ABSTRACT

In a cryogenic air separation plant, the raw material – air – is available absolutely free in nature. However, the capital cost of the plant and the running cost of power consumption are high enough to push up the price of the final products. Moreover, the cost of maintenance and the losses due to faulty operations also add to the price.

A cryogenic plant consists of a number of equipment connected together by pipelines, which help the working fluid undergo through certain processes from the beginning to the end. The final target is to separate air into its components with maximum production at the desired purity incurring minimum cost. A major portion of the cost can be reduced and the production can also be improved if the equipment work at their design efficiency. Design efficiency is again linked to the level of technology at a given time and capital investment. When an equipment do not function at their design efficiency and the related operating parameters can not be held at their design values due to one reason or another, the question that often arises is how a particular parameter affects the entire performance of the plant. The answer can almost always be given qualitatively by experienced persons and can almost never be given quantitatively. However, it is the quantitative answer, which helps in repairs, replacements and technological changes. It is this specific requirement of Air Separation Industry that has inspired the present work, where attempt has been made to evaluate the effects of some of the parameters on some specific types of plants and their results are presented as trends.

Primarily, we have taken the following types of plants for the parametric analyses:

1. High pressure column of a double column
2. Simple double column
3. Crude argon column
4. Double column integrated with crude argon column
5. Low-pressure gas plant
6. Medium-pressure liquid plant

The first four plants of the above list are analyzed to understand the influence of operating parameters like the quantity of liquid nitrogen (LIN) draw, gaseous oxygen (GOX) draw and crude argon product recovery etc. on the plant performance. All the systems have been simulated using ASPEN PLUS, a commercial package.

A large quantity of gaseous oxygen having a purity of about 99.5% is needed in the LD process to accelerate the oxidation and conversion of iron to steel in a steel-making plant. These plants are therefore equipped with low-pressure cryogenic air separation plant to produce mainly gaseous oxygen of standard grade (purity 99.5% O_2).

Liquid products — liquid oxygen (LOX) and liquid nitrogen (LIN) — are required for a wide variety of applications in different fields including food, space and also for on-site compression of oxygen gas. Insulated tankers are used to store and transport a large quantity of cryogenic liquids, which creates not only a large buffer of mass to take care of supply-demand fluctuation, but also a cold vector for process industries. LOX (purity 99.8% O_2) and LIN (at ppm level impurity) are generated in a medium pressure liquid plant.

In case of the low-pressure gas plant, the effects of variations of the following parameters on the plant performance are discussed: (1) number of stages in LP column, (2) location of RL feed at LP column, (3) location of vapor feed draw from LP column for crude argon column input, (4) pressure drop in the return stream at the main heat exchanger, (5) pressure drop per stage in LP column, (6) ΔT across the condenser-reboiler, (7) flow rate of Lachmann air, (8) flow rate of vapor feed to crude argon column, (9) turbine efficiency, (10) flow through turbine, (11) temperature approach at main HE and (12) temperature of air at inlet to main HE.

In case of medium pressure liquid plant, the parameters studied are as listed in the above paragraph with the only exclusion of the parameter Lachmann air. Additionally included are the effects of variation of recycle air and a lean liquid draw on the plant performance. The effects of variation of the four parameters: turbine efficiency, air flow through turbine, temperature approach at main HE and temperature of air at inlet to main HE on the plant performance of a liquid plant have been represented by a common set of characteristic curves. With the help of these curves one can determine the equivalent LOX production and its purity for the variation of any one of the four parameters without simulating the actual liquid plant.

The second part of the present work involves the application of exergy analysis to a simple double column, to a low-pressure gas plant and to a medium pressure liquid plant for identifying the irreversibilities in the components. Exergy analysis takes a holistic approach to recognize quality of energy while energy analysis ignores this aspect. In this

work, exergy analyses of a double column without argon attachment, a low- pressure gas plant and medium pressure liquid plant have been performed. The analysis leads to some suggestions towards improvement of the plant configuration with an aim to the reduction of exergy loss.

Key words: Air separation, efficiency, exergy, parametric evaluation, distillation