CGA P-8—2013

SAFE PRACTICES GUIDE FOR CRYOGENIC AIR SEPARATION PLANTS

FIFTH EDITION

CELEBRATING CGA Compressed Gas Association 100 YEARS

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Work Item 08-044
Atmospheric Gases and Equipment Committee

NOTE—Technical changes from the previous edition are underlined.

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

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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 must include 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 peculiar 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 (HP) 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 HP column

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

is condensed by the reboiler and the liquid used to reflux both columns. Condensing nitrogen releases heat to vaporize liquid oxygen (LOX) in the low pressure (LP) column sump, which is then taken as product or sent as stripping gas to the LP column.

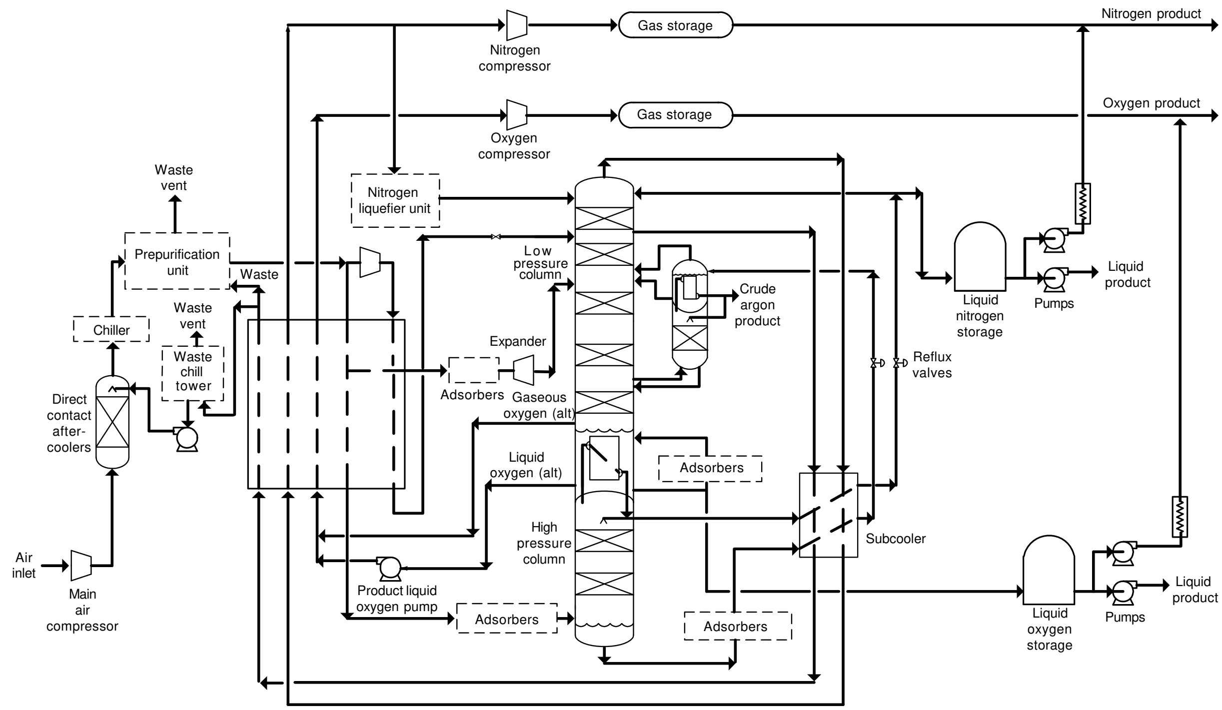

Figure 1—Representative air separation plant flow diagram

Oxygen has the highest boiling point of the three main components and is taken from the bottom of the LP column. Nitrogen is taken from the top of the LP or HP columns. An argon-rich stream can be withdrawn from the middle of the LP column and refined to a pure product in other distillation columns. The product streams are warmed to ambient temperature against incoming air in the main heat exchanger to recover the refrigeration. It is also possible to remove the products from the distillation system as liquid, if sufficient refrigeration is available. Producing large quantities of liquid products requires extra refrigeration, often supplied by a nitrogen liquefier unit. Liquid may be stored for pipeline backup or merchant sales.

There are two typical ASU configurations for producing pressurized oxygen. In the gas plant configuration (also called gaseous oxygen [GOX] process or classic gas process), oxygen is taken as a vapor from the bottom of the LP column and warmed by incoming air in the main heat exchanger. If an HP oxygen product is needed, it is compressed to the required pressure. A LOX purge stream is taken from the sump of the LP column to prevent the trace contaminants from concentrating above allowable safety limits. In the pumped LOX process (also known as the internal compression process), oxygen is taken as a liquid from the LP column sump, pumped to the required pressure, and vaporized in the main exchanger against HP air from the booster air compressor. The pumped oxygen stream removes trace contaminants from the LP column sump, so a separate LOX purge stream from the LP column sump may be eliminated.

There are many other configurations of the ASU process that are specifically tailored for different products mixes and customer needs. A detailed discussion of these is beyond the scope of this publication.

4 Definitions

4.1 Publication terminology

4.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

4.1.2 Should

Indicates that a procedure is recommended.

4.1.3 May

Indicates that the procedure is optional.

4.1.4 Can

Indicates a possibility or ability.

4.2 Acid gas

Air contaminants such as chlorine, NO_x, and SO_x that can form acid when combined with water.

NOTE—Acid gases can create corrosive conditions in brazed aluminum heat exchangers (BAHXs) and other equipment.

4.3 Adsorption

Purification process in which one or more components from a gas or liquid is preferentially adsorbed onto a solid desiccant or other adsorbent.

NOTE—Typical adsorbents include:

- Molecular sieve—granular adsorbent (typically 13X) used in air PPUs for water, carbon dioxide, and hydrocarbon removal;
- Alumina—granular adsorbent typically used in air PPUs or dryers for water removal; and
- Silica gel—granular adsorbent typically used in cryogenic adsorbers for carbon dioxide and hydrocarbon removal.

4.4 Asphyxiation

To become unconscious or die from lack of oxygen.

4.5 Blow out

Maintenance or commissioning procedure in which a fluid, typically dry air, is blown through piping and equipment to eliminate dirt, moisture, or other contaminants.

4.6 Brazed aluminum heat exchanger (BAHX)

An aluminum plate and fin heat exchanger consisting of corrugated sheets separated by parting sheets and an outer frame consisting of bars with openings for the inlets and outlets of fluids, equipped with headers and nozzles to connect to external piping.

NOTE—The approximate thickness of the corrugated sheets is 0.2 mm to 0.5 mm, while the parting sheets have thicknesses between 1.0 mm and 2.4 mm. More information is provided in CGA G-4.9, *Safe Use of Brazed Aluminum Heat Exchangers for Producing Pressurized Oxyge*n [2].

4.7 Casing

Outside walls of a coldbox or cryogenic piping duct. The cross section can be circular or rectangular.

4.8 Catalyst

Material that helps promote a reaction but is not changed itself.

4.9 Cavitation

This phenomenon occurs when the pressure of a liquid drops below the vapor pressure of the liquid at a certain temperature. At this point, liquid will vaporize, thereby creating vapor bubble. These bubbles can cause a pump to lose prime or suffer heavy vibration and damage.

4.10 Centrifugal
Dynamic compressor or pump that works by accelerating a fluid in a rotating impeller with subsequent conversion of this energy into pressure.

4.11 Cleanup
Removing trace contaminants from a stream or from process equipment.

4.12 Coldbox
Structure that contains cryogenic distillation columns, other process equipment, piping, and insulation; can also refer to the cryogenic portion of an ASU.

4.13 Control system
System that responds to input signals from the process, operator, or both and generates an output that causes the process to operate in the intended manner.

4.14 Crude argon purification system
Warm equipment including compressors, catalytic reactors, heat exchangers, driers, and chillers used for removing oxygen from crude argon.

4.15 Cryogenic liquid
Liquid that is extremely cold, less than –130 °F (–90 °C).

4.16 Dead end boiling (pool boiling, pot boiling)
The condition occurring in thermosyphon reboilers where, due to blockages, the flow of liquid is restricted within the channels of the reboiler, thereby reducing the removal of contaminants by the flushing action of the liquid. Also known as pool or pot boiling. This phenomenon can also occur in cavities and sections of piping where oxygen-enriched liquid can be trapped and vaporized by heat leak.

NOTE—This process is particularly hazardous when the oxygen-enriched liquid contains hydrocarbons that become concentrated during vaporization.

4.17 Differential temperature (ΔT)
Temperature difference between two streams in a heat exchanger, which is an indicator of the exchanger's performance and efficiency.

4.18 Deriming
Periodic preventive maintenance procedure where the process equipment is warmed up while simultaneously being swept with clean dry gas to remove any accumulated moisture, carbon dioxide, and atmospheric contaminants.

NOTE—Also known as defrosting, de-icing, and thawing.

4.19 Deoxidation or deoxo
Catalytic removal of trace oxygen contaminant from a gas by a reaction with hydrogen, typically in warm argon production in ASUs.

4.20 Deoxo systems
Catalytic-based system used in some argon refining systems to remove oxygen. Hydrogen is added to the crude argon stream and then reacts with oxygen to form water.

4.21 Distance piece
Extended spacer, intermediate support, or carrier frame that isolates the process end of a pump or compressor from its motor or bearings to prevent migration of process fluid, oil, heat, or refrigeration.

4.22 Double block and bleed
Piping or instrument arrangement that combines two block (or isolation) valves in series with a vent valve in between the block valves as a means of releasing pressure between the block valves with the intent to provide positive isolation.