



CGA P-40—2017
CALCULATION METHOD FOR
THE ANALYSIS AND
PREVENTION OF
OVERPRESSURE DURING
REFILLING OF CRYOGENIC
TANKS WITH RUPTURE DISK(S)

FOURTH EDITION

PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published CGA P-40, *Calculation Method for the Analysis and Prevention of Overpressure During Refilling of Cryogenic Tanks with Rupture Disk(s)*, 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.

PLEASE NOTE:

The information contained in this document was obtained from sources believed to be reliable and is based on technical information and experience currently available from members of the Compressed Gas Association, Inc. and others. However, the Association or its members, jointly or severally, make no guarantee of the results and assume no liability or responsibility in connection with the information or suggestions herein contained. Moreover, it should not be assumed that every acceptable commodity grade, test or safety procedure or method, precaution, equipment or device is contained within, or that abnormal or unusual circumstances may not warrant or suggest further requirements or additional procedure.

This document is subject to periodic review, and users are cautioned to obtain the latest edition. The Association invites comments and suggestions for consideration. In connection with such review, any such comments or suggestions will be fully reviewed by the Association after giving the party, upon request, a reasonable opportunity to be heard. Proposed changes may be submitted via the Internet at our web site, www.cganet.com.

This document should not be confused with federal, state, provincial, or municipal specifications or regulations; insurance requirements; or national safety codes. While the Association recommends reference to or use of this document by government agencies and others, this document is purely voluntary and not binding unless adopted by reference in regulations.

A listing of all publications, audiovisual programs, safety and technical bulletins, and safety posters is available via the Internet at our website at www.cganet.com. For more information contact CGA at Phone: 703-788-2700, ext. 799. E-mail: customerservice@cganet.com.

Work Item 16-049
Bulk Distribution Equipment and Standards Committee

NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendix A (Normative) is a requirement.

NOTE—Appendices B, C, D, and E (Informative) are for information only.

FOURTH EDITION: 2017
THIRD EDITION: 2011
SECOND EDITION: 2007
FIRST EDITION: 2004

© 2017 The Compressed Gas Association, Inc. All rights reserved.

All materials contained in this work are protected by United States and international copyright laws. No part of this work may be reproduced or transmitted in any form or by any means, electronic or mechanical including photocopying, recording, or any information storage and retrieval system without permission in writing from The Compressed Gas Association, Inc. All requests for permission to reproduce material from this work should be directed to The Compressed Gas Association, Inc., 8484 Westpark Drive, Suite 220, McLean, VA 22102. You may not alter or remove any trademark, copyright or other notice from this work.

Contents	Page
1 Introduction.....	1
2 Scope	1
3 Definitions.....	1
4 Nomenclature	2
5 Preventing overpressurization.....	3
5.1 Methods.....	3
5.2 External protection device	4
5.3 Tank fill and relief system	4
6 Calculations.....	5
6.1 Step 1: Input tank and piping data.....	5
6.2 Step 2: Determine tank upper pressure limit, UPL	5
6.3 Step 3: Determine maximum frictional pressure loss through the relief system, ΔP_{rel_max}	6
6.4 Step 4: Determine flow resistance of the pressure relief system, K_{rel}	6
6.5 Step 5: Calculate maximum flow rate through the relief system, Q_{rel_max}	6
6.6 Step 6: Determine flow resistance of the truck and tank fill system, K_{truck} and K_{fill}	7
6.7 Step 7: Determine pressure loss through the fill system, ΔP_{fill_line}	7
6.8 Step 8: Determine fill line orifice pressure drop, ΔP_{ori}	7
6.9 Step 9: Determine required fill orifice flow resistance, K_{ori} and size, d_{ori}	8
7 References	8
 Table	
Table 1—Definition of variables	2
 Figure	
Figure 1—System configuration	4
 Appendices	
Appendix A—Equation sets for the analysis and prevention of overpressure during refilling of cryogenic storage tanks (Normative).....	10
Appendix B—Sample calculation 1—orifice is required (Informative).....	13
Appendix C—Sample calculation 2—orifice is not required (Informative).....	24
Appendix D—Blank calculation forms for the analysis and prevention of overpressure during refilling of cryogenic storage tanks (Informative).....	35
Appendix E—Reference data (Informative)	45
 Appendices Figures	
Figure B-1—Sample calculation 1—relief line sketch	13
Figure B-2—Sample calculation 1—fill line sketch.....	13
Figure C-1—Sample calculation 2—relief line sketch	24
Figure C-2—Sample calculation 2—fill line sketch	24
 Appendices Tables	
Table E-1—Liquid density	45
Table E-2—Overall height for typical tanks	45
Table E-3—Pipe and tube inside diameters and inside diameters to the 4th power.....	46
Table E-4—Typical hydraulic truck pump performance	47
Table E-5—Fill line orifice sizes and flow resistance coefficient referenced to 1.481 in (37.6 mm) internal diameter	47

This page is intentionally blank.

1 Introduction

Cryogenic transports often use pumping systems that discharge product at pressures exceeding the working pressure of the liquid storage tank being filled. In North America, pumping systems for transferring oxygen, nitrogen, or argon are typically capable of delivering pressures greater than 400 psi (2760 kPa).^{1,2} The cryogenic storage tank being refilled usually has a maximum allowable working pressure (MAWP) that is considerably less than the pump discharge pressure. Depending on the inherent tank design safety factors and the size and flow capacity of the tank pressure relief system, the potential to overpressure the tank during operator-attended manual refill operations exists. CGA P-59, *Prevention of Overpressure During Filling of Cryogenic Vessels* was written in response to overpressure events that occurred in the compressed gas industry [2]. CGA P-59 discusses the requirements necessary to ensure that cryogenic storage tanks are not overpressurized in manual refill operations [2].

It is the responsibility of each tank owner to complete a technical evaluation of the storage tank fill and relief device piping. This technical evaluation shall be repeated any time a change is made in either the pump flow and pressure capability or the tank fill and relief system flow capacities. The storage tank owner shall ensure that pump operators are trained and certified.

2 Scope

This publication provides technical guidance and the complete equation set needed to determine if a particular vessel can or cannot be overpressurized during the refill operation. Acceptable engineering controls for the protection of cryogenic storage tanks and transport tanks with rupture disk(s) as part of the relief system are provided. The application of these engineering controls constitutes a minimum standard.

The calculations in this publication may be used to evaluate each pumping system and cryogenic tank combination in use with oxygen, nitrogen, or argon. It applies to tanks filled either by pump from a cryogenic transport or by a ground-mounted pump. This applies to cryogenic tanks greater than 265 gal (1000 L) water capacity. This does not apply to cryogenic tanks with flat bottoms. For flat bottomed cryogenic tanks, refer to CGA P-8.9, *Bulk Liquid Oxygen, Nitrogen, and Argon Storage Systems at Production Sites* [3].

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 **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 kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Metric Practice Guide for the Compressed Gas Industry* [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.