

CGA P-8—2020

**GUIDELINE FOR SAFE
PRACTICES FOR CRYOGENIC
AIR SEPARATION PLANTS**

SIXTH EDITION

CGA
Compressed Gas Association

The Standard For Safety Since 1913

PREFACE:

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published CGA P-8, *Guideline for Safe Practices for Cryogenic Air Separation Plants*, 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 website, 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 17-026
Atmospheric Gases and Equipment Committee

NOTE—Technical changes from the previous edition are underlined.

SIXTH EDITION: 2020
FIFTH EDITION: 2013
FOURTH EDITION: 2005
REAFFIRMED: 1994, 2002
THIRD EDITION: 1989

© 2020 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., 14501 George Carter Way, Suite 103, Chantilly VA 20151. You may not alter or remove any trademark, copyright or other notice from this work.

Contents	Page
1 Introduction.....	1
2 Scope	1
3 Typical ASU features.....	1
4 Definitions.....	3
5 Health hazards	8
5.1 Cryogenic liquids	8
5.2 Gas products	8
5.3 Asphyxiation	8
5.4 Oxygen hazards	9
5.5 Protective clothing and personal protective equipment.....	10
6 General plant considerations.....	10
6.1 Site selection	10
6.2 Safety factors in plant layouts.....	11
6.3 Materials of construction.....	11
6.4 Insulation—other than coldbox	12
6.5 Cleaning	12
6.6 Electrical requirements.....	12
6.7 Noise	13
7 Intake air quality	13
7.1 Contaminants	13
7.2 Reactive contaminants that concentrate in oxygen.....	14
7.3 Reactive contaminants that concentrate in nitrogen.....	15
7.4 Plugging components.....	15
7.5 Haze and smoke from fires.....	16
7.6 Contaminant sources.....	17
7.7 Identification of contaminants.....	17
7.8 Location of air intake	17
7.9 Monitoring intake air	17
8 Compressors	18
8.1 Axial compressors	18
8.2 Centrifugal compressors.....	18
8.3 Other dynamic compressor considerations	18
8.4 Reciprocating compressors	19
8.5 Diaphragm compressors	21
8.6 Rotary positive displacement compressors.....	21
8.7 Refrigerant gas compressors	21
8.8 Screw compressors	21
8.9 Lubrication systems.....	22
8.10 Coolers and separators	23
8.11 Suction filters or screens	23
8.12 Special considerations for oxygen service	24
8.13 Operating and maintenance procedures	24
9 Air contaminant removal.....	25
9.1 Removal methods.....	25
9.2 Contaminant removal stages.....	26
9.3 Prepurification unit operation.....	28
9.4 REVEX operation	30
9.5 Supplemental mechanical chillers	32
9.6 Caustic scrubbers.....	33

10	Expanders	33
10.1	Loss of loading and overspeed	33
10.2	Oil contamination of the process	34
10.3	Failure of shaft seals	35
10.4	Abnormally low temperatures	35
10.5	Solids in gas stream	35
10.6	Loss of lubrication	36
10.7	Abnormal bearing temperature	36
10.8	Abnormal vibration	36
10.9	Abnormal speed	36
10.10	Critical speed	36
10.11	Fouling of expander with ice or carbon dioxide	36
10.12	Startup and shutdown	37
10.13	Operating and maintenance procedures	37
11	Cryogenic pumps	37
11.1	General	37
11.2	Types of pumps	38
11.3	Materials of construction	38
11.4	Pump system design	38
11.5	Special considerations for oxygen service	39
11.6	Pump motor	39
11.7	Pump operation	40
11.8	Operating and maintenance procedures	40
12	Coldbox	40
12.1	Removing particulate material	41
12.2	Cryogenic adsorbers	41
12.3	Liquid levels	42
12.4	Monitoring contaminants	43
12.5	Argon separation and purification	44
12.6	Noncondensable purge	45
12.7	Coldbox cleaning	45
12.8	Safe holding time for liquid oxygen	45
12.9	Liquefaction of air in the main heat exchanger	45
12.10	Brazed aluminum heat exchangers (BAHXs) in cyclic service	45
12.11	Process upsets	46
13	Control systems	47
13.1	Instrumented systems functions	47
13.2	Critical safety systems	48
13.3	Operational safety systems	48
13.4	Routine plant operation control systems	49
13.5	Unattended or partially attended operation	49
13.6	Remote operation	50
13.7	Additional considerations for computer-based control systems	50
13.8	Additional considerations for failsafe systems	50
13.9	Alarm system	51
13.10	Regulatory considerations	52
14	Product handling equipment	52
14.1	Liquid storage	52
14.2	High pressure gas storage vessels	53
14.3	Liquid vaporizers	53
15	Cooling systems	53

16	Plant piping.....	54
16.1	General design considerations for plant piping	54
16.2	General design considerations for check valves	54
16.3	Expansion joints	54
16.4	Oxygen piping hazards.....	55
16.5	Pressure relief devices	55
16.6	Cryogenic piping.....	56
16.7	Dead legs	56
16.8	Carbon steel piping	57
16.9	Venting	57
16.10	Product delivery.....	57
17	Shutdown procedures	58
17.1	Coldbox shutdown.....	58
17.2	Liquid and gas disposal.....	58
17.3	Plant derime	59
18	Repair and inspection.....	59
18.1	General maintenance considerations.....	59
18.2	Supervisory control.....	59
18.3	Special construction and repair considerations.....	60
18.4	Coldbox hazards.....	60
18.5	Hazards of working in oxygen-enriched or oxygen-deficient atmospheres	61
18.6	Cleaning	61
19	Operations and training.....	61
19.1	Operating procedures.....	61
19.2	Commissioning procedures	61
19.3	Emergency procedures	62
19.4	Management of change.....	62
19.5	Personnel training.....	62
20	References	63

Figure

Figure 1—Example of an air separation plant flow diagram	2
--	---

Tables

Table 1—Effects at various oxygen breathing levels	9
Table 2—Plugging, reactive, and corrosive contaminants in air	13
Table 3—Typical default air quality design basis	14
Table 4—Typical removal in PPU process.....	27
Table 5—Typical removal in REVEX process.....	27
Table 6—Cryogenic adsorber names	41

This page is intentionally blank.

1 Introduction

This publication provides guidance on the safe operation of cryogenic air separation plants. It is based on the experience of CGA member companies that operate cryogenic air separation units (ASUs).

Industrial cryogenic air separation has some potential hazards that must be recognized and addressed. The hazards include electricity, gases under pressure, very low temperatures, the ability of oxygen to accelerate combustion, and the asphyxiant properties of nitrogen, argon, and the rare gases [1].¹

Cryogenic air separation technology is not static; it has been progressing for decades and will continue to do so because of engineering development efforts. Consequently, plant process cycles, equipment, and operating conditions can be and are of varying kinds. Therefore, this publication includes generalized statements and recommendations on matters for which there is a diversity of opinion or practice. Users of this guide should recognize that it is presented with the understanding that it cannot take the place of sound engineering judgment, training, and experience. It does not constitute, and should not be construed to be, a code of rules or regulations.

2 Scope

This publication serves the interest of those associated or concerned with air separation plant operations and applies to safety in the design, location, construction, installation, operation, and maintenance of cryogenic air separation plants. Emphasis is placed on equipment and operational and maintenance features that are specific to cryogenic air separation processes. Limited coverage is given to plant equipment such as air compressors, which are used in other industrial applications and for which safe practices in design, installation, and use have already been established elsewhere. Further, as this publication is not intended as a universal safe practice manual for specific design and safety features, it is also important to refer to the operating manuals of the equipment suppliers.

The following are excluded from this publication:

- cylinder filling facilities;
- rare gas purification systems; and
- product transmission piping outside the plant boundaries.

3 Typical ASU features

Cryogenic ASUs have these features:

- air compression;
- air contaminant removal;
- heat exchange;
- distillation; and
- expansion (or other refrigeration sources).

Figure 1 is an example of a flow diagram for separating air by cryogenic distillation producing oxygen, nitrogen, and argon products. Air is compressed in the main air compressor (MAC) to between 4 atm and 10 atm. It is then cooled to ambient temperature. Trace contaminants such as water, carbon dioxide, and heavy hydrocarbons are removed using systems such as a prepurification unit (PPU) or a reversing heat exchanger (REVEX). The main heat exchanger cools the air to near its liquefaction temperature before entering the high pressure distillation column. Some of the air is reduced in pressure in the expander to produce refrigeration, overcoming heat leak and process inefficiencies. Gaseous nitrogen from the top of the high pressure column is condensed by the reboiler and the liquid used to reflux both columns. Condensing nitrogen releases heat to vaporize liquid oxygen

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