Standard liquefier-test results with improved turbines

Schoenfeld H., Cretegny D., Loehlein K.

Linde Kryotechnik AG, Daettlikonerstrasse 5, CH-8422 Pfungen, Switzerland

Gas bearing turbine efficiency has been increased. These turbines are used in helium plants for refrigeration and liquefaction. Turbine design modifications have been presented in [1]. The impact of higher turbine efficiency on liquefaction capacity was predicted for small scale Helium liquefiers. Measurements were performed to confirm the predictions. The performance results on capacity and operation are presented in this paper.

INTRODUCTION

A large number of standard helium liquefiers is used in scientific institutions and in industry. Standard technology guarantees high reliability. Cost effectiveness in both investment and operation has become more and more important. However, low operational costs often demand higher investment costs. Linde Kryotechnik AG has demonstrated how to increase the efficiency of a standard liquefier by using improved turbines. In future customers will benefit from a more cost effective liquefaction process with same or lower investment costs.

TCF20 HELIUM LIQUEFIER

For the field test a Linde TCF20 standard helium liquefier was used. It covers a range of 20 - 40 l/h. Linde Kryotechnik AG has taken over this kind of plant after more than 80 units were built by Linde CryoPlants Ltd. (UK). The process flow diagram is shown in figure (1).

Gaseous helium compressed at ambient temperature enters the coldbox through the high pressure (HP) pipe. In a first step the compressed helium is cooled in heat exchanger HX1. Heat exchanger HX1 is a counter flow plate fin heat exchanger with an integrated liquid nitrogen (LN2) evaporator. The cooling capacity of the heat exchanger is supplied from the returning low pressure (LP) stream of helium and the liquid nitrogen (LN2). Once the helium gas passed HX1 it will enter the heat exchanger HX2, which is separated into two sections. Between the two sections the HP stream is split into the turbine and the Joule-Thomson (JT) stream. A large fraction of the helium gas will flow through the turbine string, passing turbine inlet valve and filter before expanding in turbine TU1. After being further cooled in heat exchanger HX3 the helium gas flows to turbine TU2, where it is expanded to an even lower pressure before joining the returning JT-stream. The rest of the helium gas from HX2 continuous as the JT-stream to be cooled down in heat exchangers HX3 - HX5. After the helium exits heat exchanger HX5 it is transferred to the dewar. A liquid fraction of the two phase flow is kept in the dewar. The gaseous fraction is returning as LP stream to the coldbox. It is warmed in the heat exchangers before returning to the intake of the compressor.

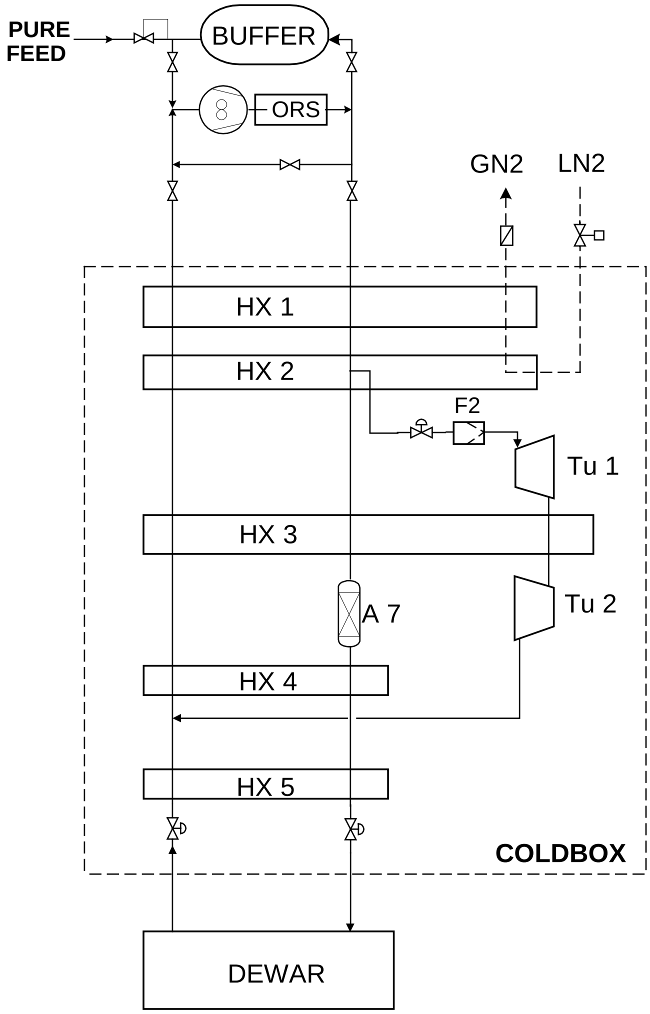

Figure 1 Process flow diagram of a TCF20 standard liquefier

IMPROVED TURBINE DESIGN

Linde Kryotechnik AG has been using well proven turbine technology. Experience of several hundred applications, reliability and low manufacturing costs were convincing arguments for the former design. Presently, Linde Kryotechnik AG has been achieving significant improvements in the design of dynamic gas bearing turbines. Most outstanding improvement is the increase in turbine efficiency.

Expansion turbines are used to extract work from helium process gas. HP helium gas is expanded over a rotating turbine wheel. Process gas temperature is decreased. Turbine efficiency is expressed as actual turbine work relatively to isentropic (ideal) expansion work.

$$\eta_s = \frac{w_a}{w_s} = \frac{h_0 - h_{3a}}{h_0 - h_{3s}}$$

Improved blade design, reduced heat inleaks and increased rotational speed are the main reasons for reaching higher turbine efficiencies. Enthalpies at inlet and outlet of the turbine are calculated from measured pressure and temperature data. Experimental results from the test bench were presented in [1]. The same instrumentation was now brought into a standard TCF20 liquefier. For the turbine chain it consists of pressure transducers and Rhodium- iron temperature sensors at the inlet and outlet of the turbines.

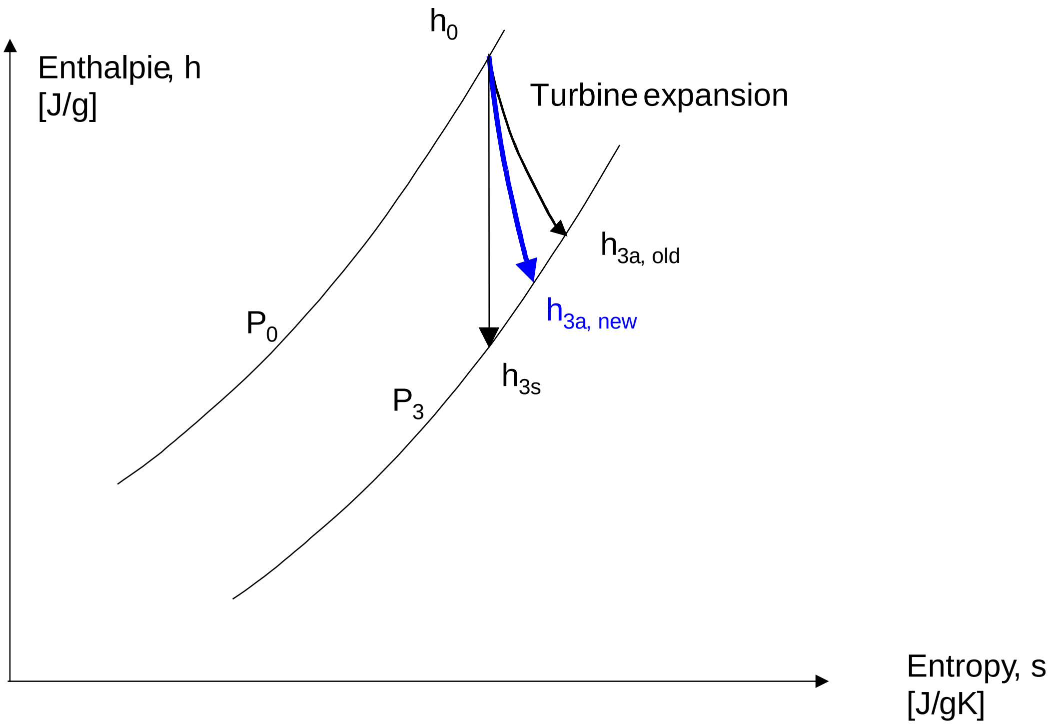

Figure 2 isentropic and real expansion in a turbine

The following table shows turbine efficiencies before (0) and after (1) the development work.

Table 1 Turbine efficiency comparison

Design case	0	0	1	1
Turbine position	Tu 1	Tu 2	Tu 1	Tu 2
Isentropic efficiency	61%	67%	80.9%	79.3%

Improved design of the axial bearing widens the operating field of the turbine. A further improvement, which was achieved with the new turbine generation, is larger robustness of the turbine. The rotor is kept by a spiral - grooved dynamic gas bearing. The use of carbon material allows that touching of the bearing does not lead to a turbine damage. It only results in an tolerable, increased wear of the bearing.

IMPACT ON LIQUEFIER CAPACITY

The test was carried out with a constant level of liquid helium in the dewar and constant pressure in the buffer tank. Liquid helium was constantly taken out of the dewar and warmed up to ambient. Mass flow was taken by a thermal flow meter.

The liquefaction rate was 1.36 g/s. In comparison to a TCF 20 under the same test conditions with conventional gas bearing turbines this is an improvement of 52 %.

The accuracy of the mass flow measurement was 4%. The accuracy of the turbine efficiency measurement was 1% for turbine 1 and 3.5 % for turbine 2.

FURTHER ADVANTAGES FOR THE PROCESS

The enlarged operating field of the turbine will allow improved cool down performance of liquefiers and refrigerators. Especially for refrigerators with different operation points optimal turbine design can be found less dependent from restricting axial force considerations.

REFERENCES

1. Cretegny D. et al. *Efficiency improvements of small gas bearing turbines - impact on standard helium liquefier performance*, CEC/ICMC 2003