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This model depicts a discharge mode for a Liquid Air Energy Storage (LAES) system. Here, cold liquefied air produced by the charging system is used in a cycle that produces electricity and directly services a district cooling load, thereby avoiding electricity consumption in a chilling system. It is an alternative to the energy recovery system used by the LAES described in {1}.

Liquid Air Energy Storage (LAES) systems operate in two modes:
(1) Energy Storage (S5-30a), and
(2) Energy Recovery (this model as an alternative to that in {1}), and (S5-30b) representing the recovery system described in {1}.

Energy Discharge Model Details:
Cold liquid air enters the system from the storage tank using Fuel Source [18] at 496.5 psia / -226F (34.2 bar / -143.3C). It is pumped to 1820 psia (125 bar) and heated to 45F (7C). This air is expanded, reheated, and expanded to atmospheric pressure to produce 5.3MW electricity. Primary liquefied air heating is accomplished in stages that act to cool the return water from a District Cooling loop. Closed loops using R410A are employed to heat the air, cool the water and produce a modest amount of power. Other closed loops using Duratherm HTF ferry heat from the district cooling water to the cold air. Final air heating is accomplished using warm seawater (86F / 30C).

Net direct power generation is 5470 kW. The avoided electric consumption to cool the district water is computed by the script using a custom input for "COP of Alternative Electric Chiller for District Cooling", which is set to 3.5 by default. In this model that avoided electricity consumption (a credit for power generation) is 3120 bringing the Equivalent net power generation to 8590 kW, or about 100 kWh/ton of liquid air processed.

Roundtrip Efficiency:
Conventional electricity storage systems (batteries, pumped hydro, etc.) are self-contained, aside from the two-way connection to an electric grid. They're characterized by a 'round-trip efficiency' that relates the electricity delivered to the grid during a discharge cycle to that consumed from the grid during a charge cycle. All internal losses that reduce discharged energy are conveniently lumped into this characteristic for easy comparison with other storage systems. These systems have round-trip efficiencies in the 65% to 75% range, depending on the specifics.

The equivalent calculation for this system considers energy consumed to liquefy the air (charge mode), together with the energy generated by this system (discharge mode). Energy Storage, model (S5-30a), computes specific power of 265 kWh/ton of liquid air produced. This model computes energy recovery a the rate of 100 kWh/ton of liquid air processed. Resulting round-trip efficiency for this combination of systems is about 38%.

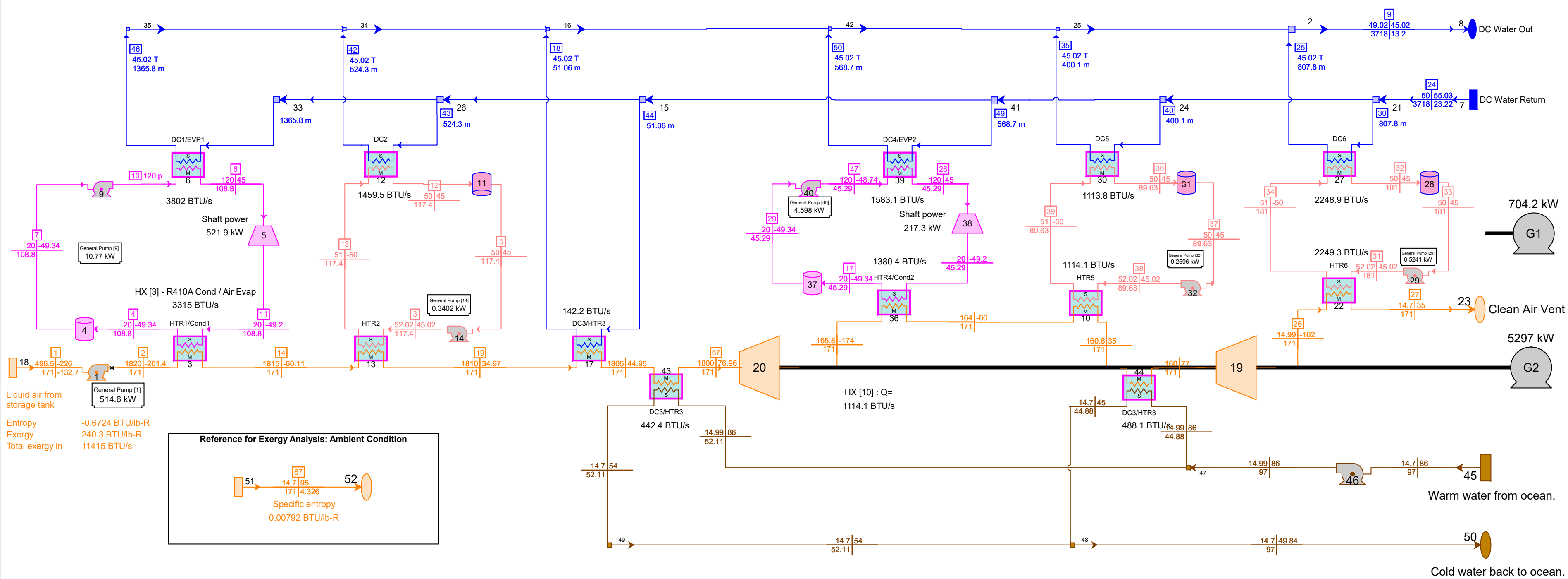
THERMOFLEX Specifics:
The 'Air' stream in this cycle is modeled using THERMOFLEX's LNG Fuel (orange) stream. Thermo-physical properties for LNG Fuel are handled in the same way as the "User-defined general fluid" feature for Refrigerant streams. In both cases, the properties are pre-computed using the widely used, but very slow, NIST (REFPROP) formulations and stored in a lookup table. The time-consuming process needed to populate the table is only done once, as a pre-processing step. Thereafter, cycle calculations use a speedy lookup method to evaluate properties needed to model the cycle. In this model either the LNG fluid or the Refrigerant fluid could have been used to model the air, equivalently. The rationale for using LNG here is consistency with the cousin sample file (S5-30b) where the LNG was selected because it could be mixed with water, a feature unavailable for the refrigerant fluid.

Related Models:
LAES discharge cycles where power is recovered is modeled in:
(1) (S5-30a) Liquid Air Energy Storage - Storage Mode (Air Liquefaction).TFX
(2) (S5-30b) Liquid Air Energy Storage - Recovery using Combined Cycle.TFX

References:
{1} VPS Cycle with Steam Feasibility Study for Bulk Power Storage in New York City, New York State Energy Research and Development Authority report number 13-12 (May 2013)

Liquefied Air Energy Recovery Coupled with District Cooling

Gross power	6001 kW
Plant auxiliary	531.1 kW
Net power	5470 kW
Total district cooling load	10350 BTU/s
Electric credit for district cooling (avoided power consumption @ COP=3.5)	3120 kW
Equivalent total net power recovery	8590 kW
Liquid air exergy input	11415 BTU/s
Exergy efficiency (equivalent net power / total exergy inflow)	71.33 %



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