Cryogenic Liquid Expanders

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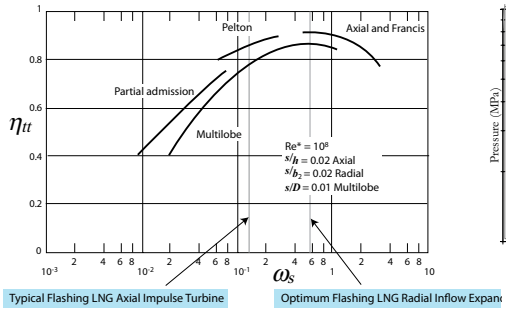
One of the applications for the Variable Phase Turbine (VPT) is replacement of liquid or two-phase Joule-Thomson valves in cryogenic systems. The power generated by the VPT is removed from the cryogenic process, increasing the process refrigeration. The efficiency of LNG production and air separation processes can be improved and liquid production increased.



Typical Flashing LNG Axial Impulse Turbine

Optimum Flashing LNG Radial Inflow Expan

Figure 1

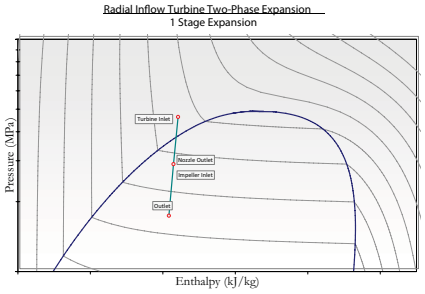


Figure 2

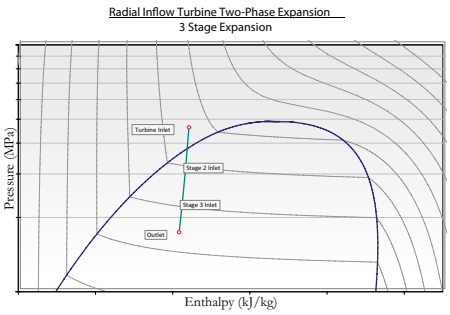


Figure 3

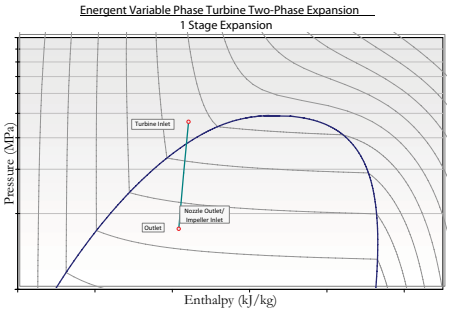


Figure 4

The VPT is an axial impulse flow expander that has advantageous features relative to radial inflow (RIF) expanders for liquid or flashing liquid expansions. **Figure 1** illustrates the specific speed of the VPT and a radial inflow expander for a flashing LNG expansion. As can be seen the optimum VPT specific speed (~.15) is about 1/3 that of an optimum radial inflow expander (~.6). The VPT, having a lower speed can directly drive a conventional generator. However, single stage RIF expanders require a gearbox or VFD drive. A RIF with direct drive of the generator requires multiple stages to optimize.

Figure 2 shows a typical expansion process for a single stage Variable Phase Turbine flashing LNG expander. A two-phase mixture is produced at the nozzle exit with a rectilinear flow path. No further flashing expansion takes place. The thermodynamic conversion process is complete. The turbine rotor is an axial impulse rotor which has been designed specifically for two-phase flow and demonstrated to have stable operation and high mechanical conversion efficiency with two-phase flows .

Figure 3 and Figure 4 illustrate the expansion paths for single stage and three stage RIFs respectively. Two-phase flow is generated within the inlet guide vanes and rotor(s) in each case. The deleterious effects of two-phase flow in radial inflow machines are well documented. Erosion from particles or liquid trapped within the guide vane- rotor gap has been observed. Degradation of performance has also been demonstrated. For example, **Figure 5** shows the results of gas in a liquid radial inflow expander. Addition of only .2% (by mass) causes a decrease in efficiency from 80% to 60%.

Recent tests of a VPT with flashing liquid nitrogen demonstrated the advantages. **Figure 6** shows the VPT during testing with flashing liquid nitrogen. The turbine was directly connected to a generator which was immersed in the liquid nitrogen. The expander has no gearbox or external shaft seals. Close agreement with predicted output was demonstrated.

The first application is planned for an LNG production plant. The addition of a single VPT to the first stage flash will increase the entire plant output by as much as 3%. Substituting VPTs for each of the six (6) Joule-Thomson flashes in the process can increase plant output by more than 6%.

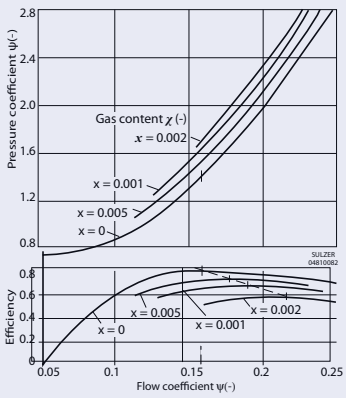


Figure 5: Performance of a 3 stage centrifugal pump operated as a radial inflow turbine in water with changing amounts of air vapor content at the turbine inlet. The *x* stands for the mass fraction of vapor in the flow at the turbine inlet. Note the 20 points decrease in efficiency as *x* goes from 0 to only 0.2% mass fraction (which is 0 to 30% volume fraction). [reference: Gülich, "Centrifugal Pumps", 2010, 2nd edition].

Figure 5

Figure 6

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1 Hays, L., History and Overview of Two-Phase Turbines, International Conference on Compressors and Their Systems, Institution of Mechanical Engineers, London, September 1999