

Air Separation Technology

Cryogenic air separation units (ASU), membrane, and adsorption (PSA, VSA) technologies are discussed. Cost estimates for producing oxygen, nitrogen (and argon) from air using an ASU and producing oxygen using a VSA are given. Supply considerations; global markets and market drivers for industrial gases are outlined.

PERP 08/09S1

Report Abstract
February 2010

Report Abstract

Air Separation Technology PERP 08/09S1

February 2010



www.chemsystems.com

The ChemSystems Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a report by report basis.

Nexant, Inc. (www.nexant.com) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, ChemSystems has helped clients increase business value through assistance in all aspects of business strategy, including business intelligence, project feasibility and implementation, operational improvement, portfolio planning, and growth through M&A activities. Nexant has its main offices in San Francisco (California), White Plains (New York), and London (UK), and satellite offices worldwide.

For further information about these reports, please contact the following:

New York, Dr. Jeffrey S. Plotkin, Vice President and Global Director, PERP Program, phone: + 1-914-609-0315, e-mail: jplotkin@nexant.com; or Heidi Junker Coleman, Multi-client Programs Administrator, phone: + 1-914-609-0381, e-mail: hcoleman@nexant.com.

London, Dr. Alexander Coker, Manager PERP Program, phone: + 44-(20)-70950-1570, e-mail: acoker@nexant.com.

Bangkok, Maoliosa Denye, Marketing Manager, Energy & Chemicals Consulting: Asia, phone: + 66-2793-4612, e-mail: mdenye@nexant.com.

Website: www.chemsystems.com

Copyright © by Nexant Inc. 2010. All Rights Reserved.

INTRODUCTION

The first commercial use for oxygen was driven by the development of “lime lights” in theatres in the mid-19th century, until their replacement late in the same century by electric arc lighting. These bright stage lime lights required a steady supply of oxygen and hydrogen to feed a flame that was directed on to a cylinder of calcium oxide, causing it to glow brightly without melting.

The modern air separation industry developed at the start of the 20th Century with the development of cryogenic air processing, this time driven by a desire to produce calcium carbide, required for the manufacture of acetylene. Oxygen demand received a further boost, and an industry was born, when it was realized that combining oxygen and acetylene in an oxy-acetylene torch resulted in a very high temperature flame, able to melt and therefore weld a wide variety of metals.

The industry enjoyed a further boom starting in the 1950s as new oxygen blown steel furnaces (LD or BOP/BOS processes) replaced air blown Bessemer furnaces. This new requirement for large volumes of dedicated oxygen supply allowed the air separation industry to develop large scale “tonnage” oxygen supply plants, now capable of processing thousands of tons of air per day to produce high purity oxygen, nitrogen and argon.

Tonnage air separation plants now find use in a growing range of applications including: onsite oxygen supply to the chemical industry (e.g., ethylene oxide, methanol and reformer processes), onsite oxygen supply to the developing gas-to-liquid (GTL) sector and nitrogen supply (generally by pipeline) to pressurize oil fields and maintain crude oil production.

The key areas covered in the report are:

- Air Separation process technology
- Air Separation process cost of production modelling (including the impact of liquid make on power requirement etc)
- Market for Air Separation (primarily an overview of the total market, but including a listing of mega-methanol etc projects requiring large scale air separation)

SEPARATION TECHNOLOGY

The basic technology choice between cryogenic or non-cryogenic technology, is largely determined by the number of products that must be supplied (e.g., nitrogen or oxygen or both), the required production rates for each gas and/or liquid product, and required product purities. Cryogenic distillation is necessary to produce argon. Because argon is only one percent of air, it cannot be produced economically unless it is a co-product, usually of a high purity oxygen plant or sometimes of an ammonia plant. The need to accommodate user demand patterns (flow rate fluctuations) leads to additional system optimizations.

Cryogenic air separation is a process by which highly purified gases or liquids are produced. This is achieved by taking large volumes of air from the atmosphere, which are then compressed, cooled, and liquefied. Through a process of distillation the air is then separated into its major components. After the air is compressed, impurities must be removed. Depending on user requirements, different variations can be used in cryogenic air separation cycles to produce industrial gas products.

In cryogenic gas processing, various equipment is used such as distillation columns, heat exchangers, cold interconnecting piping etc. These operate at very low temperatures and therefore must be well insulated and located inside sealed "cold boxes". Cold boxes are tall structures with either a round or rectangular cross section. Depending on the plant type, size and capacity, cold boxes may have a height of 15-60 meters and 2-4 meters on each side. A Cryogenic unit as described above is commonly described as an "air separation unit" ("ASU").

Adsorption air separation (pressure swing adsorption or PSA) processes rely on the fact that under pressure gases tend to be attracted to solid surfaces or "adsorbed". The higher the pressure, the more gas is adsorbed; when the pressure is reduced, the gas is released, or desorbed. PSA processes can be used to separate gases in a mixture because different gases tend to be attracted to different solid surfaces more or less strongly. For example, if a gas mixture such as air is passed under pressure through a vessel containing an adsorbent bed that attracts nitrogen more strongly than it does oxygen, part or all of the nitrogen will stay in the bed, and the gas coming out of the vessel will be enriched in oxygen. When the bed reaches the end of its capacity to adsorb nitrogen, it can be regenerated by reducing the pressure, thereby releasing the adsorbed nitrogen. It is then ready for another cycle of producing oxygen enriched air.

Vacuum swing adsorption (VSA) differs from pressure swing adsorption (PSA) techniques due to the fact that it operates at near-ambient temperatures and pressures. VSA may actually be best described as a subset of the larger category of PSA. It differs primarily from PSA in that PSA typically vents to atmospheric pressures, and uses a pressurized gas feed into the separation process. VSA typically draws the gas through the separation process with a vacuum. For oxygen and nitrogen VSA systems, the vacuum is typically generated by a blower. Hybrid vacuum-pressure swing adsorption technology (VPSA) systems also exist. VPSA systems apply pressurized gas to the separation process and also apply a vacuum to the purge gas. VPSA systems, like one of the portable oxygen concentrators, are among the most efficient systems, measured on customary industry indices, such as recovery (product gas out/product gas in), productivity (product gas out/mass of sieve material). Generally, higher recovery leads to a smaller compressor, blower, or other compressed gas or vacuum source and lower power consumptions. Higher productivity leads to smaller sieve beds.

Membrane air separation is based on the principle that different gases have different permeation rates through the polymer film. Oxygen (plus water vapor and carbon dioxide) is considered a "fast gas" which diffuses more rapidly through the tube walls than the "slow gases," argon and nitrogen. This "fast gas/slow gas" diffusion allows dry air to be converted into a product that is an inert mix of mostly nitrogen gas and argon, and a low-pressure "permeate" or waste gas that is enriched in oxygen (plus water vapor and carbon dioxide) and vented from the shell.

DEVELOPING TECHNOLOGIES

Ion Transport Membrane (ITM) Oxygen technology is a radically different approach to producing low-cost, high-temperature, high-quality tonnage oxygen. The developing ITM, Ceramic Autothermal Recovery (CAR) (which is not based on ceramic membranes; instead, it carries out the adsorption and storage of oxygen at high temperatures) and Oxygen Transport Membranes (OTM) technologies are also briefly outlined in the report.

SUPPLY CONSIDERATIONS

Depending on the demand, supply may be met via gas cylinders, stored and vaporized liquid products, on-site gas production or pipeline supply. The various considerations around which of these supply options is most suitable in what circumstances is briefly discussed in the report.

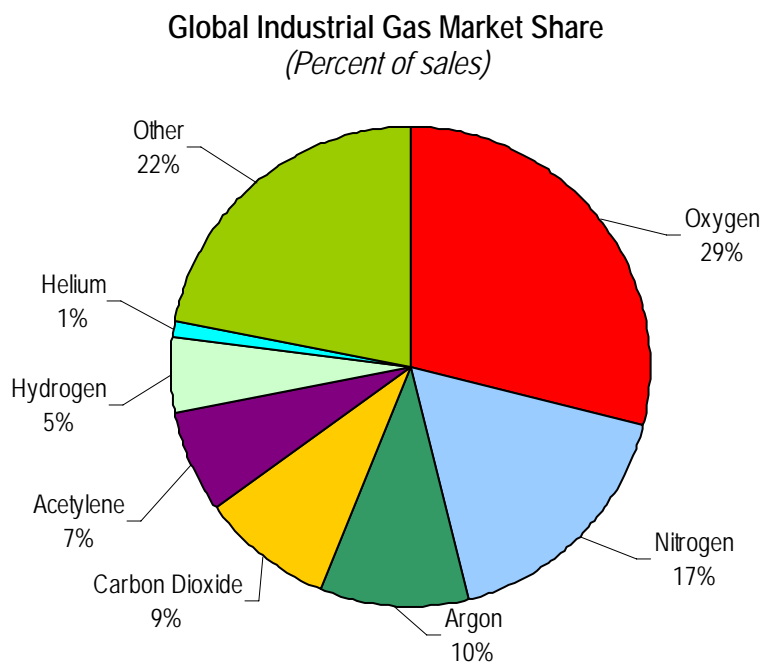
ECONOMIC ANALYSIS

- The cost of production for operating a nominal 3 000 tons per day cryogenic ASU producing 99.99 percent pure gaseous oxygen have been estimated for (three scenarios of) an ASU with (1) minimal liquid make, (2) with 10 percent liquid make and (3) with 10 percent liquid make plus argon recovery. Gaseous oxygen (GOX) is produced as high pressure internally compressed stream and gaseous nitrogen is recovered as the low pressure product.
- The cost of production for a case producing 93 percent pure oxygen via a VSA at a capacity of 150 tons per day has also been estimated.

Various sensitivities have been explored to illustrate the effects of variations in certain parameters on the base case economics presented. These results can also be used to make approximate comparisons between cases for which detailed economics that have not been provided by adjusting for capacity differences, alternative feedstock valuation, etc. The sensitivity of the development process economics as a function of liquid make, power costs, capital investment, by-product pricing and economy of scale are analyzed.

COMMERCIAL ANALYSIS

Besides oxygen, nitrogen and argon, whose applications are described in the report, industrial gases include carbon dioxide, acetylene, hydrogen, helium and others such as carbon monoxide, nitrous oxide, noble gases (krypton, xenon and neon) and a large number of specialty gases and gas mixtures for different applications. The global market share is shown in the figure below.



Q409_00101.0009.4109_Charts.xls\Figure 7.1

- The global market for the industrial gas business is discussed
- The main market drivers to growth for industrial gases are briefly discussed, in particular oxygen and nitrogen demand



Nexant, Inc.

San Francisco
London
Tokyo
Bangkok
New York
Washington
Houston
Phoenix
Madison
Boulder
Dusseldorf
Beijing
Shanghai
Paris