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This is a model of an air liquefaction system. It consumes air at ambient conditions, and produces cold, high pressure, liquefied air. The specific process modeled here, from Reference {1}, uses 265 kWh/ton (292 kWh/tonne) of electricity per unit of liquid air produced. The efficiency, ratio of minimum power required over the actual power consumed, is 45.7%.

This model is one of several samples used to model the Liquid Air Energy Storage (LAES) system described in {1}. The proposed LAES system operates in two modes:
(1) Energy Storage (this model), and
(2) Energy Recovery demonstrated in companion sample files (S5-30b) and (S5-30c).

Air Liquefaction / Energy Storage Model Details:
Refrigerant Air Source [1] supplies dry ambient air, pre-treated to remove moisture and CO2. This incoming stream is compressed from ambient pressure to 500 psia in six intercooled stages, compressors (C1 through C6). This is shown in the yellow box on the [Main] tab. The power to drive the compressor train is the primary electric load in this plant.

Refrigeration to liquefy the air is provided by the cryogenic stream, split downstream of compressor C6. The low cryogenic temperature is achieved by compressing, cooling, and expanding the split stream to produce the -261 F (-163 C) stream entering the Air Liquefier. This portion of the system is enclosed in the gray box on the [Main] tab.

The compressor train is intercooled to reduce electric load. The intercooler is comprised of three heat exchange steps. The first step, "High Temperature After Cooler" (HTAC) transfers heat used to run the absorption chillers modeled on the [Absorption Chiller] flowsheet. Intermediate cooling step is accomplished using the fin-fan cooler model on the [FFC] flowsheet that rejects heat to the environment. Air exiting the intermediate cooler is further cooled using chilled water returned from the absorption chillers.

A control loop is used to find the inlet air temperature to compressors C1 through C7 that is possible given the absorption chiller's capacity, as determined in part by the air exit temperature from compressors C1 - C7. The control loop is setup to sort out this inter-dependency automatically.

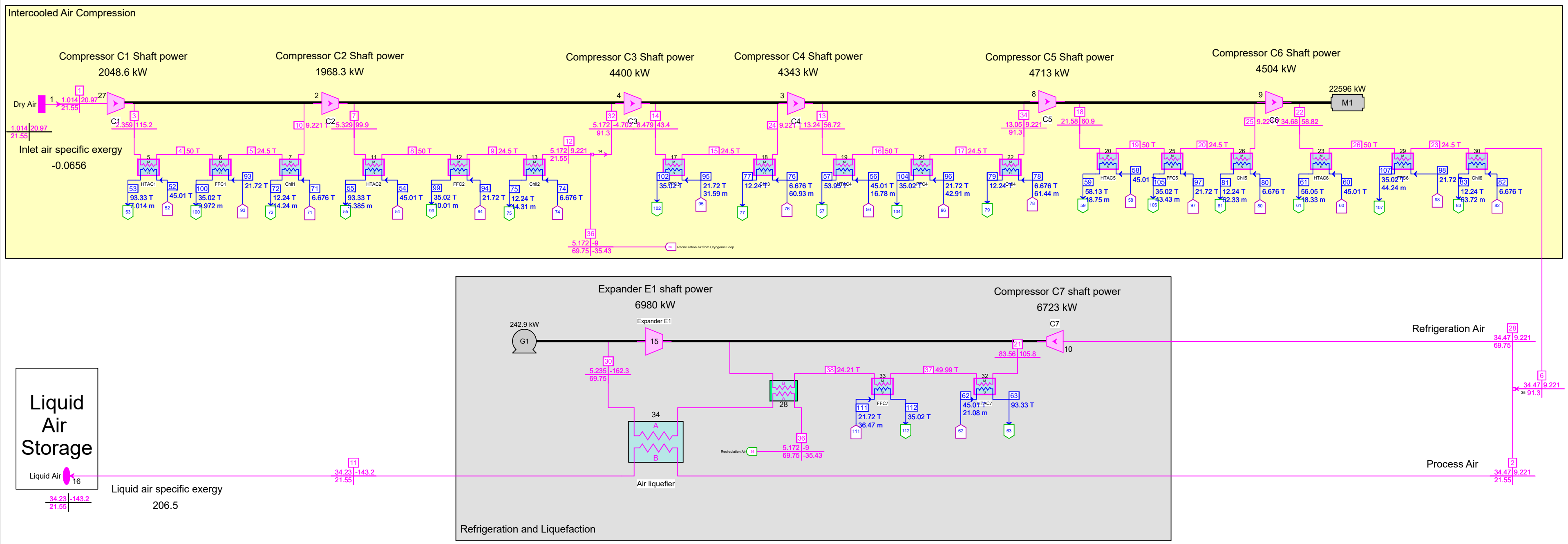
THERMOFLEX Specifics:
Since the 'Air' in this model goes through a phase change, the air properties rely on THERMOFLEX's "User-defined general fluid", a feature built-into the purple (refrigerant) Source. A property lookup table for dry, CO2-free air (78.12% N2 + 20.96% O2 + 0.92% Ar) is pre-computed using the widely used, but very slow, NIST (REFPROP) formulations. The time-consuming process needed to populate the lookup table with data 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. The speed advantages of this approach are dramatic, but require the air to be treated as pseudo-pure, and thus it cannot be separated into its constituent components (O2, N2, Ar) as would be done in an air separation process. However, that imposes no limitations on this model.

Related Models:
LAES discharge cycles where power is recovered is modeled in:
(1) (S5-30b) Liquid Air Energy Storage - Recovery Mode using Combined Cycle.TFX
(2) (S5-30c) Liquid Air Energy Storage - Recovery Mode with Direct Expansion + District Cooling.TFX

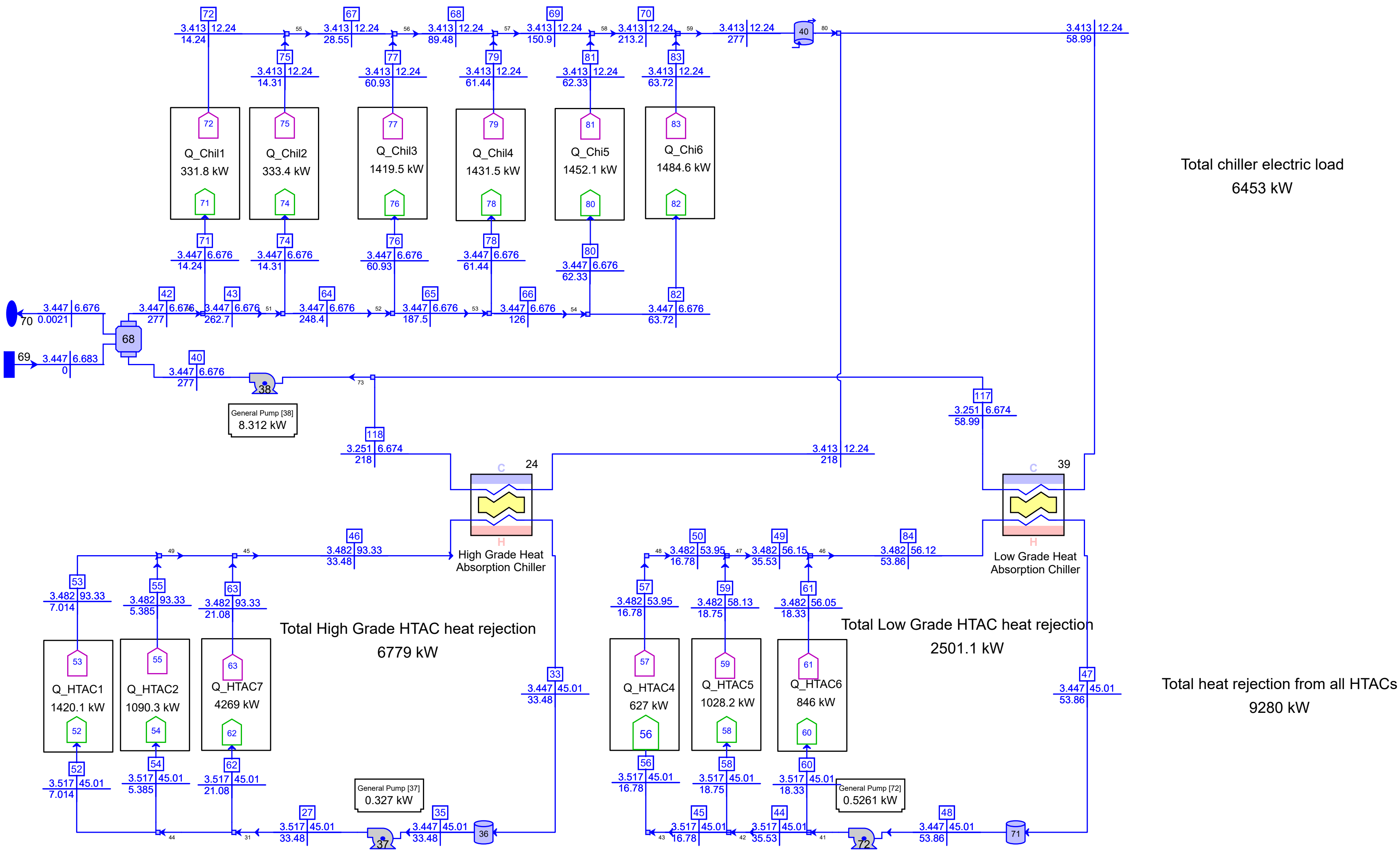
References:
{1} VPS Cycle with Steam Feasibility Study for Bulk Power Storage in New York City, New York State Energy Research and Development Auth...

Liquid Air Energy Storage System - Charging Process

Net power	-22666 kW
Air liquefaction specific power	292.2 kWh/tonne
Minimum specific power (exit air exergy - inlet air exergy)	133.5 kWh/tonne
Exergy efficiency (minimum specific power / computed specific power)	45.68 %



bar | C
kg/s | kJ/kg



Intermediate heat loads from intercooler rejected to the environment