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Romanian scientific research in the field of cryogenics

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Abstract. Cryogenics was developed especially after 1990, when Romania's economy has become a free economy. Specialists in the field of cryogenics were only a few and Romanian contribution in research and development of Cryogenics were almost nonexistent. After 1990, development of the main industrial objectives of the country, required the construction and reconstruction of large and modern facilities cryogenic liquefaction of gases, such as ASU Galati GOX 60,000 Nm^3/h in 2010 or Hydrogen Factory - 15,000 Nm^3H_2, Petrobrazi, Ploiesti, in 2014. Achieving these plants contribute to the development of scientific research, technological progress in improved editing and design schemes.

Keywords. cryogenics, development, research, new Technologies.

1. Introduction

The invention of the thermometer by Galileo in 1592 may be considered as the start of the science of thermo- dynamics. Guillaume Amontons predicted for the first time the existence of an absolute zero in 1702, which marks the beginning of the science of low temperatures. Around 1780, the liquefaction of a gas was achieved for the first time. It took almost another 100 years before a so-called ‘‘permanent’’ gas, i.e. oxygen, was successfully liquefied. Thereafter Linde and Claude founded the cry-ogenic industry, which today has annual sales of more than 30 billion US $. Progress in the production of cold is based to a great extent on the increasing knowledge of thermodynamics. A real perception of the thermal processes within a refrigeration cycle is not possible without sound study of the laws of thermodynamics and the theory of the cycle processes [1]. The cryogenic route for separating air by lique-

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faction and distillation is used because, up to date, it is the most economic method on an industrial scale, not because an industrial firm likes the complications of a cryogenic route [2]! In cryogenics, the content of the research involves gas liquefaction and separation, study on physical properties of cryogenic fluids and materials, storage and transportation of cryogenic fluids, refrigeration, etc. The application areas include industry, biotechnology, medical engineering and physics, especially space cryogenics and superconductivity [3]. The use of very low temperatures in the advanced technology for application in medicine, electrotechnics, computer technology, space and military missions requires the achievement of high performance cryogenic systems [4]. Cryogenics plays an important role at the European Spallation Source, a world class neutron science center, currently under construction in Lund, Sweden. Three principal applications of cryogenics are found at ESS. The SRF cryomodules of the ESS proton linac require cooling at 2 K, 4.5 K and 40 K; the hydrogen moderator surrounding the target that produces neutrons, require cooling via 16.5 K helium and LHe is required for many of the scientific instruments. These needs will be met by a set of three cryogenic refrigeration/liquefaction plants and an extensive cryogenic distribution system. Significant progress has been made on the ESS cryogenic system in preparation for the expected first beam on target in 2019. This work includes: funding of industry studies for the accelerator cryoplant, preliminary design of the cryogenic distribution system, investigation of possible in kind contributors and release of the invitation to tender for the accelerator cryoplant [5]. Cooldown of the 1,100 tons cold mass down to 4.5 K has been addressed as one of the great challenges for the Super-FRS cryogenics. For the iron dominated cold mass the advantage of using LN2 precooling at 80 K is obvious in order to have a reasonable cooldown time of three to four weeks down to 4.5 K operation temperature [6].

In the context of the last decades, Romanian’s future energy system is uncertain. It is clear that the European context will put its mark. But this in turn is a sharp change in the desire of ‘20-20-20’ [7]. Romania is a country with relatively good opportunities to manage the transition from the dependence on fossil energy to an energy industry based on renewable energy sources (RES), supported by hydrogen as an energy carrier. In order to ensure Romania's energy security in the next decades, it will be necessary to consider a fresh approach incorporating a global long-term perspective based on the latest trends in energy systems [8].

2. Technological developments in cryogenics

Air purification system in Air Separation Units. This include:

- Replacing regenerator adsorber molecular sieve;
- Reducing the amount of metal (stainless steel) used in the manufacture of equipment;
- Reduce the area occupied by the installation;
- Increase the reliability of the plant;

- Reduce energy consumption by eliminating reverse blowing through the regenerator exhaust into the atmosphere of considerable quantities of residual nitrogen compressed to 7 bar that cannot be recovered;
- Reduce the period starting from 6-7 days to one day;
- It improves the rate of removal by canceling exhausting into the atmosphere;
- Adsorbent molecular sieve; The technology used is the TSA adsorption-desorption cycle: a vessel is in adsorption and the other is in the regeneration cycle (Figure 1).

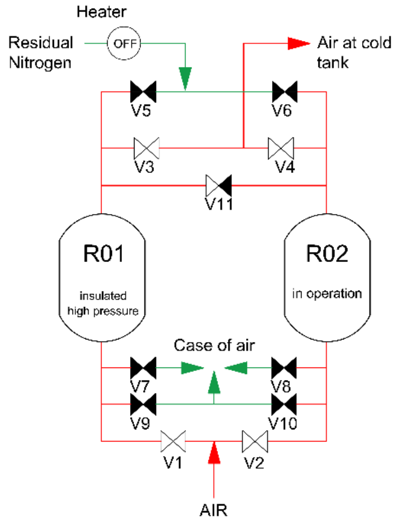


Fig. 1: Sequence initiation

There are two types of containers: containers with horizontal layers for adsorbents (Figure 2), adsorbents radial ply containers (Figure 3). The adsorbents used to remove water and carbon dioxide from the air, based on adsorption and temperature oscillation are classified according to internal codes. This code enables products to be identified without prejudice to the supplier.

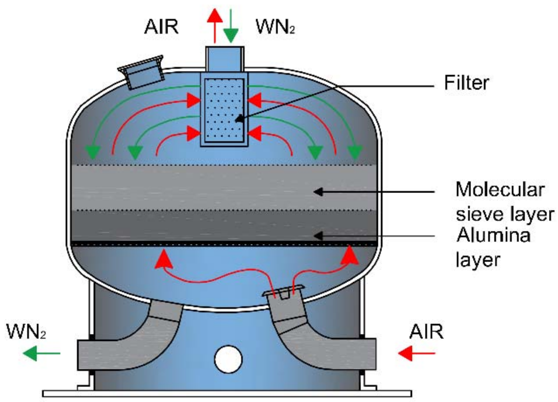


Fig. 2. Container with horizontal layers

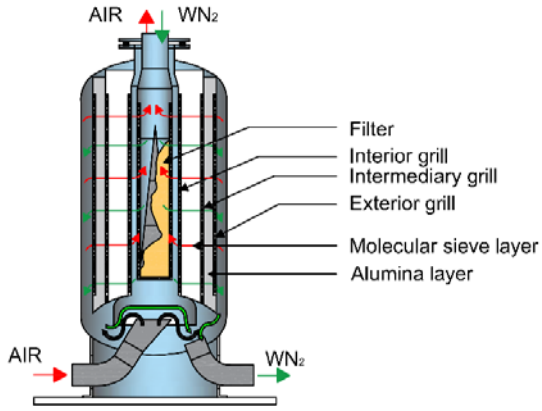


Fig. 3. Container with vertical layers

Plate heat exchangers. Heat exchangers are among the most vital components of any cryogenic refrigeration/liquefaction system. Unlike their counterparts in most other chemical process industries, cryogenic heat exchangers need very high effectiveness. The performance of refrigerators, liquefiers and separation units is strongly dependent on the effectiveness of the heat exchangers used. In fact, if the effectiveness of the heat exchanger is below a certain critical value, most cryogenic processes would cease to function [9], [10]. Mounting plate heat exchangers aluminum shows the following advantages:

- Reduced surface;
- Elimination valve switching systems;
- Ability to transfer heat between several fluids;
- Use of equipment in high pressure levels. In case of regenerators, the pressure could not be greater than 7-8 bar because it implicitly generates too-large thickness and weights;

The structure and installation of a plate heat exchanger made of aluminum, used in cryogenics can be observed in figures 4 and 5 respectively.

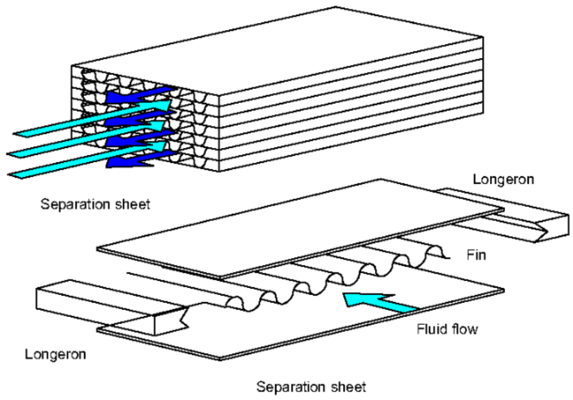


Fig. 4. The structure of plate heat exchanger made of aluminum

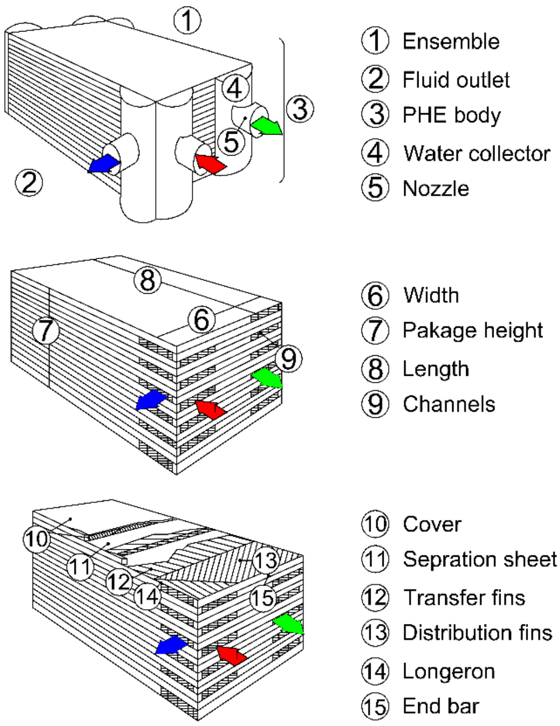


Fig. 5. Installation of the plate heat exchanger made of aluminum

Rectification system. Usually, a separation plant was composed of a lower column, an upper column and a multi-tubular condenser, separately. This kind of plant leads to:

- Deficiencies major start-ups
- Hydraulic losses between the condenser and high-pressure column
- Large areas covered by three enormous containers;
- Consumption of large expensive materials (austenitic steel, copper, brass, aluminum etc.);
- Double Column built multi-storey condenser (heat exchanger plates);

In air separation there are two types of stuffing column. Clearly, the most common type is the sieve plate (perforated) that is found in all plants. In recent years, it was introduced stuffing structured and used in parts or in whole column. In some older plants type REVEX to produce GOX, occasionally can occur type of pan bubbling with bells.

Cross linking plates are metal disks which show a large number of drilled holes. The vapors moving upward, passing through these holes so as to prevent lowering of the liquid through the same holes. The liquid is fed into a drain pipe which penetrates into the liquid (= barrier liquid) on the next lower tray. Liquid vapor barrier prevents cutting through the pipe. The large number of small holes causes a strong division vapor up in tiny bubbles so that contact between the vapors and liquid becomes very

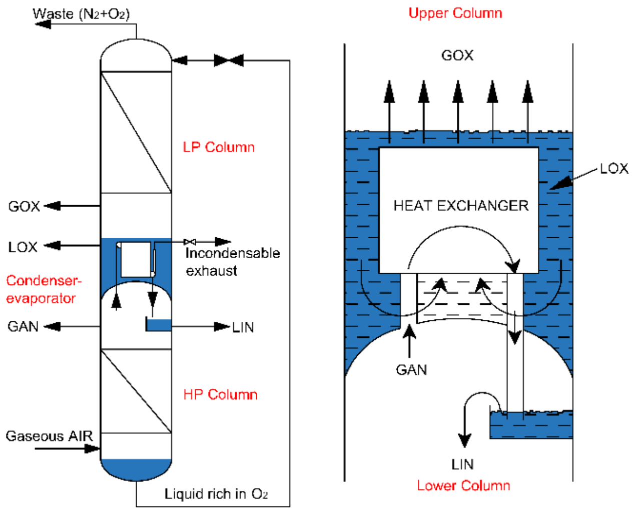


Fig. 6. Double Column built multi-storey with incorporated condenser (plates heat exchanger)

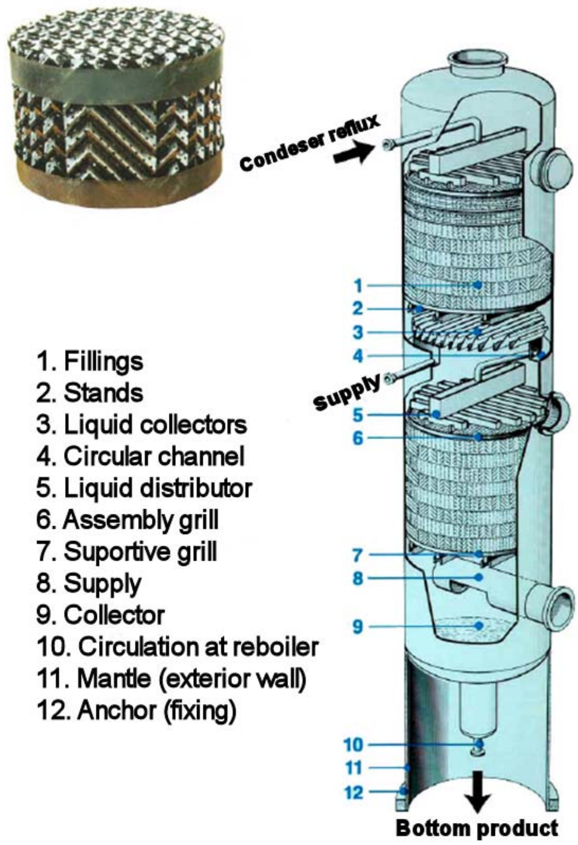
intense. With this type of dish, the amount of vapor should be high enough at any time to support liquid. If, for whatever reason, the amount of vapor is too low, the liquid will flow through the holes and distillation process will not arise in the correct manner.

Corrugated structured packing containing arranged next to one another so that each plate is another wave in the same direction. Crimping direction of plaque compared with the direction of the next plate, forming an "X". Liquid flows downward and mix in the center of the "X's" vapor moving upward in the opposite direction through the same passages. Undulations ensure breadth contact area between liquid and vapor, which is very important. To increase further the contact zone there are undulations in the opposite direction of the plates.

These types of columns have a pressure drop significantly lower than that of the sieve plate column, which is an advantage, as it leads to a reduced requirement for the operation of the compressor. The difference in pressure in a sieve plate column is higher as the vapor has to support the liquid at the top of the plates.

Internal Compression. This process is based on an air compressor supplying air at 5 bar for separation. An additional compressor is used to achieve the required compression pressure expansion turbines for the production of cold. There is a cold and a warm turbine, as well as in new installations of the recirculation of nitrogen. The main heat exchanger is combined to produce cold air for cooling and separation.

The traditional method of delivery of gas to a nearby recipient, the low pressure gas is compressed in the main heat exchanger, a compressor of the gas product and the customer sending the pipe. Innovation is the replacement compressor with internal compression pump, which pumps fluid with adequate pressure and it evaporates in a heat exchanger. This eliminates the need for evolving product compressors (O2, N2, Ar).



3. The research was continued in some Ph.D. thesis:

- Alexandru Serban Thesis, researches into the Krypton-xenon concentrate in air separation plants, "Dunarea de Jos", Galati, 2004;
- Marius Cuzic Thesis, Research on increasing the performance of separation fraction of argon in the air, "Dunarea de Jos", Galati, 2014;

4. European projects and cooperation

- Projects EURATOM / EFDA Fusion Program;
- Projects within FP7 Research Program;
- European bilateral collaborations: FZK Karlsruhe, ENEA Frascati, CEA Cadarache, UKAEA, SCK-CEN Mol, IMP Odeillo, INP Grenoble, JINR Dubna, St. Petersburg PNPI;
- Develop technology 13C isotope separation by cryogenic distillation of carbon monoxide / D04;
- Integrated network monitoring structural integrity of critical components of nuclear installations / F3048 / ICN Pitesti;

- Integrated platform for research and experimental studies of complex processes developed at cryogenic temperatures / C43 / UPB Bucharest;
- Develop 13C isotope separation technology for CO2-carbamate system / 71069 / ITIM Cluj,
- Optimization of heat transfer through multilayer insulation of cryogenic installations / F22139 / University of Bucharest;
- superconducting electric motor / F22118 / ICPE CA Bucharest;
- Nucleus Program - Studies of the material parameters in the 4-20K range.
- CERES / "Studies of dislocations and process parameters to influence the behavior Proprieties material in hydrogen separation plants Isotopes"
- CERES / "Experimental RESEARCHES of cryogenic helium cycles for liquefaction plants;
- CEEX MATNANTECH / "Integrated platform for experimental researches at cryogenic level of complex processes"
- CERES CEEX / "Treatment and conditioning of tritiated solid, liquid organic Wastes and sealed sources with tritium resulted from Romanian nuclear activities"
- CEEX MATNANTECH / "Separation technology of isotope C13 through cryogenic distillation of carbon monoxide"
- CEEX / Integrated network for monitoring of structural integrity of critical components from the nuclear installation "
- Nucleus Program - "Evaluation of materials behavior Between 80K to 4K"
- PNCD II / "Separation technology of isotope C13 in CO2-carbamate system";
- PNCD II / "Superconductive electric engine";
- PNCD II / "SMES"
- Nucleus Program "Complex studies of materials Used in applications cryogenic"
- "Technologies for hydrogen separation Isotopes; System for Tritium Remove / ICIT Rm. Vilcea;

5. Cryogenerators, equipment, stands

- Helium liquefaction plant type Linde L5;
- Criogenerator type hydrogen liquefaction PPH 100;
- Criogenerator nitrogen liquefaction type PPG;
- Charpy hammer F040 S1;
- Universal testing machine type TC 300;
- Stand to determine resilience to 20K -300K;
- Stand for determining the mechanical resistance at 20K-700K;
- Studies regarding the design, construction and installation of turbine gas dynamics, in collaboration with I.C.N. Pitesti making a turbodetentor gasodynamic nitrogen liquefaction;
- Designing and manufacturing of valves for cryogenic liquid hydrogen closure;
- Design and implementation of air protection system of a type turbodetentor LINDE;

- Designing a cryostat to obtain superfluid helium;
- Design an experimental system for testing carbon thermoresistences;
- Design and technical realization of heat exchangers (high temperature and cryogenic);
- Commissioning of a plant for liquefied helium type Linde L5;
- Stand the test of resilience at cryogenic temperatures;
- Create a data acquisition system of the stand test method impact resistance;
- Design a way to integrate field-point-temperature characteristics of resilience;

6. Conclusions

In Romania, Cryogenics has an important contribution in industrial development. We have a strong collaboration with major foreign companies that are present on the Romanian market, with domestic mounting companies, research institutions and technological developers and with higher education institutions. In this regard were developed in Romania, prestigious research units, such as ICSI Rm. Valcea, mounting units, as CRIOMEC S.A. GALAŢI that are present and in collaboration with external customers in the European Community. It was developed an educational network for training specialists within the higher education and Cryogenics is included in the curricula of technical universities.

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