Recovering Waste Energy in Cryogenic Processes

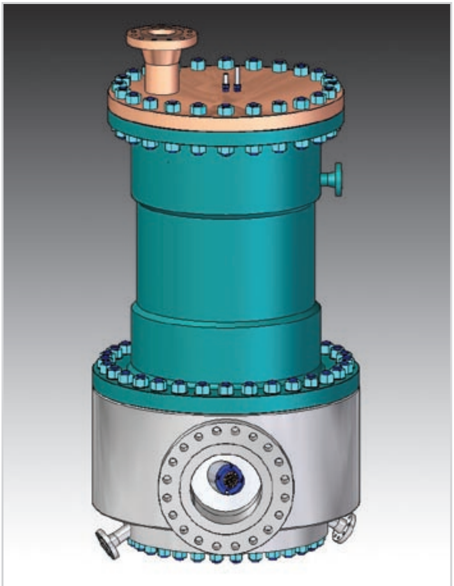

Figure 1: Two Megawatt Variable Phase Turbine for LNG

Exploiting the huge resource of lost energy to produce useful power has long been the goal of Energent Corporation, a research and development group and member of Cryogenic Industries. Currently in development are projects to recover wasted energy and improve efficiency in cryogenic processes, including air separation, LNG production, and ethylene production.

Lost energy is defined as waste heat, waste pressure, and under-utilized renewable energy. Wasted pressure energy, for example, is found in the throttling loss of an expansion valve such as the Joule-Thomson (J-T) valve in a refrigeration cycle. An example of wasted heat energy would include the use of cooling water, in conjunction with a cooling tower, to reject heat from a compressor in an air separation plant.

As reported in the 2008 summer issue of Frostbyte, Energent Corporation is developing technology to recover both forms of wasted energy and convert them into valuable power. This technology is readily applicable to many cryogenic and high-temperature, industrial processes.

Recently, the design of a 2 MW Variable Phase Turbine (VPT) was completed for Conoco-Phillips Company. The ConocoPhillips Optimized Cascade® Process currently uses a J-T valve for the expansion of high pressure, flashing LNG. Application of a VPT will not only produce power, which would otherwise be lost in the J-T valve, but will also increase the refrigeration of the expansion, boosting the LNG output of the entire plant by approximately 3%.

Smaller units suitable for air separation plants are being developed. A hermetic 25 kW unit with a submerged generator will soon be qualified for flashing liquid nitrogen service.

Waste heat generated in a cryogenic process can be recovered in a heat engine power cycle. By utilizing heat exchangers and a working fluid, this waste heat can be converted into electricity.

The conventional power cycle used for waste heat recovery is the organic Rankine cycle (ORC). Figure 2 illustrates the ORC in a heat recovery application. Hot water transfers heat to a working fluid in a vaporizer, generating a high pressure vapor. A separator is required to separate liquid carry-over. The vapor drives a high speed turbine, conventionally a radial inflow turbine, which spins a generator through a reduction gear. The vapor leaving the turbine is then condensed and sub-cooled. To close the cycle, the sub-cooled liquid is pumped back to the vaporizer.

As can be seen in the temperature-enthalpy diagram, the boiling heat transfer occurs at a constant temperature over most of the heat exchange. Consequentially, a "pinch point" is created, limiting the minimum water outlet

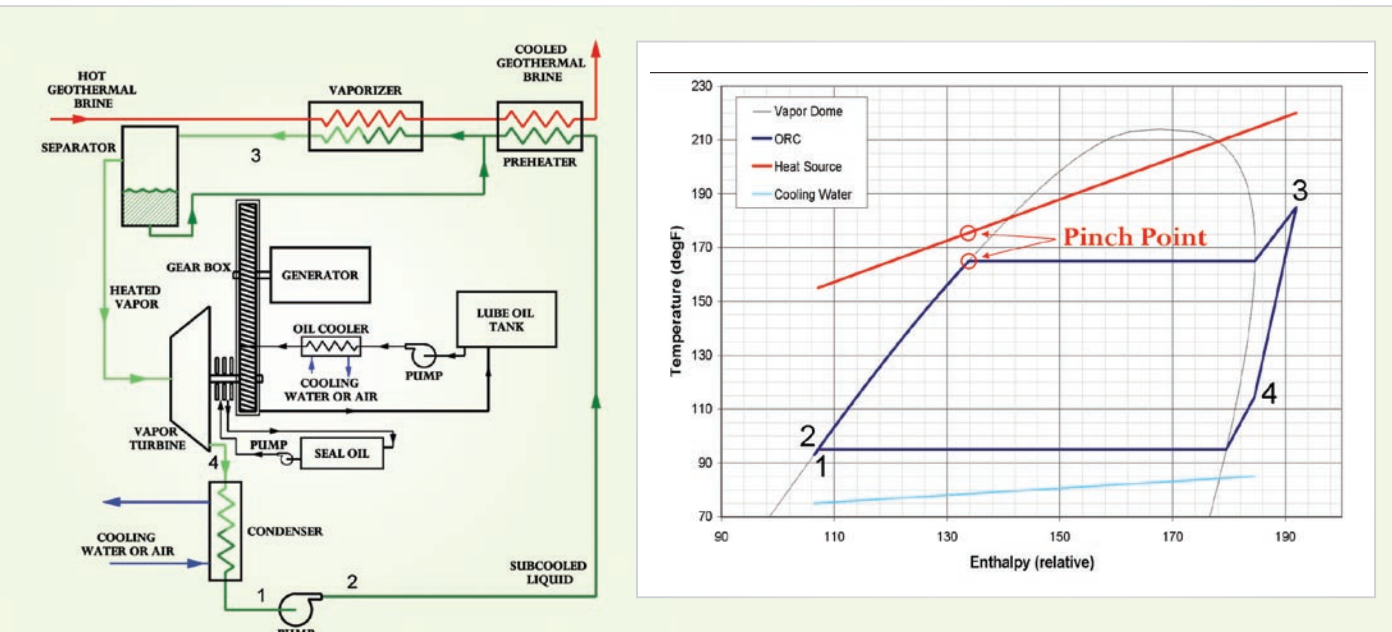

Figure 2: Organic Rankine Cycle Waste Heat Power Cycle

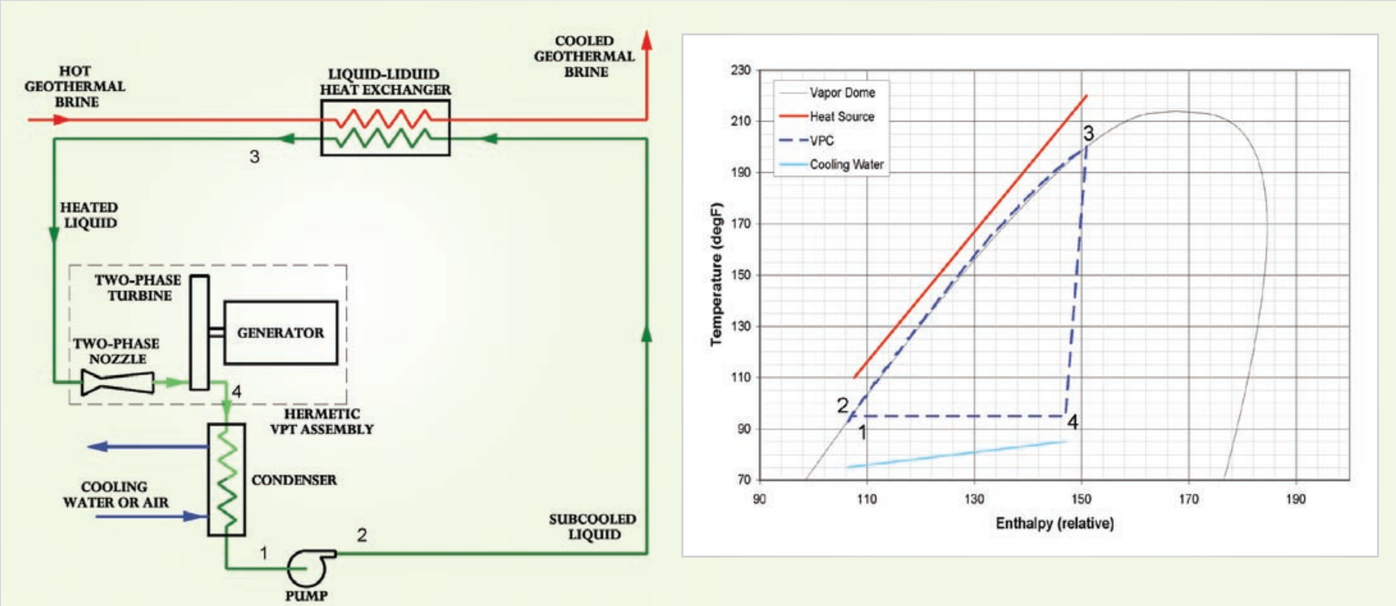

Figure 3: Variable Phase Turbine Waste Heat Cycle

temperature, and therefore the amount of heat that can be transferred into the power cycle.

To minimize the cost of the power cycle and to maximize the power produced from the waste heat, a new power cycle, the Variable Phase cycle (VPC), is being developed. The thermodynamic cycle and process diagram of the VPC is illustrated in Figure 3. The waste heat source, such as compressor cooling water or geothermal brine, transfers heat to the working fluid in a simple liquid-liquid heat exchanger. Heated liquid working fluid then flashes in a Variable Phase Turbine and generates power. The resulting vapor is condensed and sub-cooled in the condenser. Subsequently, the sub-cooled liquid is re-pressurized by a pump and returned to the heat exchanger to close the cycle.

Advantages the of the Variable Phase cycle include the elimination of the vaporizer and separator required by the ORC. Also, the Variable Phase Turbine spins at 50 or 60 Hz, allowing for the direct drive of the generator, which eliminates the gearbox and lube oil system required by an ORC. Elimination of the vaporizer simplifies the controls and makes the system more robust. In addition, a hermetic turbine-generator eliminates the seal system and potential seal failure.

Notably, the most significant benefit of the Variable Phase cycle is the use of a liquid-liquid heat exchanger, which eliminates the "pinch point" limitation encountered by the ORC. As shown in the temperature-enthalpy diagram, Figure 3, the water temperature can be dropped lower in the VPC. When compared to the ORC, 200% more energy is transferred into the power cycle. The end result is typically a 20-30% gain in electricity production by using the Variable Phase cycle.

Energent recently received a U.S. Department of Energy award to build and demonstrate a 1 MW Variable Phase cycle waste heat system. The waste heat source is 225°F geothermal brine produced as a byproduct at a geothermal power plant in California. Analysis of large air separation plants has shown that the same VPC system could generate 1 MW from the compressor cooling water, improving the plant efficiency.

A worldwide market is emerging for the production of power from waste heat and pressure. By replacing two-phase Joule-Thomson valves with Variable Phase Turbines and converting waste heat to power with the Variable Phase cycle, Energent can improve product yields and plant efficiency.

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