

Dynamic simulations of medium-sized hydrogen liquefiers based on EcosimPro simulation software

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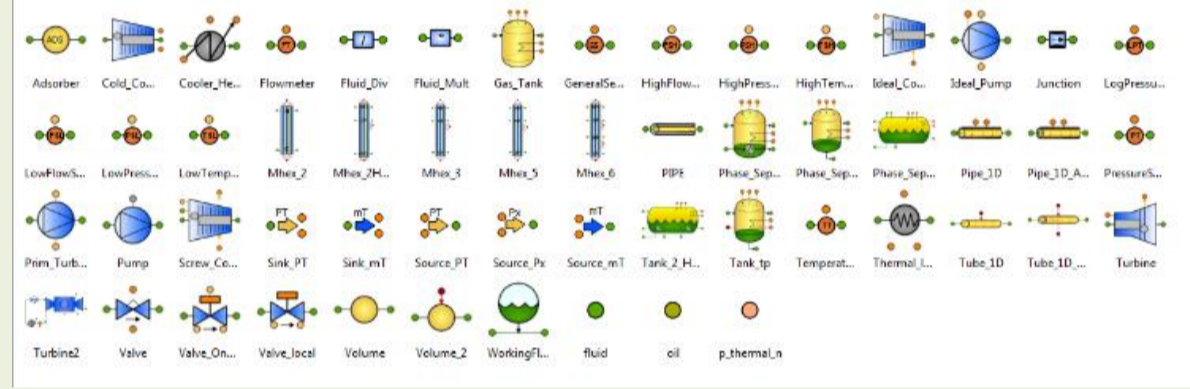
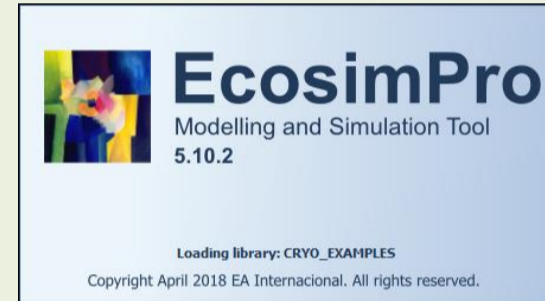
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Introduction

Liquid hydrogen has unique characteristics such as lower weight and volume and higher energy content than the gaseous hydrogen. Using a hydrogen liquefier to liquefy raw hydrogen is a traditional method to get liquid hydrogen. Dynamic simulation of hydrogen liquefier improves understanding of the processes and helps in better design, optimizes operation and controls for different system transient. In recent years, dynamic simulation are mainly about helium refrigerators/liquefiers, the reported simulation of hydrogen liquefier are mainly about process flow. The dynamic simulation of hydrogen liquefiers using EcosimPro simulation software was seldom reported in recent years. Dynamic simulations of medium-sized hydrogen liquefiers using process simulation software EcosimPro will be discussed in this research. There are two process flows, one helium turbine process flow and two helium turbines process flow. These two process flows are discussed separately.

Software EcosimPro

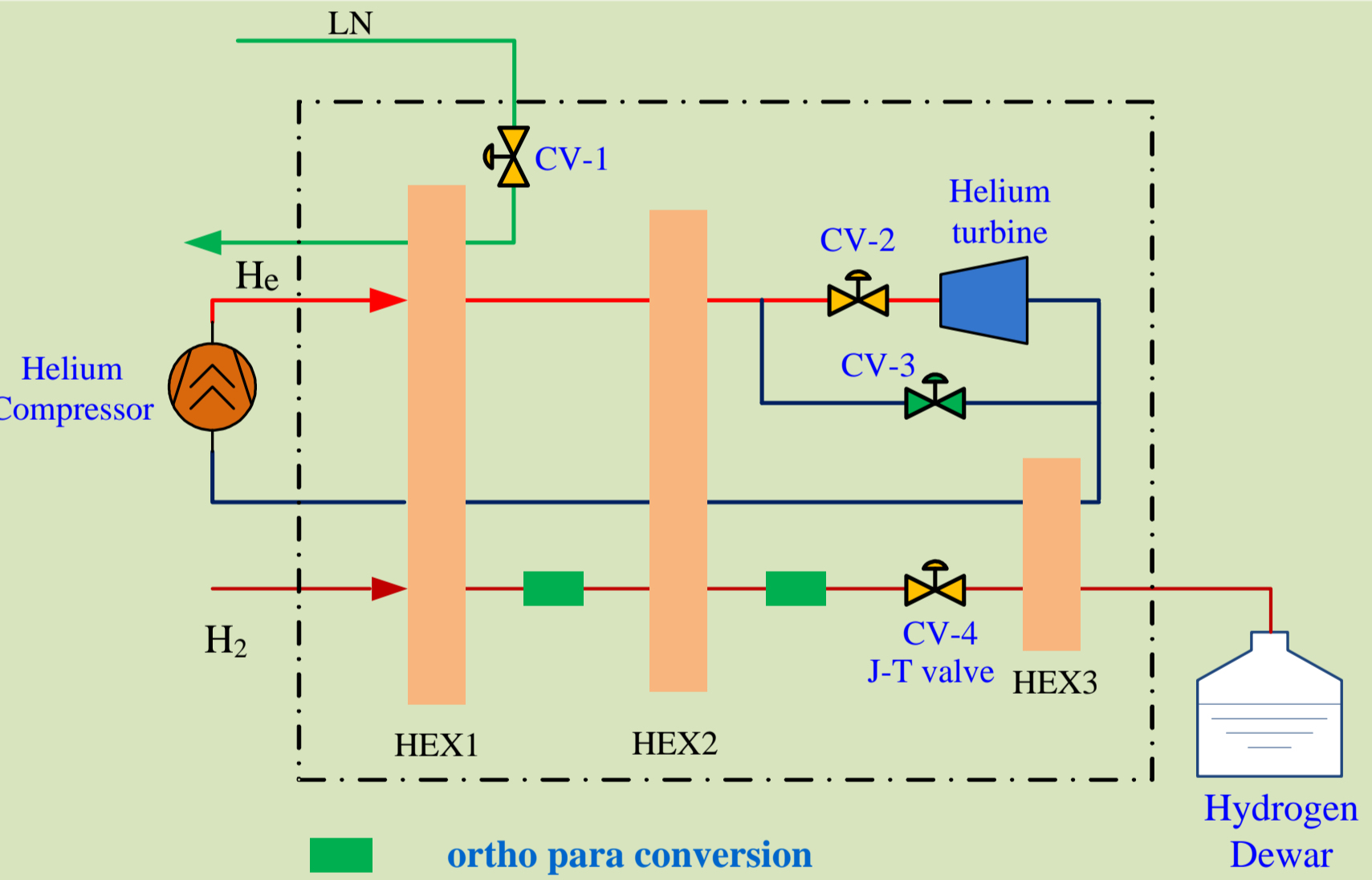
EcosimPro is a modelling and simulation tool for modelling 0D or 1D multidisciplinary continuous-discrete system and any kind of system based on differential-algebraic equations (DAE) and discrete events. A cryogenic library named CRYOLIB has been developed and validated to simulate cryogenic systems. In this research, fluids used are helium and hydrogen. Fluid properties are based on the interpolation in external tables of data generated with HEPAK (helium) and REFPROP (other fluids).



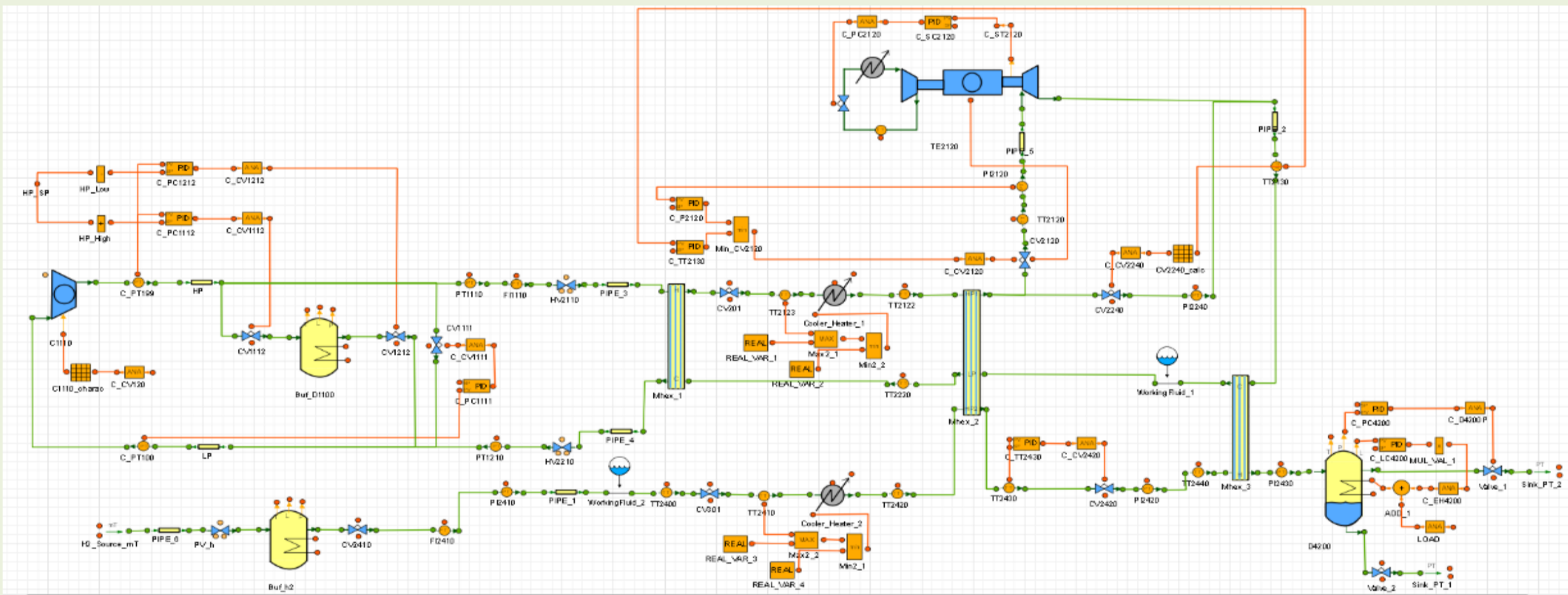
Cryolib

Dynamic simulation of one medium-sized hydrogen liquefier with one helium turbine

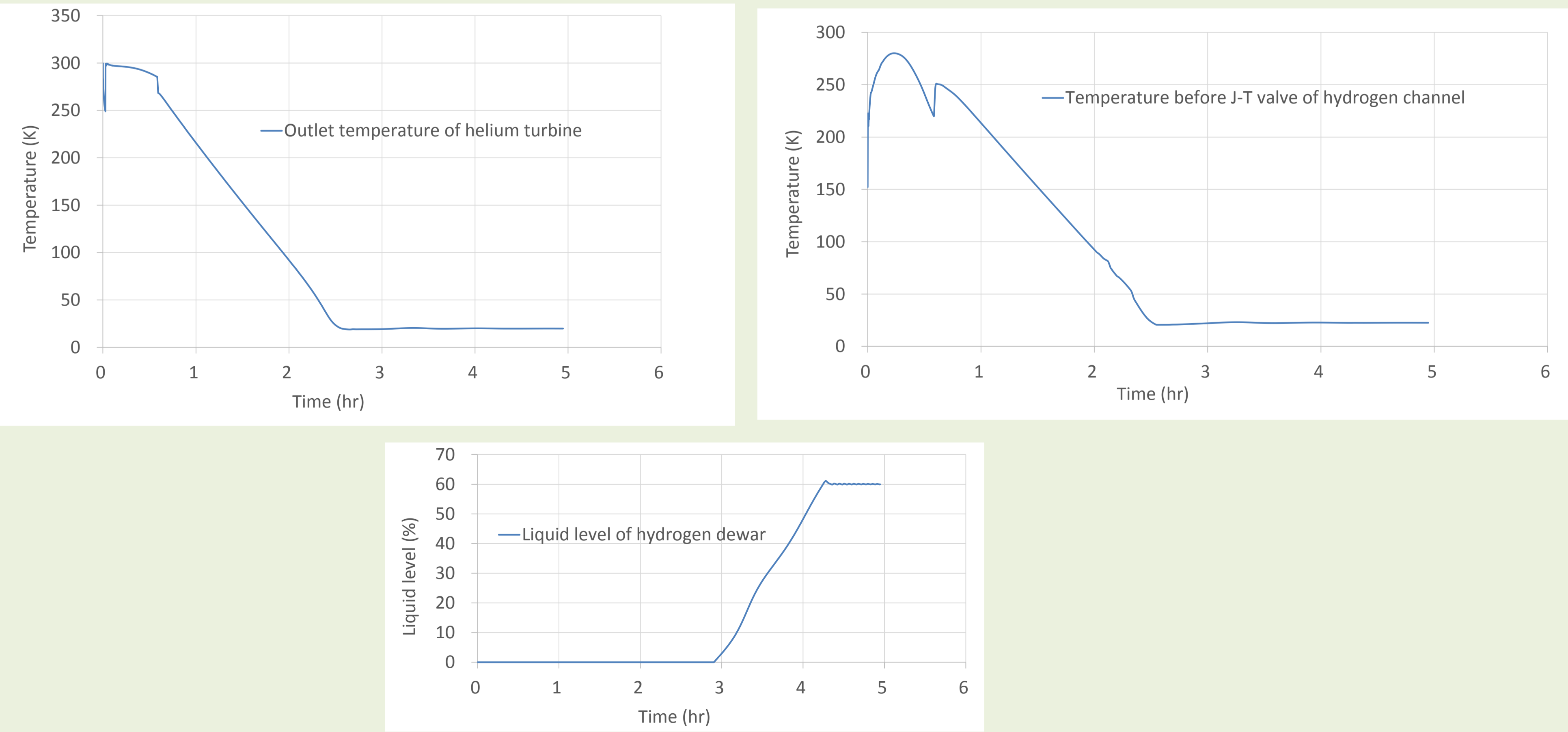
Process flow diagram



Simulation model: EcosimPro V5.0.6



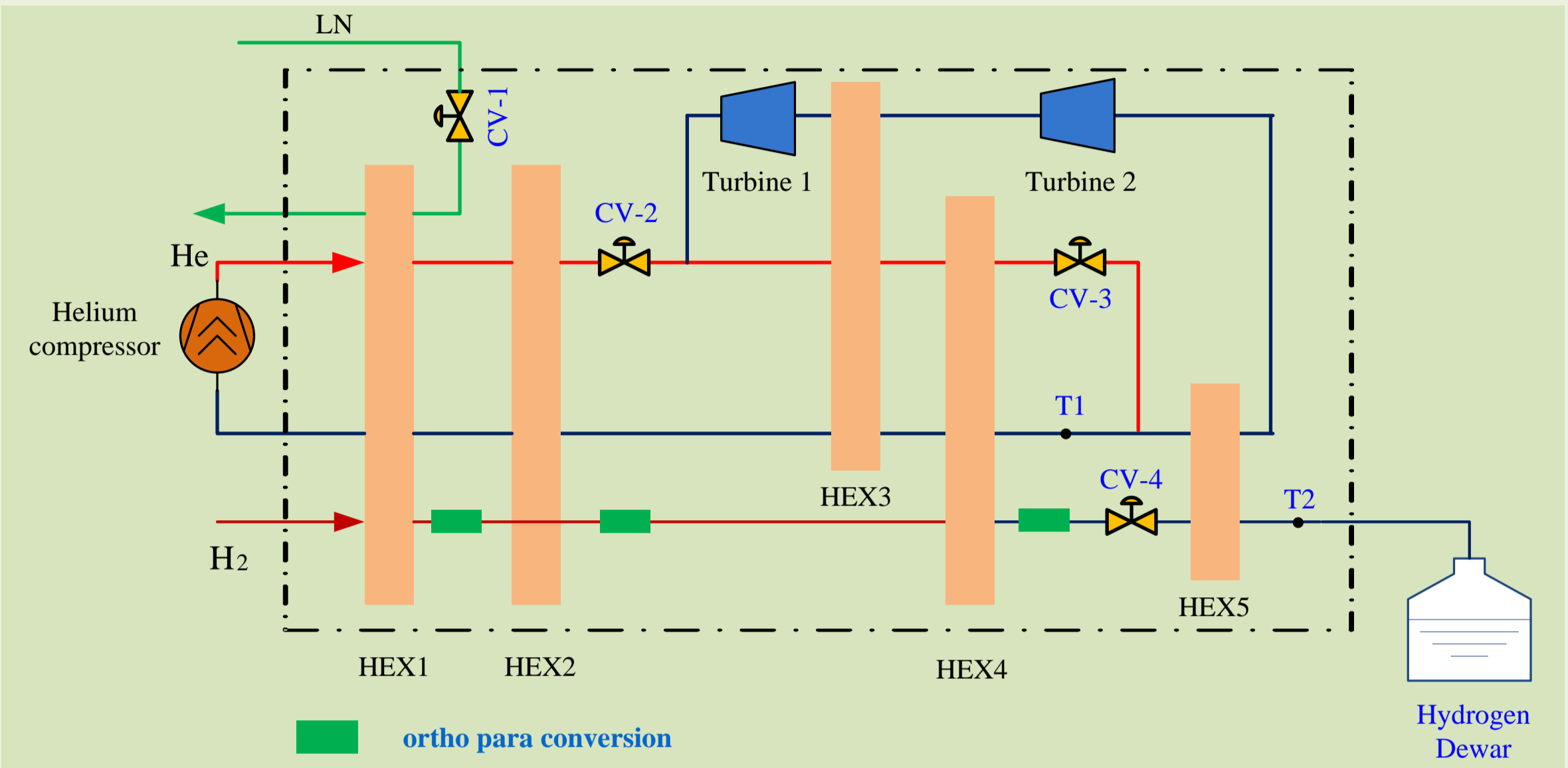
Simulation result: cooling down curve and liquid level curve



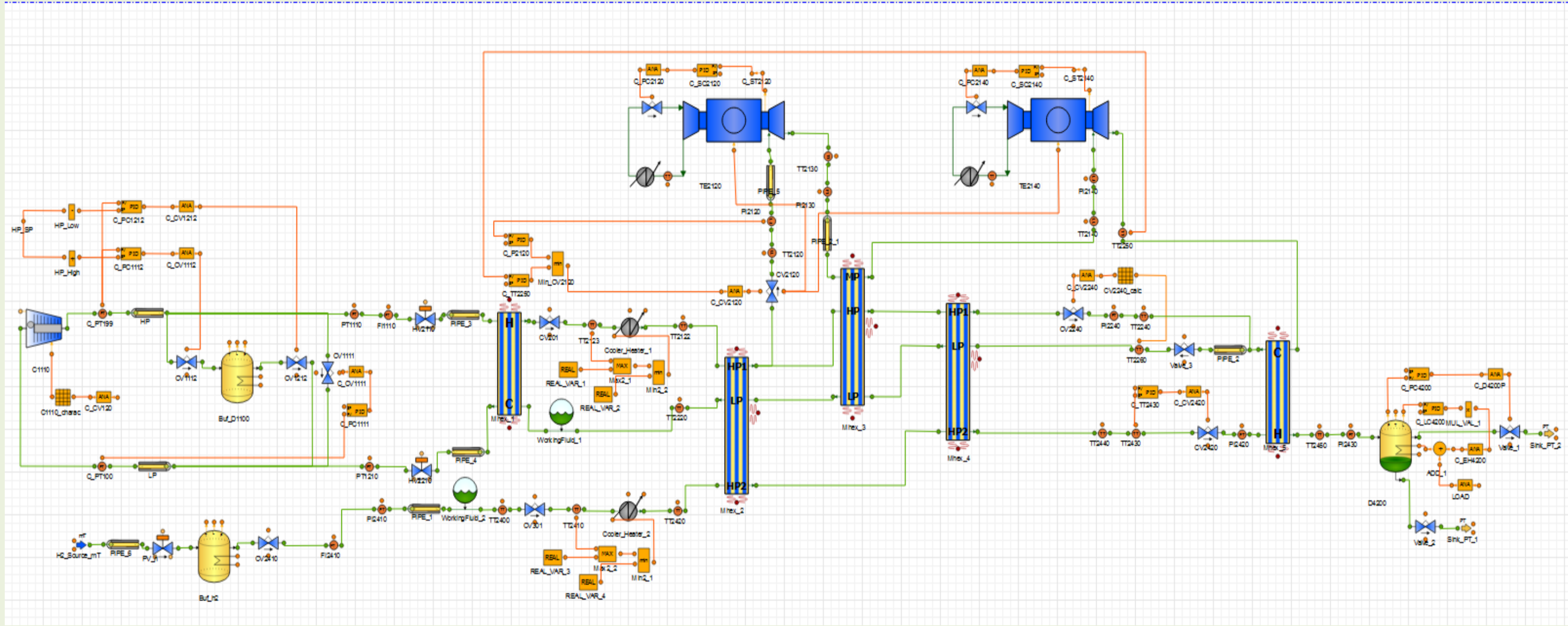
The pressure ratio of helium compressor is 2/16 bara. The mass flow rate of helium gas is 111 g/s. The pressure of hydrogen is 10 bara, mass flow rate of hydrogen gas is 4.3 g/s, the liquefaction rate is about 191 L/h.

Dynamic simulation of one medium-sized hydrogen liquefier with two helium turbines

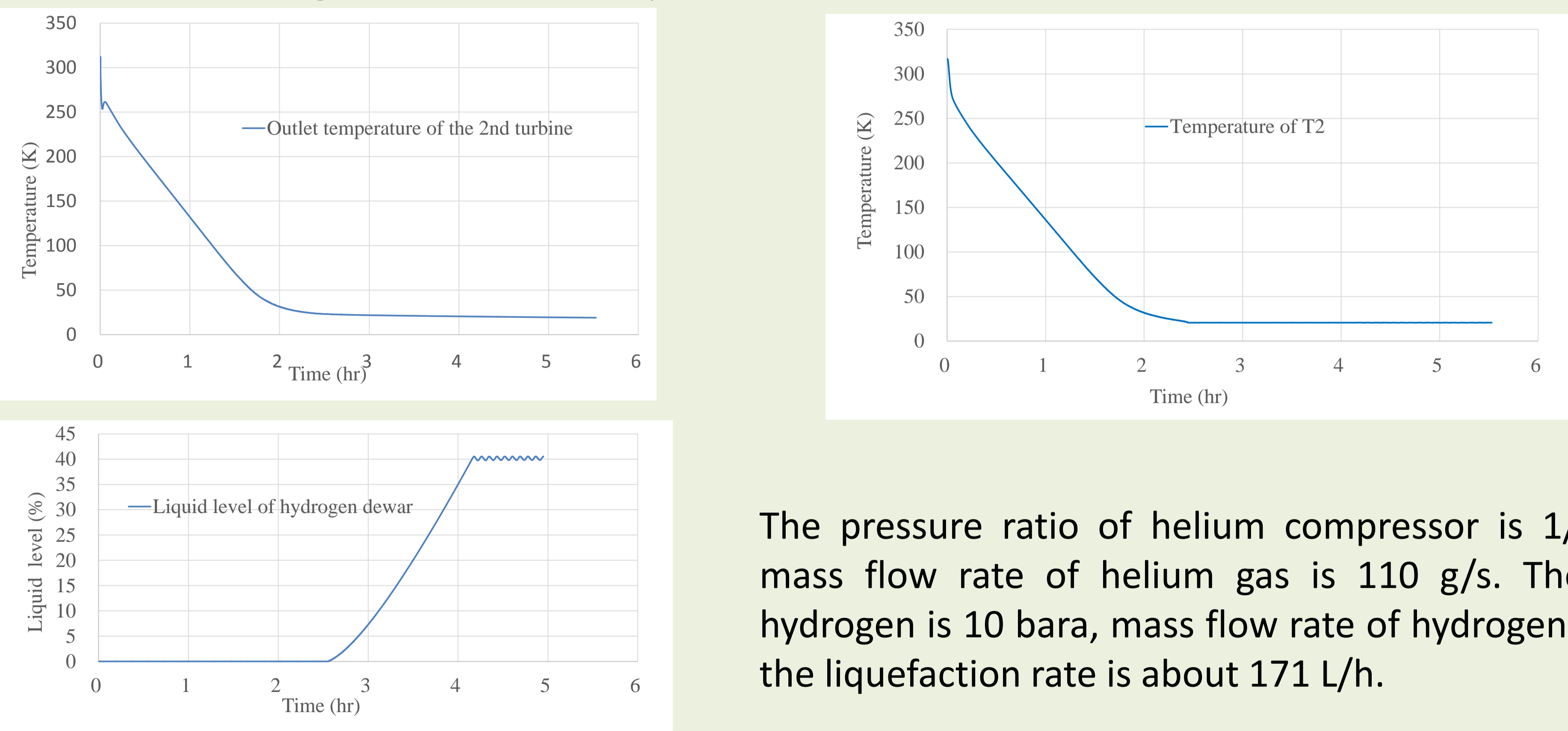
Process flow diagram



Simulation model
EcosimPro V5.10.2



Simulation result: cooling down curve and liquid level curve



The pressure ratio of helium compressor is 1/14 bara. The mass flow rate of helium gas is 110 g/s. The pressure of hydrogen is 10 bara, mass flow rate of hydrogen gas is 5.2 g/s, the liquefaction rate is about 171 L/h.

Comparison and conclusion

Hydrogen liquefier with one helium turbine has a high reliability because it has a simple structure. However, the heat exchangers of this hydrogen liquefier need bigger areas and bigger sizes. Hydrogen liquefier with two helium turbines has a compact structure because the heat exchangers of this hydrogen liquefier need smaller areas. However, there are two helium turbine expanders in series, the system is more complicated to control. Simulation software EcosimPro can be used to simulate hydrogen liquefier/refrigerator. However, such simulator was seldom reported in recent years. This research uses simulation software EcosimPro to simulate medium-sized hydrogen liquefiers. Two process flows of hydrogen liquefiers with one helium turbine and with two helium turbines have been simulated separately. It broadened the dynamic simulation's applicability.