White Paper: Hose Assembly Mechanical Integrity Guidance for Cargo Tanks Used to Transport Sodium Hydroxide and Potassium Hydroxide (Caustic), Hydrochloric Acid, and Sodium Hypochlorite

Approved by the Transportation Issue Team on May 19, 2023

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1. INTRODUCTION

The purpose of this white paper is to provide guidance on maintaining the mechanical integrity of flexible hoses used to transfer sodium hydroxide solution (NaOH), potassium hydroxide solution (KOH), hydrochloric acid (HCl), and sodium hypochlorite (bleach) into/from cargo tanks. In this document, sodium hydroxide solution and potassium hydroxide solution will collectively be referred to as caustic or caustic solution. The guidance in this white paper represents a compendium of Institute membership experience.

The scope of this document results from The Chlorine Institute's (CI's) Transportation Issue Team's review of historical U.S. Department of Transportation (DOT) 5800 incident report data on incidents involving the release of caustic, HCl, and bleach. The majority of causes were due to the failure or mishandling of the flexible hose or fittings connections (may collectively be referred to as hose assemblies in this document). Figures 1.1, 1.2, and 1.3 provide a sample of this incident data during 2016-2020. Upon review of existing CI publications, the issue team determined that sufficient guidance did not exist that provides support for the prevention of such incidents.

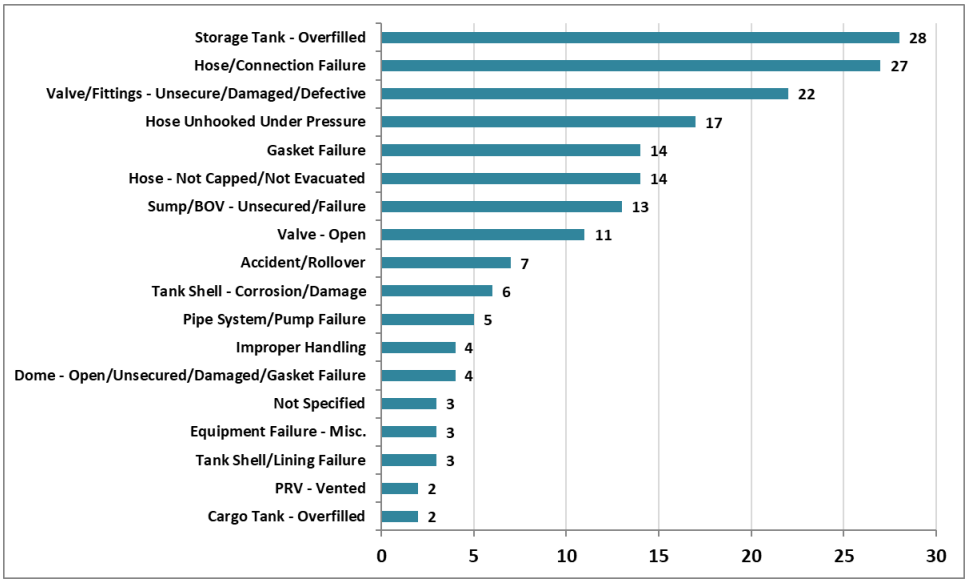

Figure 1.1
Cumulative Total of Caustic Cargo Tank Incident Causes, 2016-2020

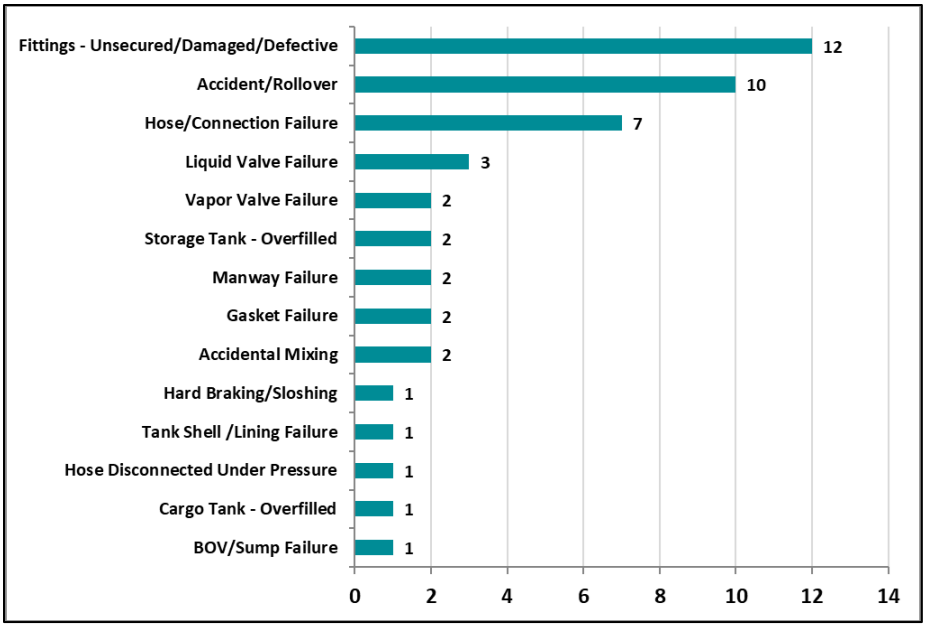

Figure 1.2
Cumulative Total of HCl Cargo Tank Incident Causes, 2016-2020

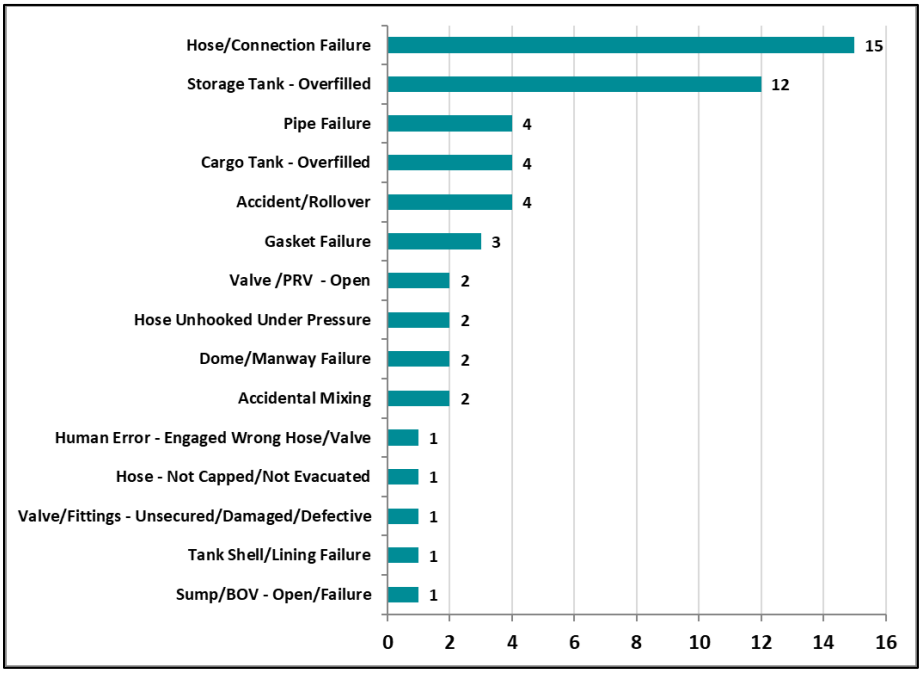

Figure 1.3
Cumulative Total of Bleach Cargo Tank Incident Causes, 2016-2020

Until this white paper guidance can be incorporated into the appropriate CI publications, it is recommended that this document be used in conjunction with the CI publications listed in Section 8.

2. DEFINITIONS

bend radius	The distance to the inside edge of the hose (not the center line) when making a 90° bend.
fitting	All items that are commonly called fittings, couplings, reducers, or adaptors that are used to connect the hose to be able to transfer materials.
hose assembly	Collectively the hose, fittings, and securement devices (clamp, ferrule, etc.) that create a system for safe transfer of product and the connection to fixed piping.
hydrostatic test	A test that subjects the hose to the action of internal water pressure under specified conditions to determine the effect of lower hydrostatic pressures in producing changes similar to those occurring in service.
maximum allowable working pressure	The manufacturer's specified maximum permissible pressure that the hose should be subjected to for normal operations. Canadian standards use the term "Hose Assembly Working Pressure" (HAWP), which may be used synonymously with "Maximum Allowable Working Pressure" (MAWP).
working pressure	The hose user's self-imposed limit on the pressure that a hose will be subjected to in a specified service that is less than the manufacturer's Maximum Allowable Working Pressure
hose safety restraint	A safety measure attached to a hose to prevent it from whipping in the event of an accidental disconnection during transfer or if the hose is intentionally disconnected while still under pressure. Sometimes also referred to as "whip check."
pressure cycling	Fluctuation of pressure which happens during normal operations.
thermal cycling	Fluctuation of temperature which happens during normal operations.

3. SELECTION & DESIGN CONSIDERATIONS

This section includes guidance and information on selection and design considerations when choosing hoses appropriate for the intended service. It is recommended that a user selects a reputable hose manufacturer and assembler/distributor to help ensure a good quality product is used in hazardous service. It is critical for the user to verify the design specifications are correct prior to purchasing and, once received, the hose specifications match the purchase order and are compatible in which the hose assembly is intended to be operated.

3.1 MATERIALS OF CONSTRUCTION

It is critical for the construction of flexible hose assembly material to be of metallic or non-metallic construction which is compatible with the commodity being transferred (see Figure 3.1 for an example result of incompatible hose fitting material).

Figure 3.1
Example Result of Using Incompatible Hose Fitting Material

Table 3.1 lists materials of construction used for the hose, fittings, and gaskets that are known to be used successfully in caustic, HCl, and bleach service.[1] These types of hoses are often layered, with an inner and outer core, which may or may not be the same compatible material, and they sometimes come with a middle layer of braided compatible material. For facilities that use a vapor connection during transfer, it is recommended to use the same hose assembly materials.

Table 3.1 Commonly Used Hose Assembly Materials of Construction[2]

Commodity	Hose	Fitting	Gasket[3]
Caustic	• Cross-linked polyethylene (XLPE) • Ultra-high molecular weight polyethylene (UHMWPE) • Stainless steel • Natural or synthetic rubber	• Stainless steel • Polypropylene (PP) • High-density polyethylene (HDPE)	• Ethylene propylene diene monomer (EPDM) • Nitrile • Neoprene • Santoprene
Hydrochloric Acid	• Natural or synthetic rubber • XLPE • Fiberglass & polyvinyl chloride (PVC) • Polytetrafluoroethylene (PTFE) • PP-lined composite • UHMWPE	• Polypropylene • Ultra-high molecular weight polyethylene • PTFE • PVC or CPVC • Lined or coated stainless steel (for wetted surfaces) • Beaded end w/ carbon steel or stainless steel backing flange (for non-wetted surfaces)	• PTFE • Fluoro-rubber (e.g., Viton) • Polyvinylidene fluoride (PVDF) • Neoprene • Santoprene • Natural Rubber

[1] Based on a survey of CI members in 2022.

Table 3.1 Commonly Used Hose Assembly Materials of Construction[2]			
Commodity	Hose	Fitting	Gasket[3]
Bleach	• PVC with synthetic braid • XLPE • UHMWPE • PTFE-lined	• PE • PP • Fiberglass reinforced plastic (FRP) w/ PE • PTFE • PVC • Lined or coated stainless steel (for wetted surfaces)	• EPDM • Fluoro-rubber (e.g., Viton) • PVDF • PTFE • Nitrile • Santoprene

[2] It is critical to consider the solution concentration and expected operating pressures and temperatures when considering materials of construction for the various hose assembly components.
[3] Facilities and carriers might currently use materials not included in this list. However, that does not preclude them from continuing use of the material. For this reason, users are recommended to maintain inspection and operation records for hose assembly materials to provide evidence of successful use based on performance and reliability.

3.2 PRESSURE & TEMPERATURE RATINGS

Choose a hose with an appropriate pressure and temperature rating based on the conditions in which it will be used. The Maximum Allowable Working Pressure (MAWP) (often referred to as the Hose Assembly Working Pressure (HAWP) in Canada) is the hose manufacturer's specified maximum permissible pressure that the hose should be subjected to for normal operations. Typically, the user operates at a working pressure that is less than the manufacturer's MAWP. The rating a user chooses should at least be equal to the setting of the pressure relief device on the shipping container or transfer system to which the hose is attached. The style of fittings used may be a limiting design consideration for the hose assembly working pressure rating. A user should operate hoses within the pressure limits of the hose or fitting (i.e., operating within the lower pressure rating of the two) established by the hose/fitting manufacturer or the assembler.

When using a pump for transfer, hoses must not collapse or deform when subjected to full vacuum at room temperature in any configuration. It is recommended to consult the hose manufacturer for vacuum capabilities at elevated operating temperatures.

3.3 CONNECTION STYLES

A camlock fitting or flanged hose end is recommended for connecting the flexible hose to the hard process piping system (see Figures 3.2(a), 3.2(b), and 3.3 for examples).

Figure 3.2(a)
Camlock Hose Fitting
(Female End)

Figure 3.2(b)
Camlock Hose Fitting
(Male End)

Figure 3.3
Flanged Hose Fitting

There are several ways of securing the fitting to the hose end, such as the use of crimped ferrules (preferred) (Figure 3.4), sleeves (Figure 3.5), or pre-formed band clamps (see Figure 3.6). Worm-gear clamps are not recommended.

Figure 3.4
Crimped Ferrule

Figure 3.5
Crimped Sleeve

Figure 3.6
Band Clamp

These components need to be appropriately sized for the hose on which it will be used to ensure effective operation and reduce the likelihood of leaks. Hose manufacturers typically provide recommendations for selecting the accompanying parts.

3.3.1 Additional Connection Safety Measures

Secondary locking mechanisms, such as locking cam arms (Figure 3.8) or Velcro®-style straps (see Figure 3.9), are often used to secure the transfer hose to the facility's fitting and piping to prevent accidental disconnection during transfer. Hose safety restraints (sometimes referred to as "whip checks") (see Figure 3.7) are also recommended to prevent a hose from whipping in the event of an accidental disconnection or if the hose is disconnected while still under pressure.

Figure 3.7
Hose Safety Restraint (i.e., "Whip Check")

Figure 3.8
Locking Cam Arms

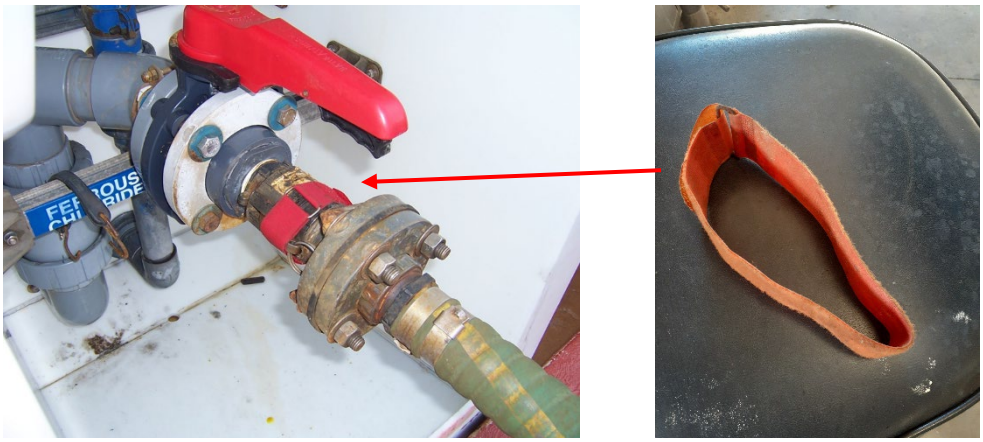

Figure 3.9
Hose Fitting Velcro-Style Strap

3.4 DIMENSIONS

The most common diameter size used for a chemical transfer hose is 2 inches, but usually not less than 1 inch or larger than 3 inches. It is ideal for the hose to be the same size as the piping it will be connected to. If the hose and pipe are different sizes, a reducer attachment will likely be needed.

The length of a hose is dependent on the loading or unloading set-up. It should be just long enough to allow ample movement for handling, without sharp bends, but not so long it impedes handling and operation.

3.5 OTHER DESIGN CONSIDERATIONS

Hose supports, such as slings (see Figure 3.10) or jack stands (see Figure 3.11), should be considered to help reduce stresses on the hose and fittings connections. They should be designed in such a manner that the hose is not subject to a bend radius less than the manufacturer's specifications.

Figure 3.10
Hose Sling

Figure 3.11
Hose Jack Stand

4. MARKING & STORAGE

4.1 MARKING

It is recommended that each hose be identified with the following information, permanently attached to the hose, by coating, stenciling, stamping, or tagging:

- A unique serial number (or other unique identifying number), assigned by the final hose assembler that can be used to obtain hose documentation.
- The final assembler company's name.
- The date of final assembly (month and year).
- Date of subsequent testing (month and year).
- The minimum allowable bend radius.
- The MAWP (the lower of the hose or fitting - see Section 3.1).

Clearly marking hoses allows for effective record keeping during the life of the hose and helps distinguish which products or services for which specific hose assemblies are used.

Federal regulations or standards may exist for hose assemblies used in certain services. It is prudent of the user to review all applicable regulations and standards.

4.2 STORAGE

While not in use, it is critical that hoses and hose assemblies be stored in a manner that they will avoid being damaged or contaminated. Conditions to avoid include kinking, sharp bends, extreme temperatures, corrosive fumes or liquids, oxidizing fumes or liquids, oils, solvents, or ozone. Hose assemblies should also be safely secured from movement and capped (see Figure 4.1) to prevent contaminants entering the hose or product escaping (see Figure 4.2) and potentially harming personnel or the environment.

Figure 4.1
Capped Camlock Hose Fitting

Figure 4.2
Liquid Escaping from Uncapped Hose

5. PROPER HANDLING & CARE

5.1 PROPER HANDLING

Operators should be trained in the proper handling and identification of hose assemblies to avoid damage and contamination. Hose ends should not be dropped on the ground or banged against other equipment, because it can cause damage to the fittings or loosening between the fitting and hose. Hoses should be dragged as little as possible to avoid excessive abrasions. It is critical that operators use the correct hose to transfer the correct product in order to prevent cross-contamination or unintended chemical reactions. Mishandling or excessive use of hose assemblies can impact the length of its useful life. Other conditions that can also affect a hose's useful life include excessive pressure cycling, thermal cycling, or exceeding the minimum dynamic bend radius (sample bend radius shown in Figure 5.1).

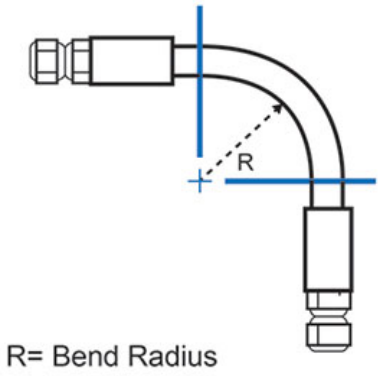

Figure 5.1
Sample Diagram of Flexible Hose Bend Radius

5.2 CLEANING

Prior to first use and prior to storing, the inside of the hose should be cleaned to remove any residual product or contaminants. Water, without cleaning solution, is usually sufficient. If a cleaning solution is used, ensure it is mild and not reactive with the hose assembly materials. After cleaning, each end of the hose should be securely capped until next use. Attaching a tag indicating the hose is clean from hazardous residue may also be beneficial.

6. PREVENTATIVE MAINTENANCE

The useful life of a hose assembly depends on how well it is handled and how often it is used. An effective preventative maintenance program, with regular inspections and testing, aids in extending the useful life of a hose assembly. Hose manufacturers typically provide recommendations for inspection and testing, which should be strongly considered in a user's defined preventative maintenance program. Also, a user needs to consider reviewing performance reliability data based on defects or failures as part of establishing an effective preventative maintenance program and inspection intervals.

6.1 ROUTINE INSPECTION

It is recommended to visually inspect hose assemblies before and after each use for adverse conditions. Conditions to look for include:

- Cracks, cuts, tears, abrasions, discoloration, flattened areas, bulges, blistering, kinks, or elongation in the hose.
- Fittings are not loose, cracked, bent, distorted, badly worn, or other compromising damage.
- The correct number of hose bands/crimps that are the correct style, tight, and undamaged.
- Reinforcement wires/braids are not frayed, worn, ballooned, bunched, exposed or protruding at the fittings or anywhere along the hose.
- No corrosion on any part of the hose assembly.
- Gaskets are present in female connectors and are undamaged, not cracked, have no wear grooves, and are pliable.
- The hose is correct for the product to be transferred, clean (or dedicated for the specific product) and ready for use.
- Hose markings are present with all required information and are legible.

See Appendix A for examples unsafe hose assembly conditions. The hose or its components should be replaced if any conditions are identified that could potentially result in leaking product or an otherwise unsafe operation (see Figure 6.1 for an example of a defective hose being used for the transfer of product).

Figure 6.1
Example of Defective Hose Used for Transfer

It is recommended that hose assembly, including gaskets and any attachments, inspection be included as part of a loading/unloading checklist, as well as a separate inspection checklist for times when the hose assembly is inspected outside of regular loading and unloading events.

A more robust inspection process is also commonly conducted on a less frequent interval, by a certain number of months or annually, at most. The appropriate frequency at which the transfer hoses are inspected depends on the operating conditions, product temperature, and environment in which they are used.

6.2 PERIODIC TESTING

It is recommended that the user conduct a pressure test of the hose assembly prior to first use and establish a defined testing frequency thereafter. Hoses taken out of storage should also be tested prior to placing it back into service.

At a minimum, users should follow the hose manufacturer's recommendations for periodic testing. These recommendations may include a minimum test pressure (typically a certain percentage over the MAWP/HAWP), recommended test method/medium (hydrostatic or gas), duration of the test, and other test instructions. It is recommended that the user maintains test records that include details such as test pressure, method, duration, and results. The person that performed the test should be identified and sign the test record. Hoses should also be marked accordingly after each test.

Operating conditions, product temperature, and environment may affect the appropriate testing interval. Based on a survey of CI members, the most common testing interval is annual. The hose or its components should be replaced if the test results in failure (i.e., leakage or damage).

6.3 REPLACEMENT FREQUENCY

Hoses should be replaced, as needed, based on adverse results from routine inspections and testing. The user may also consider a defined replacement interval based on experience with the typical useful life of hoses assemblies in certain product services. Hose manufacturers may also provide a recommended useful service life of its hoses.

7. TRAINING

Persons involved in the manufacture, assembly, use, inspection, and testing of hose components and assemblies should be trained in the procedures pertaining to their respective activities. An employer should establish a routine interval for training its employees involved in the loading and unloading of caustic, HCl, and bleach (annually is common). Training on activities pertaining to the identification, use, inspection, and testing of hose assemblies, including gaskets and any attachments, may be included in an employee's function-specific, competency-based training required by regulation.

8. DOCUMENTATION

It is recommended to save the following documentation in company records for a period of time:

- Over the life of the hose:
  - Information on hose manufacturer and assembler.
  - Design specifications of hose assembly components (e.g., materials of construction, dimensions, pressure rating, temperature rating, etc.).
  - Inspection and test records.
- Employee training records (per company policy).

These records should be readily accessible so they may be provided quickly to an authorized requesting party.

9. REFERENCES

9.1 CHLORINE INSTITUTE REFERENCES

This document is recommended to be used in conjunction with the following publications, as appropriate. The latest editions of CI publications may be obtained at http://www.chlorineinstitute.org/:

Publication #	Title
88	*Recommended Practices for Handling Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic) in Bulk Highway Transports*, ed. 5; Pamphlet 88; The Chlorine Institute: Arlington, VA, **2022**.
96	*Sodium Hypochlorite Manual*; ed. 5; Pamphlet 96; The Chlorine Institute: Arlington, VA, **2017**.
150	*Recommended Practices for Handling Hydrochloric Acid in Bulk Highway Transports*; ed. 4; Pamphlet 150; The Chlorine Institute: Arlington, VA, **2020**.
CTS-VIDEO	*Preventing Chlor-Alkali Releases During Cargo Tank Operations*; ed. 1; CTS-VIDEO; The Chlorine Institute: Arlington, VA, **2020**.
HCL-VIDEO	*Handling Hydrochloric Acid Safely*, ed. 2; HCL-VIDEO; The Chlorine Institute: Arlington, VA, **2015**.
HCS-VIDEO	*Handling Caustic Safely*, ed. 1; HCS-VIDEO; The Chlorine Institute: Arlington, VA, **2020**.
HYPO-VIDEO	*Handling Sodium Hypochlorite Safely*, ed. 2; HYPO-VIDEO; The Chlorine Institute: Arlington, VA, **2015**.

9.2 U.S. & CANADIAN FEDERAL STANDARDS & REGULATIONS

9.2.1 *Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide*; Pipeline and Hazardous Materials Safety Administration; U.S. Department of Transportation: Washington, DC. Website: https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/ctmv_pocket_guide_short_09212015.pdf

9.2.2 *Code of Federal Regulations*; Title 49; Parts 105-180 and Parts 300-399; Office of the Federal Register National Archives and Records Administration; U.S. Government Printing Office: Washington, DC, (revised annually). Website: https://www.ecfr.gov/cgi-bin/text-idx?SID=1d49a3b137cb1b6fc45251074e634b44&tpl=/ecfrbrowse/Title49/49tab_02.tpl

9.2.3 *Highway Tanks and Portable Tanks for the Transportation of Dangerous Goods*; CSA B620; Canadian Standards Association: Mississauga, Ontario. Website: https://tc.canada.ca/en/dangerous-goods/containers/tank-trucks-trailers-tc-portable-tanks/standard-csa-b620-highway-tanks-tc-portable-tanks-transportation-dangerous-goods

9.2.4 *Selection and Use of Highway Tanks, Portable Tanks, Cargo Compartments and Containers for the Transportation of Dangerous Goods Class 3, 4, 5, 6.1, 8 and 9*; CSA B621; Canadian Standards Association: Mississauga, Ontario. Website: https://tc.canada.ca/en/dangerous-goods/csa-b621

9.3 ASTM INTERNATIONAL

9.3.1 *Rubber and Plastic Hoses and Hose Assemblies – Determination of Resistance to Vacuum*; ISO 7233:2021; ASTM International: Washington, DC, **2021**.

9.3.2 *Rubber and Plastic Hoses and Hose Assemblies – Hydrostatic Testing*; ISO 1402:2021; ASTM International: Washington, DC, **2021**.

9.3.3 *Rubber and Plastic Hoses and Tubing – Measurement of Flexibility and Stiffness – Part 1: Bending Tests at Ambient Temperature*; ISO 10619:2017; ASTM International: Washington, DC, **2017**.

9.4 OTHER INDUSTRY REFERENCES

9.4.1 *Hose Safety Institute© Handbook: Design and Specification of Hose Assemblies*; ver. 1.3; Hose Safety Institute; National Association of Hose Distributors: Annapolis, MD.

10. DISCLAIMER

The information in this white paper is drawn from sources believed to be reliable. The Chlorine Institute and its members, jointly and severally, make no guarantee, and assume no liability, in connection with any of this information. Moreover, it should not be assumed that every acceptable procedure is included or that special circumstances may not warrant modified or additional procedures. The user should be aware that changing technology may require a change in the recommendations herein. Appropriate steps should be taken to ensure that the information is current when used. These suggestions should not be confused with federal, state, provincial, municipal, or insurance requirements, or with national safety codes.

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APPENDIX A – EXAMPLES OF UNSAFE HOSE ASSEMBLY CONDITIONS

Hose Abrasion

Hose Abrasions

Hose Blistering

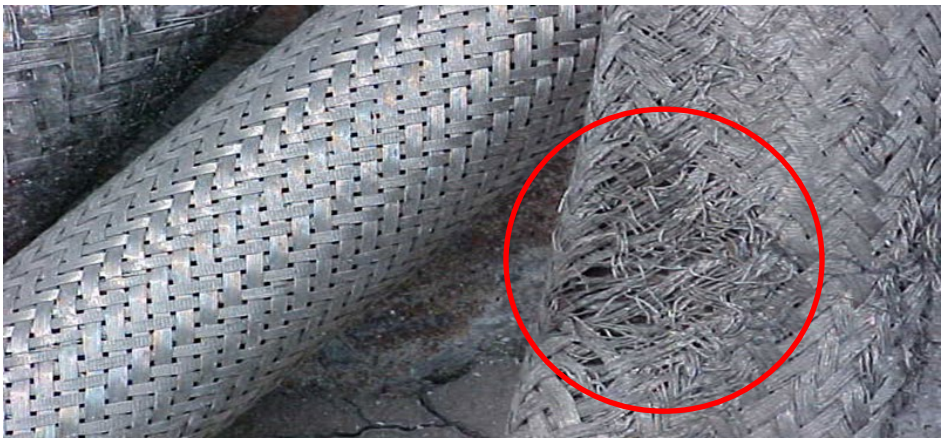
Gouge on Hose Exterior

Wear & Tear of Exterior Hose Covering

Flat Spot in Hose & General Wear

Cut Exposing Interior Reinforcement Layer

Defective Internal Lining

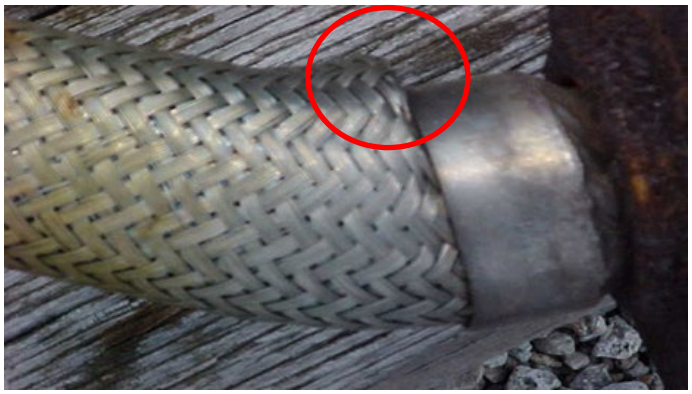


Fraying of Braided Wire

“Blow Out” Through Multiple Hose Layers

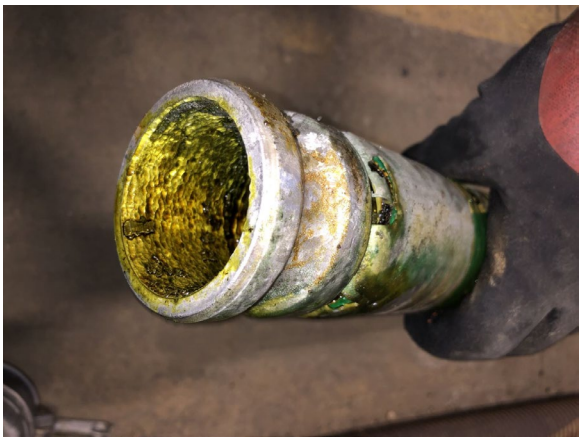
Kinked Hose

Kinked Hose

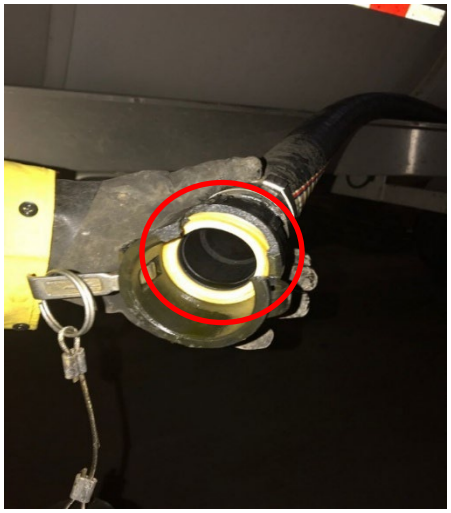


Kinked Hose at Fitting End

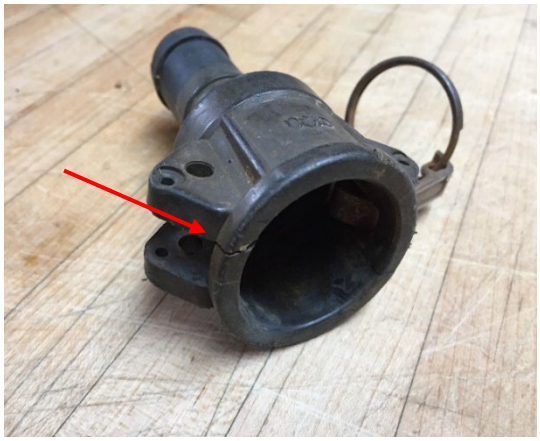
Debris at Connection End



Interior Corrosion of Fitting



Broken Camlock Fitting



Cracked Camlock Fitting

Cracked Flanged Fitting

Missing Fitting Gasket

Missing Band Clamp (Remaining Impression Shown)