Repairing Hazardous Liquid Pipelines

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Repairing Hazardous Liquid Pipelines

1 Scope

This recommended practice (RP) discusses guidelines for safe practices while repairing in-service pipelines for hazardous liquids. Although it is recognized that the conditions of a particular job will necessitate an on-the-job approach, the observance of the suggestions in this document should improve the probability that repairs will be completed without accidents or injuries.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 1104, *Welding of Pipelines and Related Facilities*

ASME B31.4 [1], *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*

ASME B31G, *Manual for Determining the Remaining Strength of Corroded Pipelines*

ASME Section IX, *Boiler and Pressure Vessel Code*

ASNT SNT-TC-1A [2], *Personnel Qualification and Certification in Non-Destructive Testing*

PRCI *PR-218-9307* [3], *Pipeline Repair Manual*

3 Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

OQ	operator qualification
LOTO	lockout/tagout
PEL	personal exposure limit
PPE	personal protective equipment
LEL	lower explosive limit
HVL	high volatile liquids
NDT	nondestructive testing
LPG	liquefied petroleum gas

1 ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.
2 American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.
3 Pipeline Research Council International, Inc., 1401 Wilson Boulevard, Suite 1101, Arlington, Virginia 22209, www.prci.org.

4 Preliminary Knowledge

4.1 Personnel

Qualified oversight is a prerequisite to the successful implementation of pipeline repair practices. Regulatory requirements for the qualification of pipeline personnel performing repair activities are covered in DOT Regulation 49 *CFR* 195.501 through 195.509 of Subpart G (Operations and Maintenance). Guidance for the development and implementation of operator qualification (OQ) programs and procedures are given in ASME B31Q, *Pipeline Personnel Qualification*, and in API 1161, *Guidance Document for the Qualification of Liquid Pipeline Personnel*. Personnel working on pipeline repairs must understand the importance of careful planning to ensure safe and efficient practices and procedures. Employees and contractors should be briefed on-site about specific repairs and safety procedures. Only personnel with the proper training, experience and demonstrated skills should be allowed to perform pipeline repairs.

4.2 Safety Procedures

Repair personnel shall have a basic knowledge of safety procedures that includes, but is not limited to, lockout/tagout (LOTO); confined space; worker's right-to-know; personal protective equipment; excavation and trenching; fire prevention and protection; emergency response; atmospheric testing devices; hot work; work permitting; respiratory protection; hydrogen sulfide; hearing conservation; first aid; hazardous substances; fall protection; ergonomics; electrical hazards; and abrasive blasting; Regulations to protect worker safety are covered in OSHA 29 *CFR* 1910 (operations) and 29 *CFR* 1926 (construction).

The company person or designee with overall responsibility for the repair should review previous testing and repair files to determine the presence or absence of asbestos-containing pipe coatings, lead-based paint, or other substances requiring special attention. If coatings are identified to contain hazardous substances, special work practices designed by the company's health and safety department to mitigate employee exposure should be used. Additional handling and disposal requirements may be specified by local, state, or federal agencies, consult regulations in your area to determine and develop appropriate handling procedures.

In addition, the company person or designee with overall responsibility for the repair should be knowledgeable about the most recent Department of Transportation Alert Notices and National Transportation Safety Board recommendations related to pipelines as they may pertain to the specific repair situation.

5 Pre-departure Practices

5.1 General

When piping revisions, replacements, or repairs are needed, the goal is to safely and efficiently complete the work. Work shall include in-service and out of service repairs. To ensure the safe and efficient completion of the repair project, the proper preplanning and groundwork shall be accomplished before any work is done.

5.2 Preplan Procedures

The preplan should include the following steps.

a) Consult and comply with all applicable laws and regulations.

b) Notify "ONE CALL" service, if provided in the area or, if not, contact the owners of the buried facilities directly, giving notice of the work and allowing ample time for other buried facilities to be located and marked. (811 National One Call number.)

c) Evaluate reported damage and determine if a Safety-related Condition Report should be filed with the Department of Transportation.

d) Evaluate reported damage and determine appropriate repair method required to mitigate the condition.

e) Develop a written work plan that includes the proper repair procedure, drain-down or isolation procedures and appropriate equipment required to complete the repair project safely and efficiently.

f) Determine pipeline operating characteristics required during the repair project. Determine if pipeline pressure de-rating and/or shut down is required to complete the repair project safely.

g) Obtain any required permits, including landowner, local government, other regulatory agencies, company general and hot work permits, if required.

h) Ensure all tools and safety equipment is in good working order.

i) Brief all line repair personnel on the proper safety procedures and preplan requirements.

j) Notify personnel at the control center and discuss the line repair plans. Pipeline flow conditions, such as pressure and flow rate at the site of the repair, should be considered prior to the actual initiation of the repair. In service repairs may require reduced operating characteristics and specific flow or no-flow conditions dependent upon specific operator procedures. Out of service repairs or replacements may require line shut down, isolation, and evacuation prior to work initiation. Emergency procedures should also be reviewed with the control center personnel.

k) Ensure adequate fire protection equipment is available for emergencies and during welding or hot work activities.

l) Ensure all communications equipment is in good working order and establish a procedure for the control center to monitor the job's progress.

m) Ensure all communications and other electronic equipment is intrinsically safe or ensure that this equipment will be used a safe distance from potential vapor sources.

n) Close, lock, and tag the valves connected to the line section to be repaired, if line is required to be isolated and taken out of service during the repair completion.

o) Open, lock, and tag the circuit breakers on any pumps and motor operated valves that could affect the safety of the job.

p) Open, lock, and tag the circuit breakers on any rectifier/ground bed installations that could affect the safety of the job.

6 Site Hazard Assessment

6.1 General

A site hazard assessment should be performed prior to commencing any work activity inclusive of piping revision, replacement or repair work, in-service or out of service. Thorough review and assessment of site conditions and project requirements shall provide the basis to organize and complete the repair activity in a safe, controlled, and efficient manner.

6.2 Site Hazard Assessment Procedures

Repair work sites shall include a pre-job hazard assessment prior to initiation of work. Proper mitigation of all hazards identified shall be completed prior to allowing entrance to the excavation. The hazard assessment shall minimally include the following:

a) specific company work or hot work permitting requirements and review with repair crew personnel;

b) review and assessment of appropriate egress and ingress type and spacing;

NOTE Excavations greater than 4 ft deep require additional considerations such as ladders, stairways, and ramps located within 25 ft maximum spacing to provide adequate means of ingress and egress.

c) gas testing and monitoring requirements;

NOTE 1 Excavations greater than 4 ft in depth require atmospheric testing to confirm oxygen deficiency or presence of hazardous atmosphere.

NOTE 2 Access or continuous gas monitoring may be required depending on the location and type of repair work to be completed.

d) excavation requirements, inclusive of sheeting and shoring design implementation requirements;

— Excavations less than 5 ft deep shall require inspection and documentation by a competent person.

NOTE Appropriate sloping may be required as a result of the competent person evaluation.

— Excavations greater than or equal to 5 ft deep shall require sloping, sheeting or shoring protection to mitigate the potential of trench wall collapse. The appropriate sloping, sheeting or shoring technique used shall be determined based upon soil conditions, as assessed by a competent person. Refer to OSHA *Safety and Health Regulations for Construction*, 29 *CFR* Part 1926.652, for specific excavation safety regulatory requirements.

e) confined space analysis, if required;

— Appropriate personnel safety control, monitoring and retrieval systems shall be available prior to initiating any work within a confined space.

f) equipment status and energy control requirements, i.e. lockout/tagout (LOTO) or specific product isolation;

— Control information and requirements should be reviewed and documented prior to work initiation.

NOTE A project may require a system walk through and review to ensure system status and control is adequate for work intended.

g) personal protective equipment (PPE) requirements to complete the job safely;

h) miscellaneous safety requirement considerations such as fire watch, ventilation, bonding/grounding, signage, and barricades.

6.3 Leak Site Area Assessment Procedures

If a repair is required because of damage that has resulted in a product release or the product has spilled during the repair, additional site specific hazard assessments shall be performed. This hazard assessment should result in a worksite safety plan. A hazard zone should be established by determining the amount of hydrocarbon vapors in the area. Information that is contained in the Safety Data Sheet shall be consulted to determine the material's volatile and toxic characteristics. The initial monitoring of the area should be completed with full protective equipment as recommended by the Safety Data Sheet.

A leak site area assessment should include the following additional steps.

a) The area's flammability level should be checked with a combustible gas indicator prior to entering site. Areas above 10 % of the lower explosive limit (LEL) should be declared hazardous and the personal exposure limit (PEL) determined. Access should be restricted. These areas should be further evaluated for proper PPE, ingress/egress and work requirements.

b) Toxicity testing should be made with direct reading instruments that may include colorimetric tubes. This toxicity testing determines the level of protective equipment required for the area.

c) If a confined space is involved, such as a trench, always check for safe oxygen level.

d) Personnel and equipment should not be permitted in the area until the hazard area has been defined and mitigation or entry plan developed.

e) Restrict equipment and other ignition sources from the flammable hazard zone.

f) If the hazard area extends into public areas, local authorities should be used to warn the public and to restrict access to the area. If public access is possible, suitable warnings should be posted.

g) The leak site should be barricaded and marked to prevent the possibility of accidents and injuries. Consideration should be given to appropriate additional security measures to prevent spectators from entering the hazard area at any time.

In addition, the following applies.

1) All personnel who enter the toxic hazard zone shall be equipped with proper protective gear (PPE).

2) All personnel leaving the toxic hazard zone shall be subjected to proper decontamination protocols prior to re-emerging into a toxic hazard free clean zone.

NOTE Some leaks, according to their severity or hazards, may require compliance with the Occupational Safety and Health Administration's (OSHA) *Hazwoper Standard* (29 *CFR* Part 1910.120).

7 Excavation

7.1 General

All excavations that personnel are required to enter shall conform to OSHA *Construction Standard* (29 *CFR,* Part 1926, Subpart P). All excavations shall be assessed by a competent person to determine appropriate level of protection required for safe entry.

NOTE The OSHA *Construction Standard* regulates the use of support systems, sloping and benching, and other systems of protection against excavation cave-ins. In addition, it regulates the means of access to and egress from excavations and employee exposure to vehicular traffic, falling loads, hazardous atmospheres, water accumulations, and unsafe structures in and adjacent to excavations. Excavations are defined in the *Construction Standard* to include trenches.

7.2 OSHA *Construction Standard* Checklist

To ensure that existing and predictable hazards are identified at the worksite, the following checklist is provided as an outline of the OSHA *Construction Standard*.

a) Have "ONE CALL" notifications been made or other means used to determine what underground utilities are in the area? (811 National One Call Phone Number.)

b) Is the excavation more than 4 ft in depth and evaluated for hazardous atmosphere (flammability, oxygen content, toxicity, H_2S, carbon monoxide)?

c) Has excavation been evaluated for adequate means of ingress and egress?

d) Has a stairway, ladder, ramp, or other safe means of ingress/egress been provided and properly spaced?

e) Has a trained and qualified competent person (as defined by the OSHA standard) been designated?

f) Has the soil been categorized (stable rock, Type A, Type B, or Type C)?

g) Does the excavation require sloping, shoring, or shielding?

h) Is the excavation greater than or equal to 5 ft in depth and have sheeting and shoring requirements been evaluated?

i) Is the excavation more than 20 ft in depth? (If yes, a protection system designed by a professional engineer will be required.)

j) Is the excavation a permit-required confined space?

k) If excavation protection is required, which system will be used?

l) Have Manufacturer's Engineering Tabulated Data Sheets, specification of the protective device load rating, for the shoring or shielding system considered been reviewed and evaluated? Has appropriate shoring protection system been selected for the proposed site conditions? Protection system engineering data should remain available for reference on site.

m) Has a safe excavation protective system installation and removal procedure been developed to protect the employees who will be performing these tasks?

n) Has adequate protection been provided to protect employees from materials falling or rolling from the excavation face or from the surface in the vicinity of the excavation?

o) Is the spoils pile a minimum of 2 ft (24 in.) from the edge of the excavation?

p) Has adequate protection been provided for water accumulation in the excavation?

q) Is emergency rescue equipment available at the jobsite? (If confined space has the local emergency response or rescue contractor been notified?)

r) Has stability of adjacent structures been considered as a result of the excavation?

s) Are daily inspections of the excavations being made?

This checklist is designed only as a reminder; the details of the OSHA *Construction Standard* can be found in Subpart P of 29 *CFR* Part 1926.

8 Repair Practices

8.1 General Repair Procedures

8.1.1 General

If damage or imperfections are discovered on a pipeline, a decision to repair or not to repair shall be made. Defect evaluation shall be conducted using ASME B31G or other acceptable engineering analysis methodology.

NOTE 1 If repairs are warranted, but not immediately practical, temporary repairs may be considered.

NOTE 2 When practical, an injurious pipe defect may be completely removed from the pipeline by replacing the portion of the pipe containing the defect.

The welding procedures and welders performing the repair shall be qualified in accordance to API 1104 or ASME Section IX, dependent upon mainline or facility piping. Consideration should be given to assuring the replacement section of pipe meets the minimum design requirements of the pipeline and has been hydrostatically tested prior to placing in service. The length of the replacement pipe should be a minimum of one half the diameter of the pipe but no shorter than 3 in. No new weld shall be installed closer than 3 in. to an existing weld. If pipe replacement is not practical, other methods of permanent repairs are covered in ASME B31.4, API 1160, PRCI's *Pipeline Repair Manual*, and ASME PCC-2. If the repair is to be performed on in-service piping, the procedures and welders shall be qualified in accordance to API 1104 Appendix B.

8.1.2 Temporary Repairs

Temporary repairs (i.e. clamps or mechanically-applied full encirclement sleeves) may be necessitated for operating purposes. The temporary repairs shall be made in a safe manner and in accordance with the manufacturer's instructions. As soon as practical, the temporary repairs shall be replaced in a permanent manner or welded permanently, if so designed. De-rating (lowering) the line's maximum operating pressure may be required until permanent repairs are made, depending on the conditions and the design of the temporary repair. For particularly sensitive or critical locations, the operator may consider leaving the repair excavation site open and maintain personnel onsite to monitor the temporary repair while it is in operation, until the permanent repair can be completed. ASME B31.4 specifically outlines recommendations that address these issues.

8.1.3 Hot Tapping

When pipe replacement or the clamping procedure is not feasible or sufficient to permit returning the line to service, hot tapping the line to provide a means of inserting plugs (stopples) to isolate the defective line section may be used (see API 2201). A bypass may be installed around the defect/release to permit continued operations while the defective section is drained and repaired. Consideration should be given to factors such as product characteristics, pipe condition, temperatures, and required differential pressures to ensure that the proper type of plug is used and that its holding capacity can adequately resist the pressure to be encountered. Only OQ qualified personnel trained for this operation should install and operate tapping and plugging equipment, or qualified representatives of the manufacturer should be available to assist.

8.1.4 Removal from Service

If it is feasible to remove the pipeline from service, repairs may be accomplished by hot tapping the line and installing a connection through which the pipeline's contents can be drained, vented, or flared, as in the case of a highly volatile liquids (HVL) line, to a place that is safe for disposal. Alternately, an inert gas such as nitrogen may be used to safely displace (purge) the contents of the pipeline system to a downstream location, for the purpose of repair or replacement. The potential energy of compressed gas, such as nitrogen, presents special concerns.

8.1.5 Section Replacement

After draining or purging has been completed and pressure has been reduced to atmospheric pressure, the line may be cold cut and the defective section replaced. Positive confirmation shall be obtained within the line of sight of the cold cut that the internal pressure has been reduced to zero before cutting the pipe. Contaminated soil and other material should be handled or disposed of in accordance with federal, state, and local requirements. When a portion of the line is to be removed, there are several methods of safely preparing the line for welding the new section into place. These methods include, but are not limited to, inert gas purging, mud plugging, ice plugging, and mechanical plugging. Each method has advantages and disadvantages based on the repair conditions. See API 2201 for more details.

8.1.6 Work Plan

In all cases a written work plan should be generated and communicated outlining the process, procedures and responsible parties required to complete the work in a safe manner. The plan should minimally include:

a) job hazard analysis;

b) review of hazards and plan with all individuals involved in the drain or purge;

c) notification of local authorities, hazmat agencies, and property owners who could be involved with noise or operational complaints/concerns;

d) maximum flow rate of the fluid being displaced;

e) maximum pressure requirements at the nitrogen injection or drain site;

f) maximum operating pressure of the pipeline system to be displaced;

g) nitrogen injection temperature and system temperature requirements;

h) inert gas handling and use precautions;

i) overpressure protection.

8.2 Available Repair Methods

The appropriate repair method selected shall be based upon the type, dimensions and severity of defect investigated and results of proper engineering analysis and evaluation.

NOTE Refer to ASME B31.4 and PRCI *Pipeline Repair Manual* for specific repair method installation guidelines and details.

Specific company specifications and procedures should be consulted to determine applicability of repair method selected.

a) Mechanically installed full-encirclement sleeve—Installed on a temporary or permanent basis to contain a leaking or near leaking condition. In some cases, the sleeve may be welded for permanent repair similar to requirements of Type B sleeves or by encapsulating with a domed fitting. Consult ASME B31.4, manufacturer's guidelines and PRCI manual for limitations of use.

b) Type A steel sleeve—Non-pressure containing steel sleeve with non-shrinkable epoxy filling any voids. The non-welded ends should be sealed to prevent water intrusion.

c) Type B steel sleeve—Pressure containing sleeve with welded ends and nonshrinkable epoxy filling any voids. Single sleeve or sleeve-on-sleeve arrangements. Considerations should be given to length of sleeve to install and fit up required. Adjacent sleeves shall adhere to minimum one half pipe diameter or 4 in. from a girth weld, whichever is greater, weld spacing to avoid notching effect. The internal design pressure of the sleeve material shall meet or exceed that of the carrier pipe.

d) Composite sleeve—Non-leaking defects with a depth <80 % and other types of anomalies approved. A written procedure and trained personnel shall be used for installation.

   — Cold applied—fiberglass resin reinforced coil system with non shrinkable epoxy filling voids and epoxy adhesive system.

   — Wet applied—Kevlar or other engineered fabric impregnated with epoxy adhesive. Engineered calculations are required to determine appropriate number of repair wraps to mitigate the defect identified.

   — Epoxy filled shell—Steel shell with a standoff distance from the pipe, with welded sides, non-shrinkable epoxy filler seals at the ends and epoxy injected into the interstitial space.

e) Grinding—Follow ASME B31.4 recommended limitations.

f) Deposited weld metal —Temper bead deposition technique may be well suited to complete this type of repair, limiting the potential for high heat affected zone (HAZ) hardness and hydrogen cracking.

g) Hot tapping—This technique should only be considered if the defect can be completely removed by the branch size selected of the hot tapping process and proper evaluation of the fitting fillet weld area conducted ensures that the pipe is free of additional defects and maintains adequate wall thickness to complete the planned welding safely.

h) Patches—Neither patches nor half soles shall be installed on pipelines. Refer to ASME B 31.4.

Use and installation of repair methods listed above shall adhere to the appropriate paragraphs of ASME B31.4 and PRCI manuals. Selection and use of a repair method should be the result of careful engineering review, analysis, and evaluation of the defect.

8.3 Safe Repair Steps

To ensure that the pipeline is repaired in a safe manner, the following steps and precautions should be taken.

a) Repair techniques used shall be in accordance with ASME B31.4.

b) OQ qualified personnel requirements shall be adhered to.

c) Repairs shall be performed under qualified supervision by trained personnel aware of and familiar with the hazards to personnel, the public, and the environment.

d) Calculations should be performed to determine the amount of pipe movement that is permissible during the proposed repair. These calculations should consider the pipe metallurgy so that proper pipeline support can be provided during the repair work. (See API 1117.)

e) Requirements for supporting pipe both during and after the repair should be determined to ensure that the pipe is not overstressed and to maximize safety.

f) All welding and testing shall be in accordance with ASME B31.4, ASNT SNT-TC-1A and API 1104. All welds shall be made by qualified welders using qualified procedures. Prior to welding pipe replacements, the internal surface of the pipe shall be inspected and documented.

g) When the carrier pipe is being welded, the wall thickness shall be confirmed through the use of ultrasonic measurement equipment or other suitable devices, to determine presence of adequate wall thickness and lack of laminations to confirm safe to weld.

h) All rectifiers in the area should be turned off, locked, and tagged. This includes the company rectifiers, as well as foreign pipeline rectifiers whose line is bonded to or passes in proximity to the line under repair.

i) Because of the possibility of electrical currents on the pipeline, an electrical bond should be made across all proposed points of separation before the line is cut or a flange joint is separated. If replacement pipe is required, the pipe joint or joints should also be bonded. The bond should not be removed until repairs have been completed. Where stray currents are present, it may be necessary to install a ground grid.

j) Line cuts, when required, should be made with mechanical cutters. Positive confirmation shall be obtained within the line of sight of the cut that the internal pressure has been reduced to zero before cutting the pipe. Removed defect area should be protected from further damage, well-marked, and stored in a controlled manner should additional third party defect testing and analysis be required.

k) Torch cutting may be considered, after the contents of the line have been positively confirmed, properly evacuated and an effective isolation barrier established to ensure that no hazardous vapors can enter the cutting area.

l) If welding is to be performed, all oils, products, and saturated earth should be removed both from within and around the excavation. It may be necessary to install a vapor barrier and spread uncontaminated dirt/sand around and on the bottom of the excavation.

m) The excavation and its surrounding area should be tested and continuously monitored with a combustible gas indicator or oxygen monitor, or both, to determine that the atmosphere is safe for such work.

n) Where vapor seals or plugs are used to prevent the escape of vapor from a pipeline, some positive method of venting or monitoring should be used to ensure against a pressure buildup in the line while hot work is in progress. Vents shall be confirmed open and periodically checked to confirm unobstructed prior to and during hot work activities.

o) If oil, product, or vapors enter the excavation after hot work is started, the work should be halted immediately, and the oil, product, or vapor removed or mitigation process identified and implemented. The atmosphere should be retested prior to continuing the hot work.

p) Upon completion of the repair, necessary inspections, tests, and operating checks should be made before placing the line in service.

q) All welds made in contact with carbon steel carrier pipe (e.g. Type B sleeve) shall be magnetic particle inspected no sooner than 12 hours after completion of the welding. Cracks that were removed by grinding or other stress risers shall be magnetic particle or dye penetrant inspected to ensure that all cracks have been removed.

9 Post-job Practices

After a repair job is completed, there are post-job considerations to ensure the effectiveness of the preplanning and the on-the-job plan execution is not compromised by improper work completion practices. The following checklist provides some of those considerations.

a) After all repair work is completed and inspected (including cure time for composite repairs), personnel at the control center should be notified that the line is ready for service.

b) All valves and circuit breakers should be unlocked and untagged and operated in accordance with company procedures and control center instructions. All affected personnel should be notified.

c) After startup, the line repair should be visually monitored for leaks until normal operation is restored.

d) All rectifiers should be untagged and turned on.

e) The pipe should be properly supported and coated per company guidelines.

f) The backfilling operation should be done in a careful manner so as not to damage any existing or new pipe coating and to affect good compaction. Adequate compaction techniques should be utilized to limit settling.

g) Following the completion of a permanent repair, the site should be restored.

h) Contaminated soil and other materials should be handled or disposed of in accordance with local, state, and federal regulations.

i) All documentation should be completed, including but not limited to, the type of repair made and the materials used, location of the repair, hydrostatic test information and welding records, the weld locations, any evidence of internal or external corrosion, nondestructive testing (NDT) records.

j) All DOT, 49 *CFR* Part 195, and any other federal, state, or local reporting requirements should be completed.

10 Special Considerations for Liquefied Petroleum Gas (LPG) or Other Highly Volatile Liquids Pipelines

10.1 Significant Characteristics and Their Related Problems

The preceding procedures are generally applicable to the repair of pipelines handling liquefied petroleum gas (LPG) or other highly volatile liquids, but personnel assigned to repair crews for pipelines should be well informed about the characteristics of the special materials that they may handle and the special problems that they may encounter if leaks occur. Repair crews should be aware of the upper and lower explosive limits of the vaporizing product. The most significant characteristics and their related problems are as follows.

a) The boiling points of LPG materials are well below usual ambient temperatures; therefore, any liquid released as a result of a leak usually converts rapidly to vapor. Further, releases of such a liquid or vapor can create an explosive atmosphere over a large area.

b) Since the vapors of LPG materials (like those of gasoline) are heavier than air and thus tend to remain close to the ground, the precautions outlined in the preceding sections are especially applicable to the potential hazards associated with LPG leaks.

c) Vaporization of leaking LPG may freeze the surrounding ground and pipeline appurtenances, and the danger exists that escaping gas could cause frostbite if it contacts exposed parts of the body.

d) The refrigerating effect of LPG on the ground can also cause difficulties in excavation.

e) Since LPGs have substantially greater volatility than crude oil or gasoline, additional precautions may be required when leaks occur.

f) Evacuation and isolation of LPG pipelines may require additional safety considerations. Vapor dispersal and accumulation during venting and drain down activities may limit effectiveness of conventional product evacuation techniques. Consideration should be given to utilizing portable flare units, if available and permitted by local or state regulations, to mitigate vapor accumulation. In situ flaring coupled with conventional drain down procedures may be effective tools in handling the unique LPG characteristics.

10.2 Precautions

Following the detection of a leak, the following precautions (not necessarily in the order shown) should be taken:

a) Eliminate all nearby ignition sources (especially those downwind of the leak) and evacuate adjacent areas that may be in danger.

b) Determine with a combustible gas indicator the extent of any explosive atmosphere in the area.

c) If conditions warrant, contact appropriate public officials for assistance in isolating the area, controlling traffic, evacuating nearby residential areas, and controlling spectators.

d) Review the characteristics of the specific LPG to determine the lower, upper explosive limits and personal exposure limits to determine appropriate level of PPE required to access and work in the release or work site.

Bibliography

[1] API Recommended Practice 1117, *Recommended Practice for Movement in In-Service Pipelines*

[2] API Standard 1160, *Managing System Integrity for Hazardous Liquid Pipelines*

[3] API Recommended Practice 1161, *Recommended Practice for Pipeline Operator Qualification*

[4] API Recommended Practice 1166, *Excavation Monitoring and Observation*

[5] API Recommended Practice 2009, *Safe Welding, Cutting, and Other Hot Work Practices in the Petroleum and Petrochemical Industries*

[6] API Recommended Practice 2201, *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*

[7] ASME B31Q, *Pipeline Personnel Qualification*

[8] ASME PCC-2*, Repair of Pressure Equipment and Piping*

[9] DOT Regulations [4], Title 49 *Code of Federal Regulations* Part 195: *Transportation of Hazardous Liquids by Pipeline*

[10] OSHA Regulations [5]*,* Title 29 *Code of Federal Regulations* Part 1910 and Part 1926

[4] Department of Transportation. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402. www.gpoaccess.gov

[5] U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov.

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