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RECIPROCATING CRYOGENIC PUMPS AND PUMP INSTALLATIONS FOR HYDROGEN AND LIQUEFIED NATURAL GAS

FIRST EDITION

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PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published CGA P-96, *Reciprocating Cryogenic Pumps and Pump Installations for Hydrogen and Liquefied Natural Gas*, jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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1 Introduction

Reciprocating cryogenic pumps are key components in hydrogen and liquefied natural gas (LNG) service. To ensure that pumps operate both safely and reliably in liquefied flammable gas service, it is important that reciprocating pumps are correctly designed, installed, operated, and maintained as required for the duty.

Pumping these fluids is accompanied by some degree of hazard. The hazards include liquid under pressure, cryogenic temperatures, volume and pressure increases due to vaporization, and flammability of the vapor.

This publication contains a summary of industrial practices and is based on the combined knowledge, experiences, and practices of industrial gas and equipment suppliers to manage these hazards.

2 Scope and purpose

This publication covers cryogenic reciprocating pumps and pump installations for hydrogen and LNG service.

The information contained in this publication only applies to new installations designed after the publication of this document and not to existing installations. However, the information contained in this publication may benefit existing installations or those in the project phase.

This publication does not cover:

- Cryogenic reciprocating pumps and installations for liquid oxygen, argon, and nitrogen, which are covered in CGA P-48, *Reciprocating Cryogenic Pumps and Pump Installations for Oxygen, Argon, and Nitrogen* [1];¹
- Centrifugal liquid oxygen pumps, which are covered in CGA G-4.7, *Stationary, Electric-Motor-Driven, Centrifugal Liquid Oxygen Pumps* [2]; and
- Carbon dioxide pumps, which are covered in CGA G-6.3, *Carbon Dioxide Cylinder Filling and Handling Procedures* and EIGA Doc 83, *Recommendations for Filling of Cylinders and Bundles with Carbon Dioxide* [3, 4].

3 Definitions

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 the procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

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

3.1.5 Can

Indicates a possibility or ability.

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

3.2 Technical definitions

3.2.1 Cavitation

Phenomenon that occurs when the pressure of a liquid drops to less than the vapor pressure of the liquid at a certain temperature. At this point, liquid vaporizes, thereby creating vapor bubble(s). These bubbles can cause a pump to lose prime or suffer heavy vibration and damage.

3.2.2 Cold end

Pump assembly, typically cylindrical, through which the cryogenic liquid passes and is elevated in pressure.

3.2.3 Cryogenic reciprocating pump

Motor (single, two, or variable speed) belt drive, gear drive, hydraulic drive, or direct couple assembly, warm end (crank drive), and one or more cold end.

3.2.4 Distance piece

Extended spacer or carrier frame between the cold end and the warm end.

NOTE—A distance piece is used to provide a thermal barrier and a physical separation between the process and the drive mechanism.

3.2.5 Classified area

Location in which a combustible gas is or can be present in the atmosphere in sufficient concentrations to produce an ignitable mixture.

3.2.6 Loss of prime

Loss of liquid flow to and/or through the pump.

3.2.7 Net positive suction head available (NPSHa)

Margin of difference (measured in height) between the actual pressure of a liquid flowing into a pump and the vapor pressure of the liquid.

3.2.8 Net positive suction head required (NPSHr)

Pressure or energy required at the pump to overcome frictional losses from the inlet into the cylinder without causing vaporization.

NOTE—NPSHr is determined by the pump manufacturer.

3.2.9 Purge gas

Ambient temperature, dry (dew point of -40°F (-40°C) or less), oil-free, particle-free, and carbon dioxide-free (less than 3 ppm) nitrogen or argon used to sweep away or prevent concentrated oxygen or moisture laden air.

3.2.10 Warm end

Mechanism such as a crank case box that drives the piston in the cold end.

4 Description of a reciprocating cryogenic pump and pump installation and components

A general arrangement of a cryogenic pump installation typically consists of a vacuum-insulated cryogenic tank, reciprocating pump, a vaporizer, and interconnecting and delivery piping. An example of a general arrangement of a typical cryogenic pump installation is shown in Figure 1. Cryogenic pumping systems shall be designed to ensure that required controls and safety elements are used in accordance with the application of the system.

Typical applications include fueling stations for vehicles and filling of compressed gas cylinders. However, there are other applications where high pressure gas or cryogenic fluid is required.

In most cases, the pump is supplied with liquid from a vacuum-insulated cryogenic tank consisting of an inner vessel and an outer jacket. There are two main types of vacuum-insulated cryogenic tanks used in cryogenic reciprocating pump installations. One type is a thermosiphon tank. The other is a conventional use tank. Both tanks are described in more detail in 5.1.

The reciprocating pump increases the pressure of the cryogenic fluid to the required pressure of operation, as described in 5.2.

If the product is required as a gas, then the product passes through a vaporizer to convert it from liquid to the gaseous phase. Vaporizers can be ambient relying on surrounding air to vaporize the product or there may be an external heat source such as hot water, steam, electricity, or hot air.

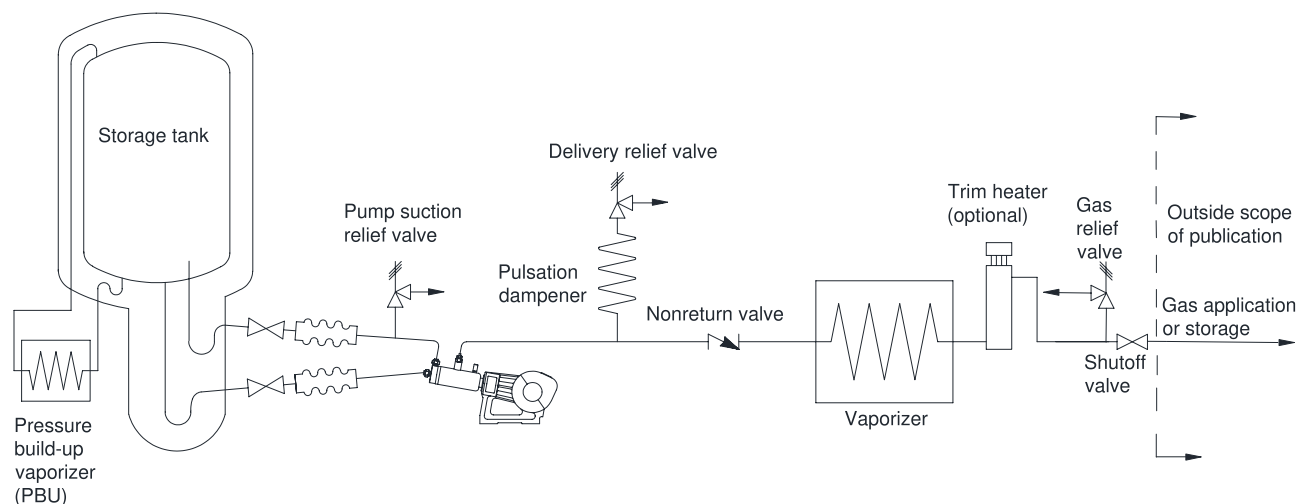


Figure 1—Example of a general arrangement of a typical cryogenic pump installation

5 Description of individual components

5.1 Tanks

Installations can use a thermosiphon tank or a conventional tank with dedicated pump feed and return piping. A simplified piping arrangement for a thermosiphon tank and a conventional tank are described in 5.1.1 and 5.1.2.

Tanks and related piping shall be designed to ensure that required controls and safety elements are used in accordance with the application of the system.

5.1.1 Thermosiphon tank

An example of a simplified thermosiphon tank piping arrangement is shown in Figure 2.

The pump feed and return piping ensures good suction conditions to the pump when running and during standby. The rate of tank pressure rise and therefore vent losses are reduced.

The thermosiphon tank design incorporates both the suction and return pipes in a vacuum-insulated jacket extension that descends from below the tank to a point almost level with the ground.

The pump suction pipe descends from the center of the inner vessel to a low point within the vacuum-insulated jacket extension. This pipe then rises and exits the vacuum jacket, continually rising towards the pump. A liquid return from the pump suction rises back towards the vacuum-insulated jacket extension. After penetrating the vacuum jacket, it is then connected to the inner vessel bottom head. The return connection is usually made closer to the inner vessel outer diameter than the suction feed. The return pipe is usually extended internally up from the bottom head to ensure that the warmer return liquid rises away from the lower pump suction feed nozzle.

Shallow gas traps are included on both feed and return pipes within the vacuum-insulated jacket extension to stop external pipes from retaining cryogen and thereby icing when a pump is isolated.

Heat gained in the external pump piping reduces the cryogenic liquid density sufficiently to generate a thermosiphon circulation of liquid from suction to return piping even when the pump is not running.

For effective operation, designers should ensure that a sufficient height difference exists between suction and return tank connections, ensure that the pipe slopes are preserved, and keep the depth of internal gas traps to a minimum.

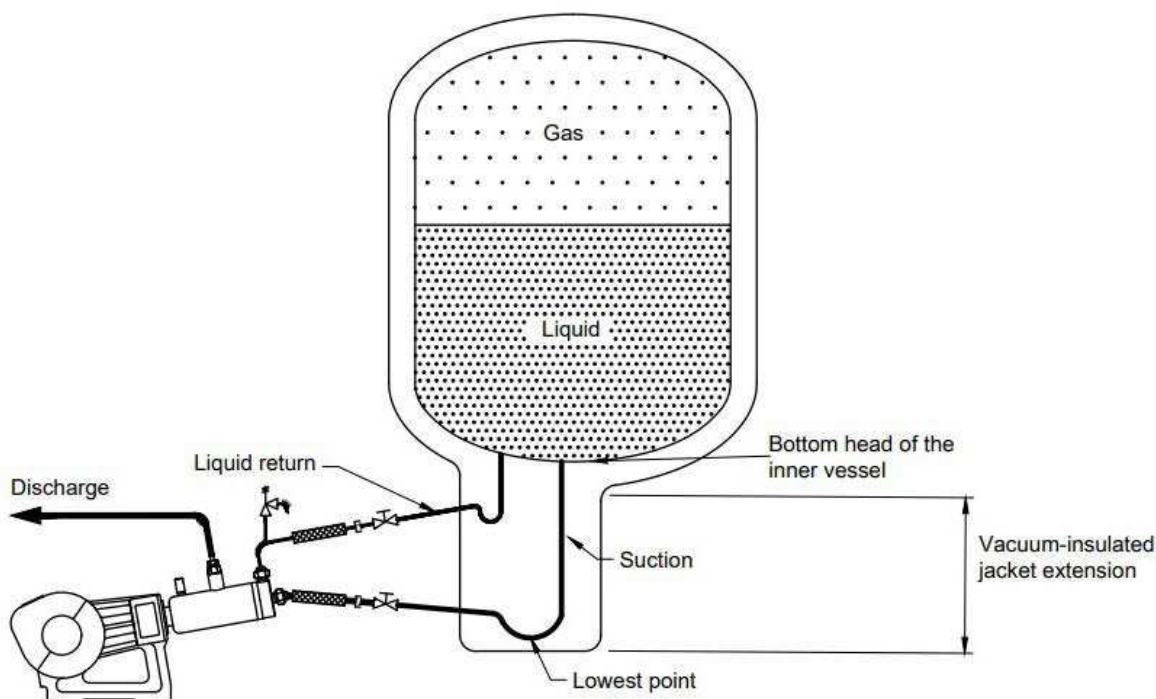


Figure 2—Example of a simplified thermosiphon tank piping arrangement

5.1.2 Conventional tank

An example of a simplified conventional tank piping arrangement is shown in Figure 3.

The pump suction feed is from a pipe dedicated for this purpose and is typically vacuum-jacketed piping for hydrogen service. A suction vapor return line allows vaporized liquid to flow to the top head of the inner vessel.

Depending on the actual pipe routing between the inner and outer vessel, the disadvantage of this liquid feed-vapor return arrangement for tanks with nonvacuum insulated pump feed lines can be that once the tank level falls below a certain level, the feed to the pump effectively becomes a long single pipe containing at least one gas trap. If the pump shuts down for even a short period, the liquid in the suction piping rapidly reaches its boiling point and the pipe becomes vapor locked.

If venting is required to achieve pump priming, it shall be done in a safe manner to an appropriately designed vent circuit.

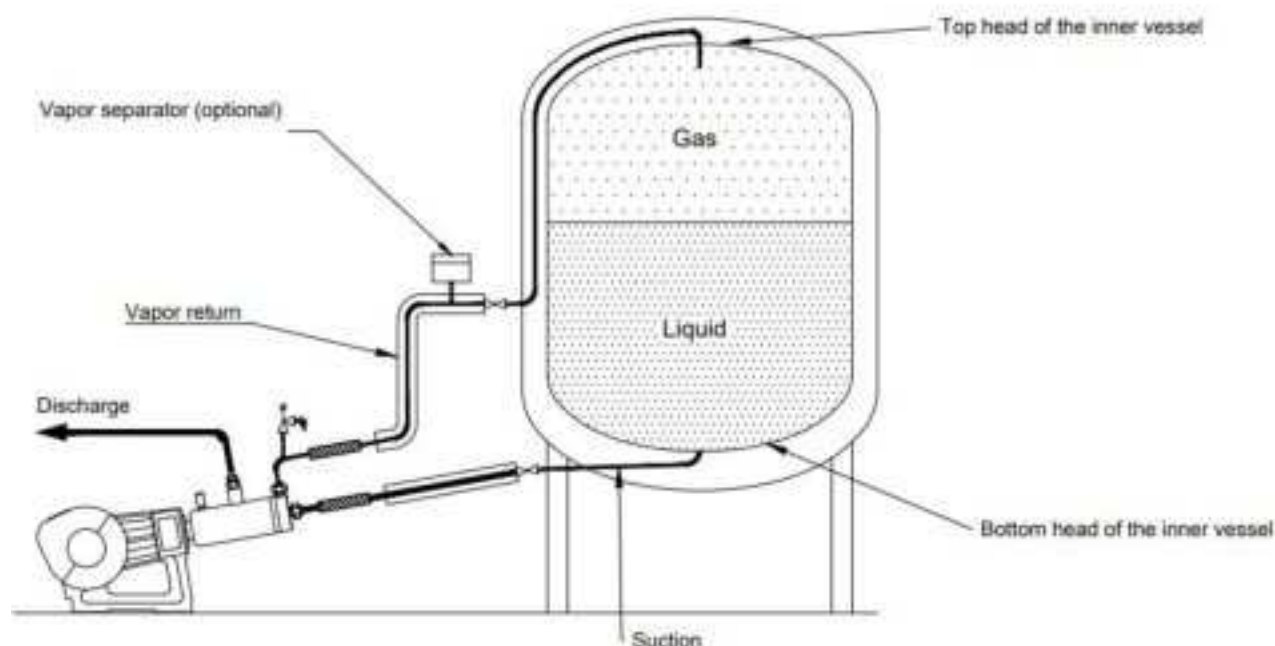


Figure 3—Example of a simplified conventional tank piping arrangement

5.2 Pump

A variety of pump configurations are in use. Typical cryogenic reciprocating pump components are shown in Figure 4 and recommended materials are covered in Section 6. Figure 5 shows a typical cold- and warm-end assembly.

A means for vapor escape for pump priming is required; typically, back to the storage tank.

The pump is usually driven by an electric motor, which shall be rated in accordance with applicable regulations (for example, NFPA 70, *National Electrical Code*®; ATEX Directive 2014/34/EU, *Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres*) for the location in which it is installed [5, 6]. Any drive belts shall be static conducting and oil resistant.

The pump shall be installed with appropriate safety features depending on which flammable liquid is to be pumped and according to its location. Area classification shall be defined by the user and transmitted to the manufacturer so that an adequate level of protection can be provided.

The user may accept international standards for electrical and mechanical equipment that meet or exceed local codes and regulations. These standards define requirements for protection against ignition of a surrounding explosive atmosphere. Potential ignition sources include leaks, releases, hot surfaces, electromagnetic radiation, mechanically generated sparks, friction, mechanical impacts, electrical arcing, and static electric discharge.

The electrical components (for example, motor, instrumentation, heater, etc.) shall be certified by the manufacturer for use in the area classification in which it will be installed. Mechanical components and their assembly shall be subject to an ignition hazard assessment taking into account the normal functioning of the equipment as well as potential failure modes.

The user shall also specify the ambient temperature range as well as the temperature class, which is the maximum surface temperature permitted.