance for the response to a cryogenic liquid release. It is intended to complement the measures that are outlined in the current version of the U.S. Department of Transportation's (DOT) *Emergency Response Guidebook* (*ERG*) [1].[1]

2 Scope

This publication is intended for civil services (fire department, police, etc.) and emergency responders. The information in this publication shall only be applied by a subject matter expert (SME) in the product, equipment, and the emergency response handling protocols or practices.

These guidelines are intended to protect public safety, safely control the release, and implement the intervention measures. They apply to sustained cryogenic liquid releases, including:

- Plant process release, especially if the source cannot be shut off, and it is of undetermined quantity and duration; and
- Stationary storage tank release.

NOTE—This publication is intended to be used within the incident command system (ICS).

This publication does not apply to transportation incidents that result in a cryogenic liquid release.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall
Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should
Indicates that a procedure is recommended.

3.1.3 Can
Indicates a possibility or ability.

3.1.4 Will
Is used only to indicate the future, not a degree of requirement.

3.1.5 May
Indicates that the procedure is optional.

3.2 Technical definitions

3.2.1 Cryogenic liquid
Liquids with a boiling point of –130 °F (–90 °C), as defined in the ERG and Title 49 of the U.S. *Code of Federal Regulations* (49 CFR), Part 173.115(g) [1, 2].

NOTE—For more information on specific cryogenic liquids, see the following sections in the ERG [1]:

- ERG 115 gases – Flammable (including refrigerated liquids);
- ERG 120 gases – Inert (including refrigerated liquids); and
- ERG 122 gases – Oxidizing (including refrigerated liquids).

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[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

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3.2.2 Flammable atmosphere (or environment)

Flammable mixtures, those that form an ignitable mixture with air at 68 °F (20 °C) and 1 atm (see CGA P-23, *Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components* [3]).

3.2.3 Oxygen-deficient atmosphere (or environment)

Air and gas mixtures in which the oxygen concentration by volume is less than 19.5% at sea level or whose partial pressure of oxygen is less than 148.2 torr (mm Hg) (see CGA SB-2, *Oxygen-Deficient Atmospheres* [4]).

3.2.4 Oxygen-enriched atmosphere (or environment)

Air and gas mixtures in which the oxygen concentration by volume is greater than 23.5% at sea level or whose partial pressure of oxygen exceeds 175 torr (mm Hg) (see CGA P-39, *Guidelines for Oxygen-Enriched Atmosphere* [5]).

3.2.5 Sustained cryogenic liquid release

A continuous spill from a source that exceeds 119 g (450 L) of liquid, see 49 CFR 171.8 [2].

NOTE—For the purpose of this publication, the DOT definition of large spill is used. The ERG definition defines a large spill as greater than 200 L of liquid [1]. The DOT definition more closely aligns with the exposure scenarios.

4 Guidelines for emergency response to cryogenic liquid release

4.1 General

The following are general actions to take when responding to cryogenic releases:

- Refer to the site's emergency response plan;
- Identify the spillage product and source. Refer to appropriate technical resources such as safety data sheets (SDS), ERG, or CGA *Handbook of Compressed Gases* to understand the properties of the material [1, 6];
- Monitor oxygen concentrations beyond the visible edge of the vapor cloud, and barricade/restrict access to the affected areas. Since the altered oxygen content can extend beyond the visible edge of the vapor cloud, monitoring shall determine where the oxygen concentration is acceptable to permit emergency response activities. If the spill is nitrogen or argon, an oxygen-deficient atmosphere can be created. If oxygen is spilled, an oxygen-enriched atmosphere can be created. Prohibit the entry of personnel into atmospheres with oxygen concentrations greater than 23.5% or concentrations less than 19.5% oxygen without appropriate breathing apparatus.;
- All vehicles shall be kept out of the affected area of the release and vapor cloud;
- Ensure that all personnel wear the correct personal protective equipment (PPE);
- Limit emergency services personnel in the affected area to the minimum number necessary to carry out emergency control;
- If possible, shut off the source of the liquid. If equipped with a remotely operated valve, shutoff shall be done remotely;
- If possible, direct cryogenic liquid release away from occupied areas, process equipment, machinery, carbon steelwork, buildings, open drains (such as storm drains/culverts) and confined areas. Compatible materials can be used as physical barriers;
- A water fog spray may be used to knock down vapors, never use a full water spray;
- Do not direct water at source of the leak or safety devices as icing will likely occur; and
- Never allow the trapping of a cryogenic liquid between two points without a safety relief valve. The expansion from liquid to gas can cause the failure of piping and related equipment and present a safety hazard such as the expansion ratio of nitrogen 1:850.

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The following can be utilized to understand the source of the leak, and available controls and remediation options:

- Drawings and reference material to understand the hydraulics of the system and determine what is contributing to and causing the leak. This requires the involvement of the SME; and
- Drawings to locate pipe spools and understand how they are run/located in box, duct work, or annulus of tanks (for example, tank leak could be bottom drain, top fill, seal loops, etc.). This requires the involvement of the SME.
- Fire water with an inert material (for example, sand, dirt, etc.) to make an ice dam to control the flow of the cryogenic liquid release:
- Continuous monitoring of the dam is required; and
- Wait until all the ice has melted based on ambient temperatures plus 30 minutes before approaching the area after monitoring has been conducted. See the International Maritime Organization's (IMO), *International Maritime Dangerous Goods* (IMDG) *Code* [7].

In case of cryogenic liquid releases that can penetrate the ground, the incident commander and SME will determine the amount of time before allowing access to the affected area based upon site conditions, amount spilled, and the duration of the release.

WARNING: *No PPE will completely protect a responder from the primary hazards of cryogenic liquids, which include but are not limited to:*

- extremely cold temperatures and their impact on other materials they contact;
- flammability (hydrogen, methane, ethylene);
- liquid expansion to vapor; and
- oxygen-deficient/oxygen-enriched atmospheres.

4.2 Air separation unit coldbox operation

These are remedial actions a SME may recommend to apply to reduce the rate of uncontrolled cryogenic liquid release:

NOTE—When conducting remedial actions with an air separation unit (ASU) coldbox operations, self-contained breathing apparatus (SCBAs) shall be used.

- Ascertain the nature of the spillage such as argon, nitrogen, or oxygen. If the spillage is oxygen, increase the coldbox nitrogen purge rate to the maximum while maintaining coldbox pressure below safe limits;
- Drain liquid from the high pressure column, low pressure column, and other vessels to the disposal system at the maximum allowable rate. Do not use such a high draining rate that the disposal system cannot safely vaporize the liquids. Consider alternative disposal means, if available, to drain additional liquid to a safe area; and

  NOTE—Disposal of liquid can temporarily increase the vapor in the affected area.

- Take oxygen analyzer readings at the edge of the vapor cloud. When the vapor cloud has dispersed and oxygen concentrations are normal around the coldbox, the area can be entered to ascertain the cause of the cryogenic liquid release.

4.3 Flammable gases (hydrogen, methane, ethylene)

In addition to the guidance outlined in ERG 115, the following remedial actions should be taken for the release of a flammable gas [1]:

- Monitor flammable concentrations;
- Shut off engines or any other sources of ignition in the affected area;

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- Do not allow anyone to enter a flammable atmosphere;

  WARNING: *A flammable atmosphere can extend beyond the vapor cloud. Monitoring shall be used to determine where safe distances are utilizing the lower explosive limit (LEL) and the upper explosive limit (UEL).*

- Whenever possible, control the direction of the vapor cloud. Attempt to direct it away from sources of ignition and from buildings. Control of the vapor cloud usually can be achieved by use of a water curtain formed by water from fire hoses fitted with spray or fog nozzles;
- Keep adjacent equipment and any combustible material cool by applying large quantities of water;
- Do not apply water directly to a burning liquid pool; and
- Do not extinguish leaking gas fire unless leak can be stopped.

NOTE—If liquid hydrogen is involved, also refer to the oxidizing section. Hydrogen at –420 °F (–251.11 °C) will liquefy the air resulting in liquefaction of oxygen at –297 °F (–182.78 °C).

4.4 Inert gases (nitrogen, argon, helium)

In addition to the guidance outlined in ERG 120, the following remedial actions should be taken for the release of an inert gas [1]:

- Entry of personnel into any vapor cloud shall be limited to fully qualified emergency response teams for activities, such as but not limited to, the saving of life or the effective isolation of the spillage by closing a valve;
- Strict control of entry is essential with the mandatory use of SCBA and all other PPE and backup personnel;
- Under no circumstance shall personnel contact the spilled liquid; and
- Whenever possible, control the direction of the vapor cloud. Attempt to direct it away from buildings in which an asphyxiating atmosphere could be produced. Keep ventilators operating on any equipment enclosures or buildings that withdraw air and take in fresh air on any side of the building not affected by the vapor cloud. Control of the vapor cloud usually can be achieved by the use of a water curtain formed by water from fire hoses fitted with spray or fog nozzles.

NOTE—If liquid helium is involved, also refer to the oxidizing section. Helium at –452 °F (–268.89 °C) will liquefy the air resulting in liquefaction of oxygen at –297 °F (–182.78 °C). The extremely cold temperature of helium presents additional challenges when using normal cryogenic PPE (such as gloves, limitation of exposure time, etc.).

4.5 Oxidizing gases (oxygen)

In addition to the guidance outlined in ERG 122, the following remedial actions should be taken for the release of an oxidizing gas [1]:

- Shut off engines on any equipment that are running in the area;
- Prohibit flames or spark-producing activities. Try to prevent other sources of ignition energy such as friction, impact, etc.;
- At no time shall any person for any reason enter an oxygen-enriched environment (exceeding 23.5% oxygen). For additional information, see CGA P-45, *Fire Hazards of Oxygen and Oxygen-Enriched Atmosphere and* National Fire Protection Association (NFPA) 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres* [8, 9];
- Whenever possible, control the direction of the vapor cloud. Attempt to direct it away from buildings, compressor intakes, and any sources of ignition. Control of the vapor cloud usually can be achieved by the use of a water curtain formed by water from fire hoses fitted with spray or fog nozzles;

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- If the vapor cloud cannot be controlled and the cloud drifts towards the compressor air intakes, shut them and the plant down immediately using the emergency shutdown procedure; and
- If liquid oxygen (LOX) contacts asphalt, oil, grease, and rubber surfaces (such as compressors, engines, asphalt parking lot, etc.) do not allow any movement of personnel and vehicles in the affected area.

5 References

Unless otherwise specified, the latest edition shall apply.

[1] *Emergency Response Guidebook (ERG),* U.S. Government Printing Office. www.gpo.gov

[2] *Code* of *Federal Regulations*, Title 49 (Transportation), U.S. Government Printing Office. www.gpo.gov

[3] CGA P-23, *Standard for Categorizing Gas Mixtures Containing Flammable and Nonflammable Components*, Compressed Gas Association, Inc. www.cganet.com

[4] CGA SB-2, *Oxygen-Deficient Atmospheres*, Compressed Gas Association, Inc. www.cganet.com

[5] CGA P-39, *Guidelines for Oxygen-Rich Atmospheres*, Compressed Gas Association, Inc. www.cganet.com

[6] *Handbook of Compressed Gases*, Compressed Gas Association, Inc. www.cganet.com

[7] *International Maritime Dangerous Goods (IMDG) Code*, International Maritime Organization. www.imo.org

[8] CGA P-45, *Fire Hazards of Oxygen and Oxygen-Enriched Atmospheres*, Compressed Gas Association, Inc. www.cganet.com

[9] NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, National Fire Protection Association. www.nfpa.org

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