VAPOR CYCLE LIBRARY

Overview

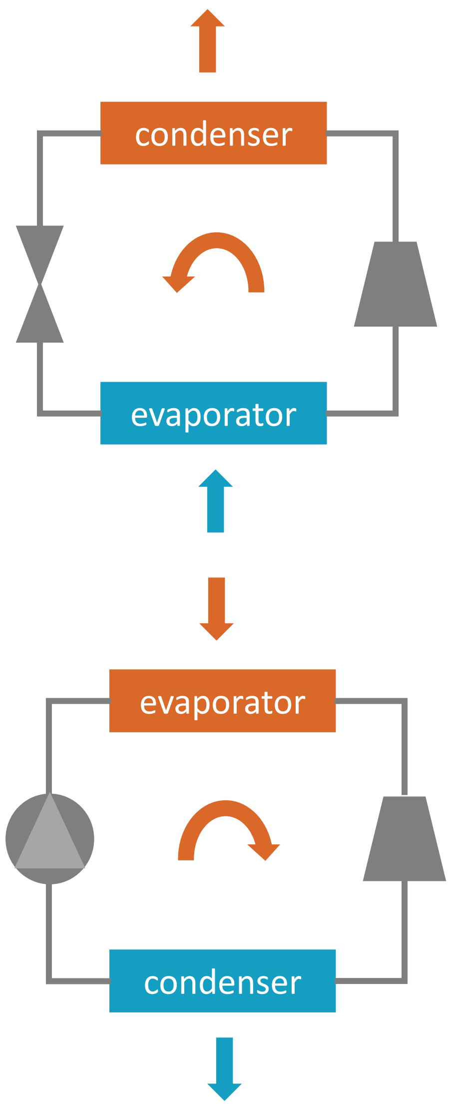
Modelon

AGENDA

- ❑ About Vapor Cycle Library
- ❑ Key Features
- ❑ Key Capabilities
- ❑ Key Applications
- ❑ Library Contents
- ❑ Modelon Compatibility
- ❑ Latest Release

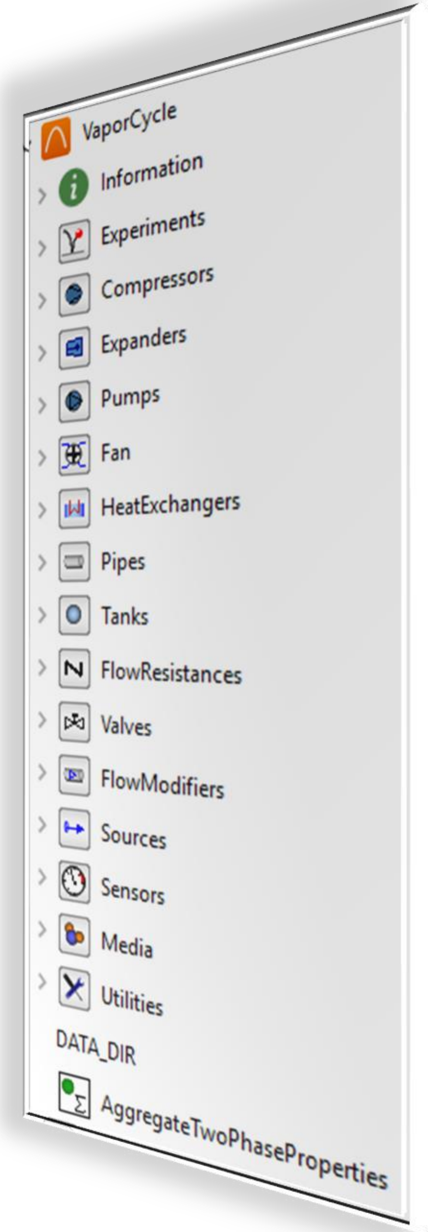
ABOUT VAPOR CYCLE LIBRARY

- Vapor Compression Cycles
  - Air-conditioning - automotive, residential
  - Refrigeration - cryogenic, supermarket, household appliances
  - Heat Pumps - automotive, residential
- Organic Rankine Cycles
  - Waste heat recovery - automotive, residential, process industry
  - Solar thermal power, geo-thermal power



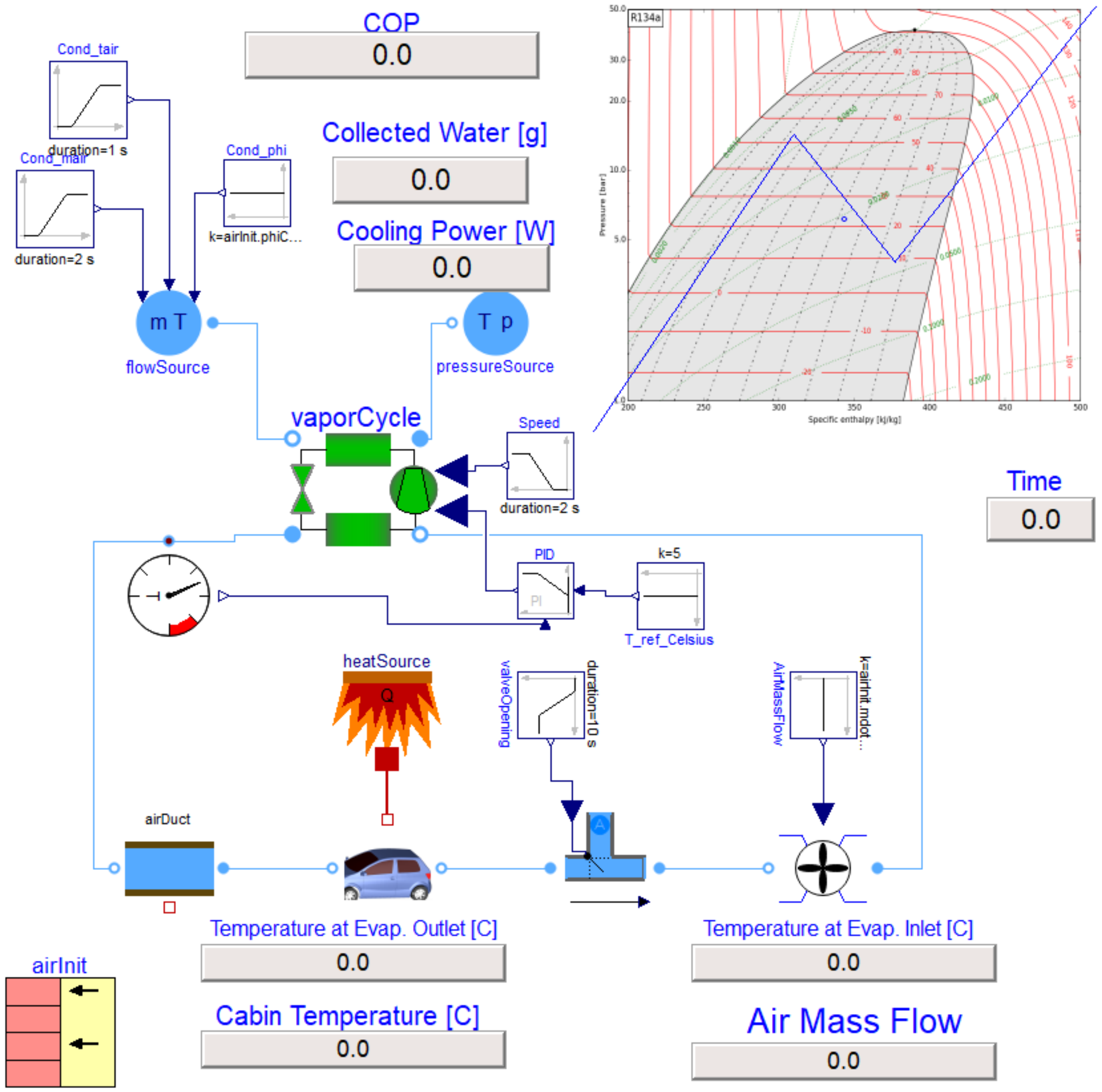
KEY BENEFITS

- Transient and steady-state simulation of component test rigs and cycle systems
- Flexible composition of user-defined system architectures
- Wide range of different working fluids including R-134a, R-1234yf, R-404a, R-407c, carbon dioxide, isobutane
- Plug and play compatible with other libraries for thermal management:
    - Liquid Cooling Library - Networks with incompressible fluids, heating and cooling
    - Heat Exchanger Library - Detailed geometry-based heat exchangers, support of inhomogeneous air inlet profiles



KEY CAPABILITIES

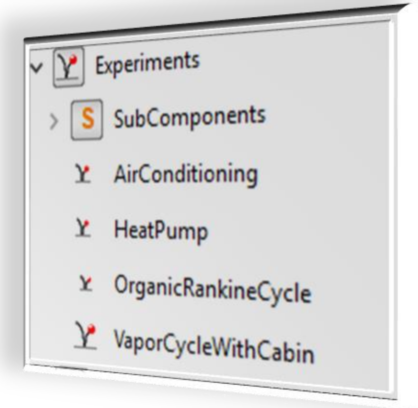
- Ready-to-use models for
    - Example cycle systems
    - Heat exchangers
    - Valves and flow resistances
    - Flow machines
    - Pipes and tanks
- Fluid domains
    - Working fluid with phase change
    - Incompressible water in heat exchangers and sources
    - Moist air in heat exchangers and sources



KEY APPLICATIONS

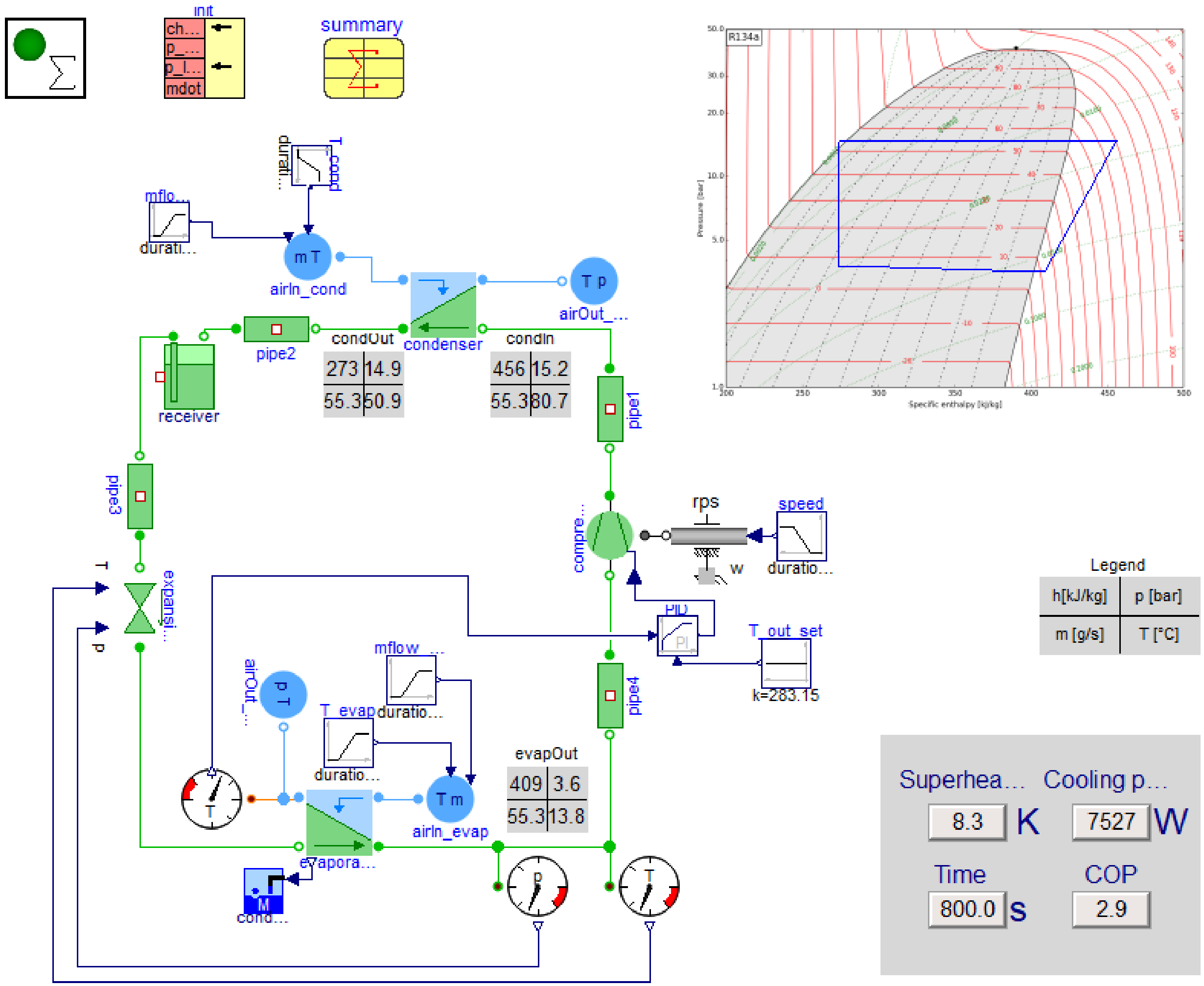
KEY APPLICATIONS

- Air-conditioning system with R134a as default refrigerant.
- Air-conditioning system with cabin model.
- Organic Rankine Cycle
- Heat Pump system



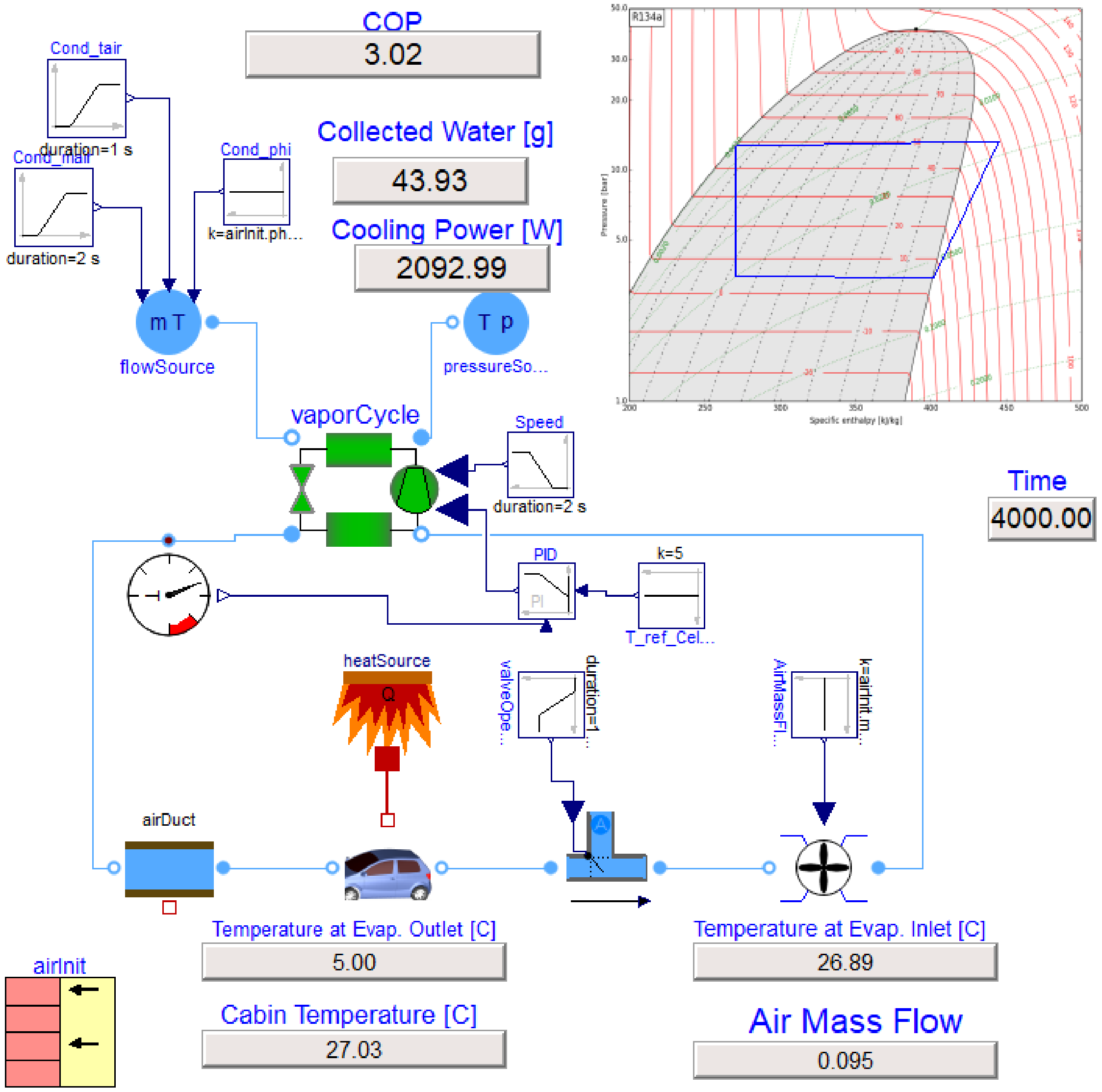
EXAMPLE: AIR CONDITIONING

This is an example of an air-conditioning system experiment with R-134a as refrigerant. A vapor compression cycle with air as secondary fluid in condenser and evaporator is controlled via a variable volume displacement in the compressor to reach a pre-defined air outlet temperature at the evaporator. The superheating at the evaporator is regulated by a thermostatic expansion valve. The system is initialized with a given specific charge.



EXAMPLE: VAPOR CYCLE WITH CABIN MODEL

This is an example of a simple cabin cooled down by a vapor compression cycle. The compressor displacement is controlled to obtain the set-point value of the outlet air temperature from the evaporator. This an extension of air conditioning model.



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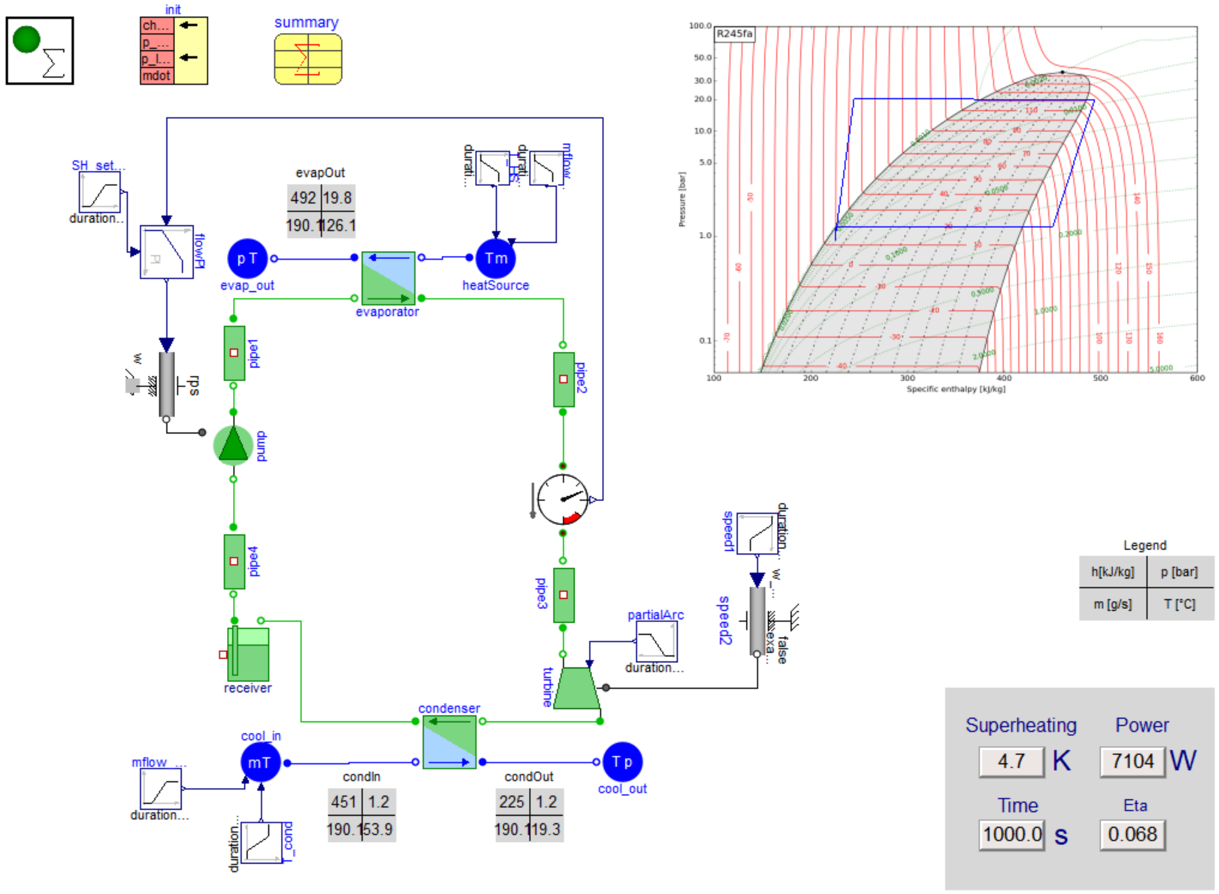
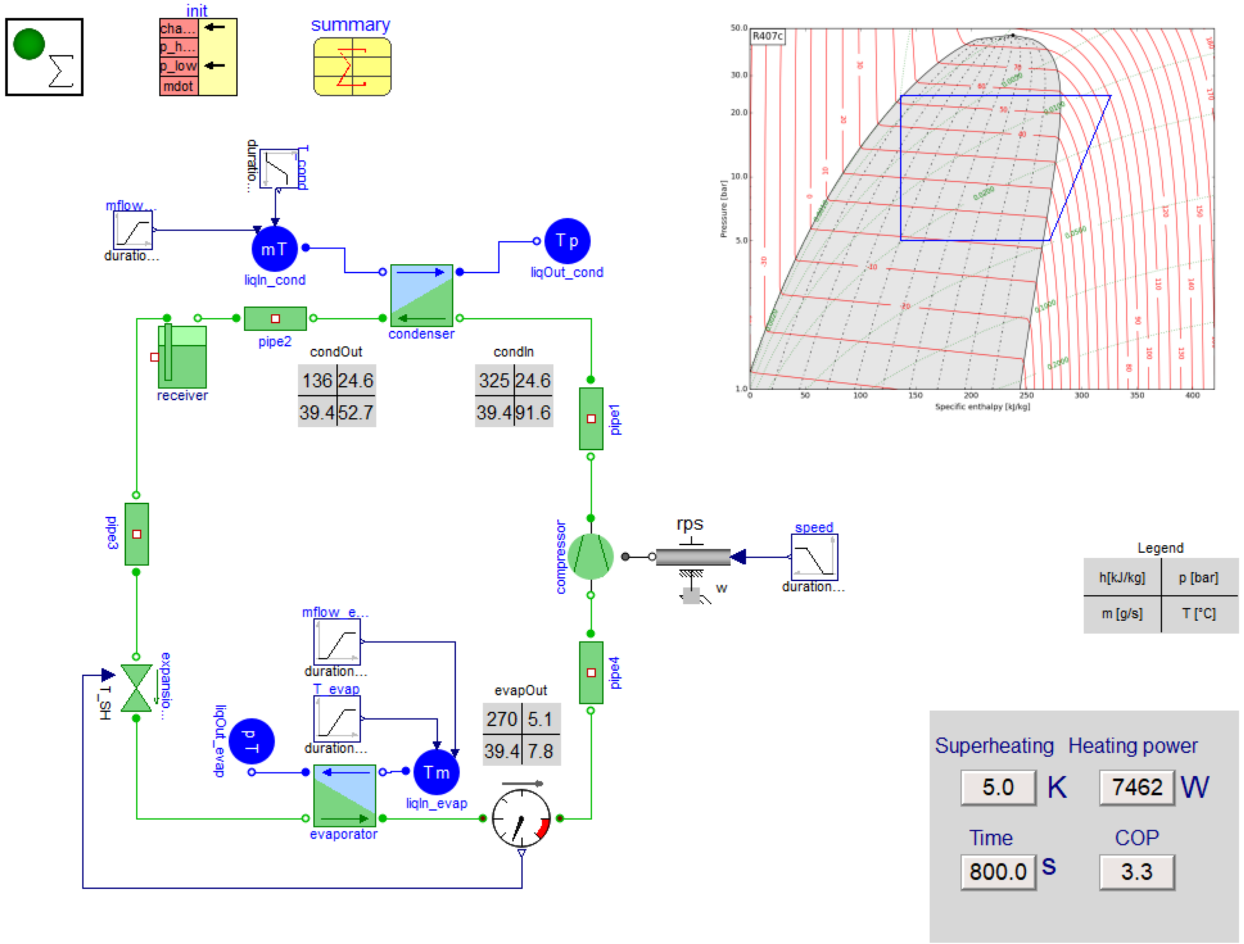
EXAMPLE: ORGANIC RANKINE CYCLE

This is an example of an Organic Rankine Cycle with R-245fa as working fluid. Water is the heat source at the evaporator which evaporates the working fluid with an expansion in the following turbine. In the condenser the working fluid is returned into its liquid state at a lower pressure (and temperature level). A pump then provides the necessary pressure elevation to start evaporation



EXAMPLE: HEAT PUMP SYSTEM

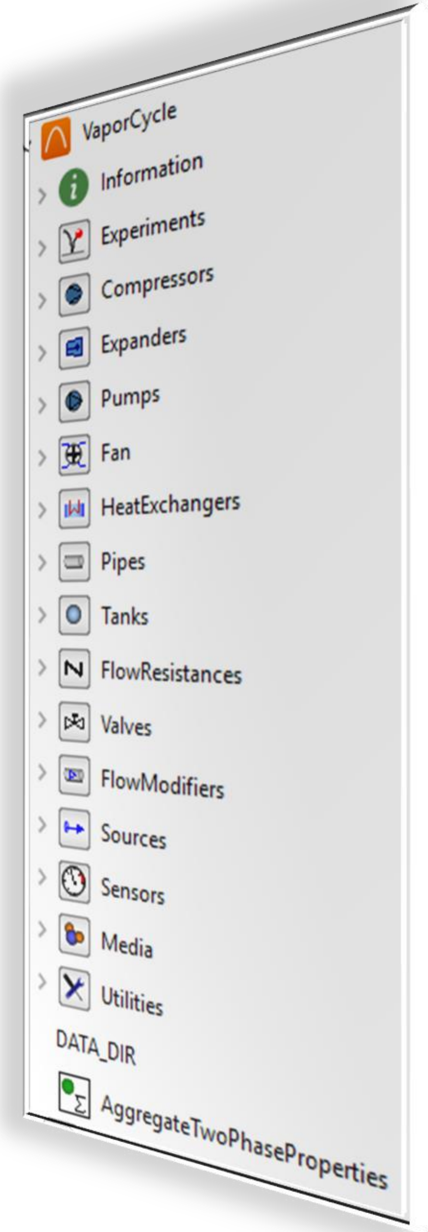
This is an example of a heat pump system experiment with R-407c as working fluid. A vapor compression cycle with water as secondary fluid in condenser and evaporator transports heat from the low temperature heat source to the high temperature heat sink. The superheating at the evaporator is controlled by the expansion valve



LIBRARY CONTENTS

LIBRARY CONTENTS

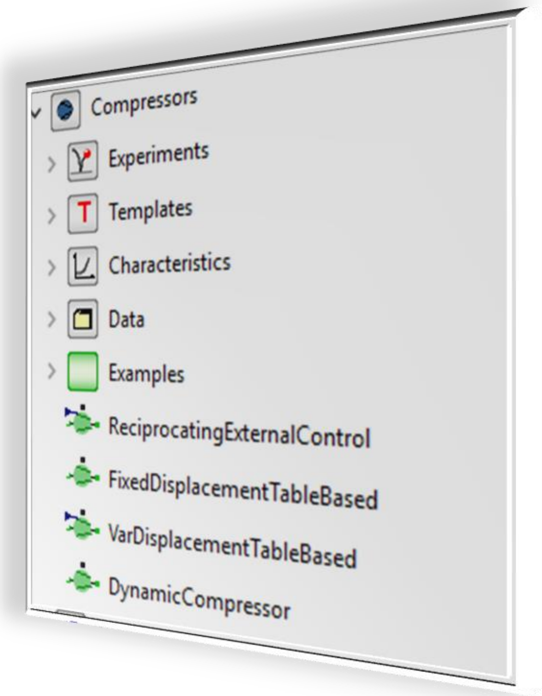
- Compressors
- Expanders
- Pumps
- Fan
- HeatExchanger
- Pipes
- Tanks
- FlowResistances
- Valves
- Media

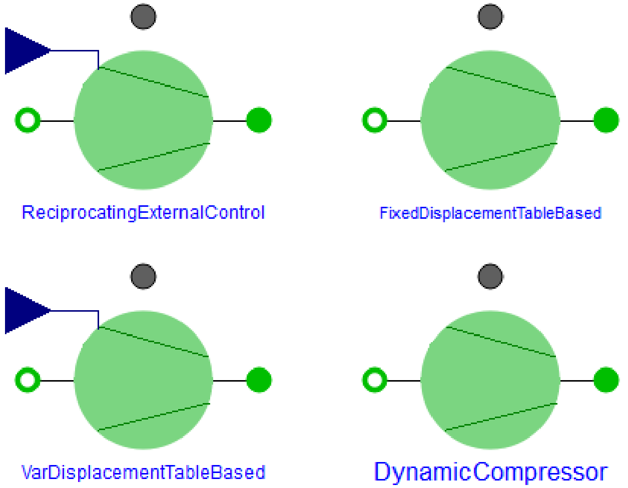


LIBRARY CONTENTS

Compressors

- Modelling approach
  - Quasi-steady state
  - Mass flow and change of enthalpy are calculated by algebraic equations
  - Displacement volume, if applicable, can be controlled by an external signal
- Parameterization
  - User input as non-linear approximation functions or tabulated data
  - Volumetric (l), isentropic (h) and effective isentropic efficiencies as functions of pressure ratio (p) and speed (n) as well as part load (x) $\lambda,\eta(\pi,n,x) = f(\pi,n)\cdot g(x,n)$

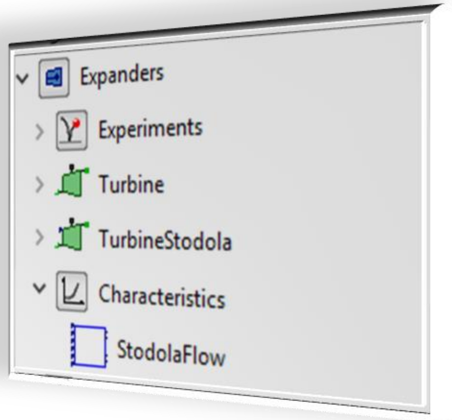


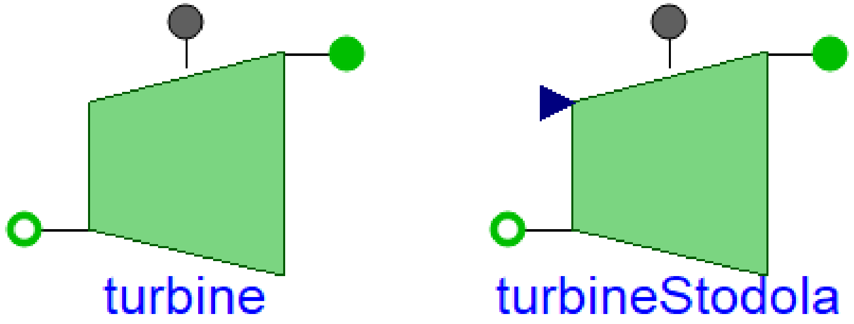


LIBRARY CONTENTS

Expanders

- Modelling approach
    - Quasi-steady state
    - Mass flow and change of enthalpy are calculated by algebraic equations
- Parameterization
    - User input as tabulated isentropic efficiency and corrected mass flow.
    - Description of flow and efficiency characteristic according to the Stodola law.

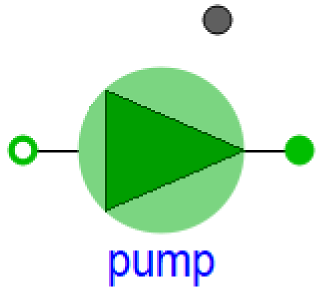


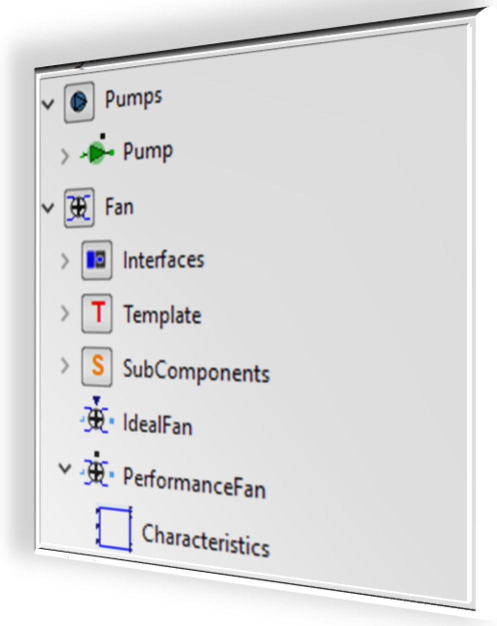


LIBRARY CONTENTS

Pumps

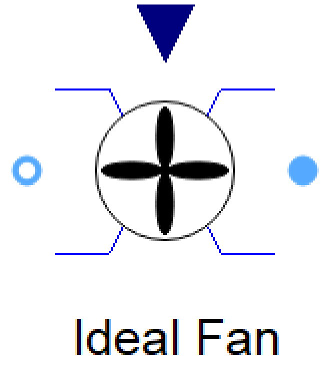
- pump combines the corresponding pump component from the Modelon Base Library with a two-phase working fluid volume

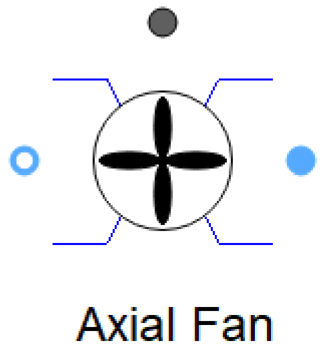




Fan

- An ideal fan with fixed mass flow and no heat losses.
- An axial fan where the fan characteristic can be given in different ways

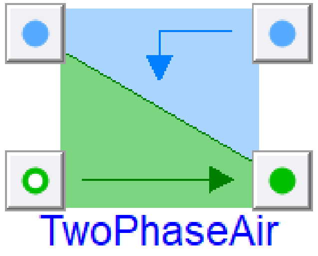


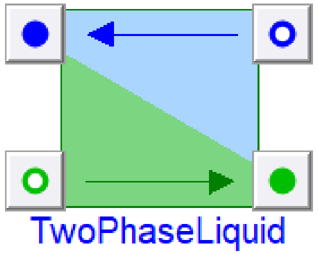


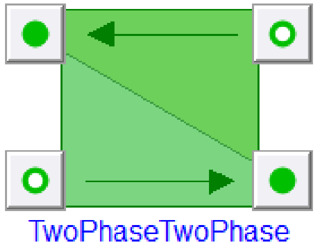
LIBRARY CONTENTS

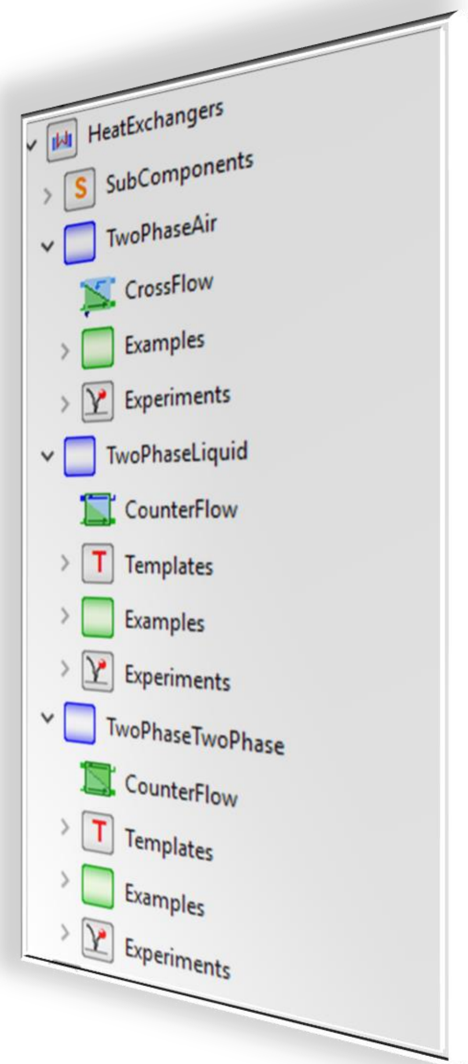
HeatExchanger

- Working Fluid - Air
  - Cross-flow
- Working Fluid - Liquid
  - Counter-flow
- Working Fluid – Working Fluid
  - Counter-flow







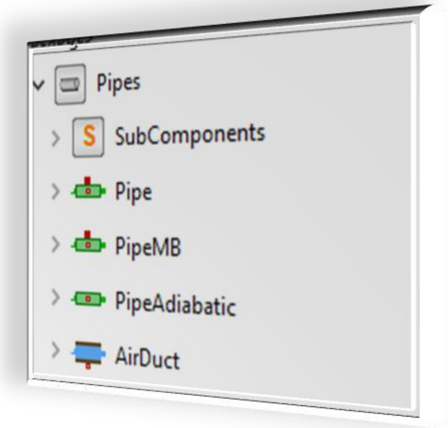


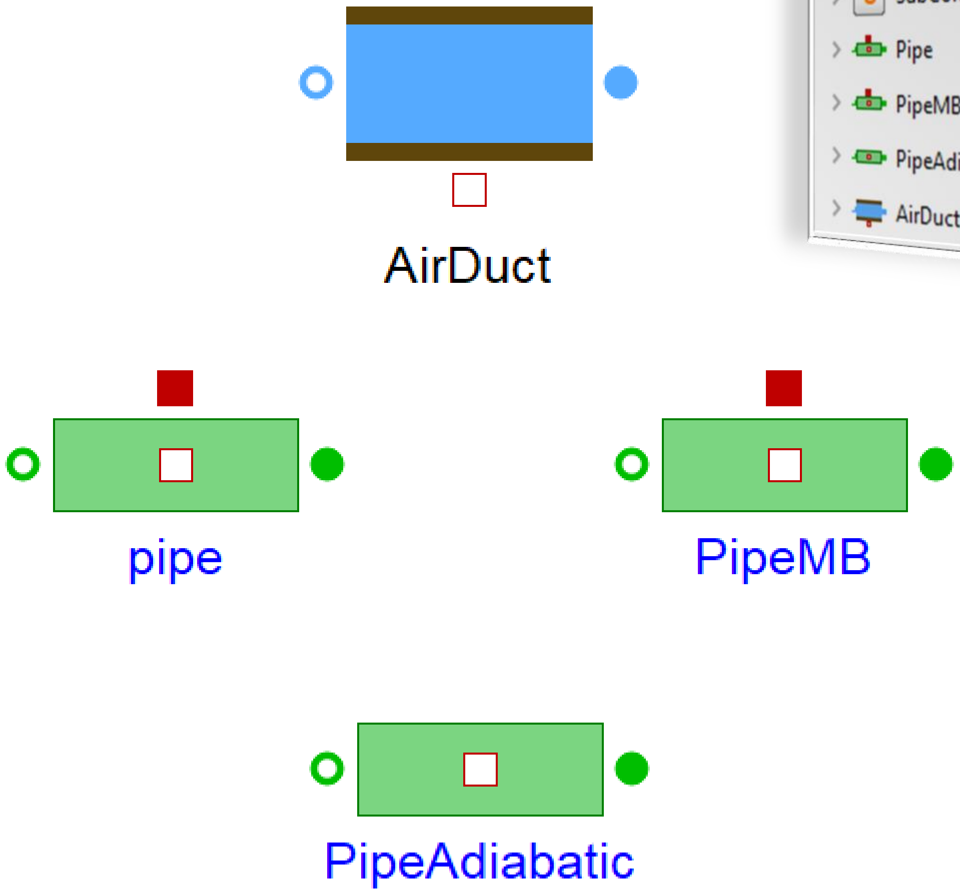
- Generic models based on finite volume method
  - Usable directly with base geometry (volumes, areas etc.)
  - Extendable by the user to more complex geometries - example included in library
  - Uniform air inlet properties

LIBRARY CONTENTS

Pipes

- Discretized pipe
- Discretized pipe which includes boundary tracking
- Discretized adiabatic pipe
- Air duct model with dynamic humidity and energy balances.

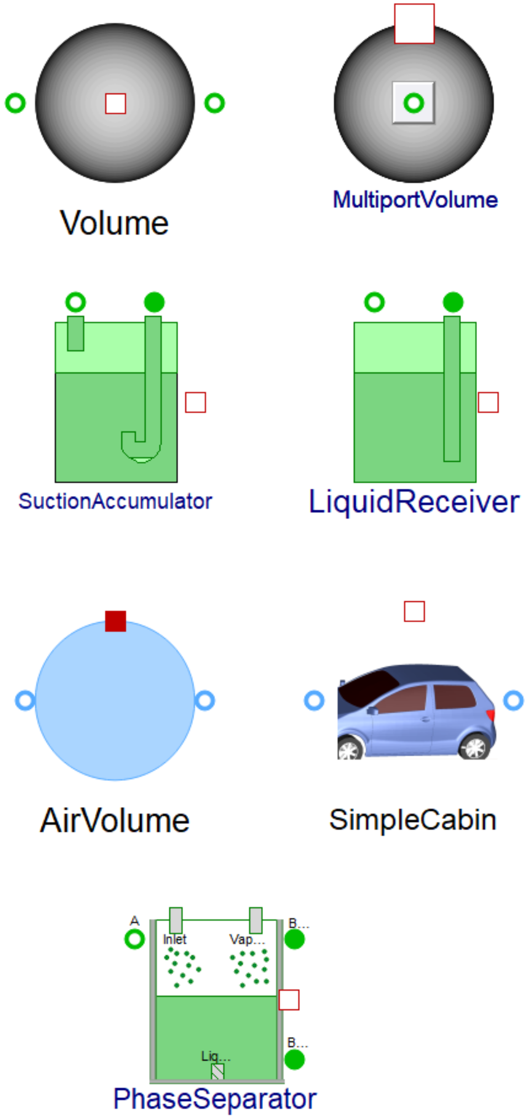


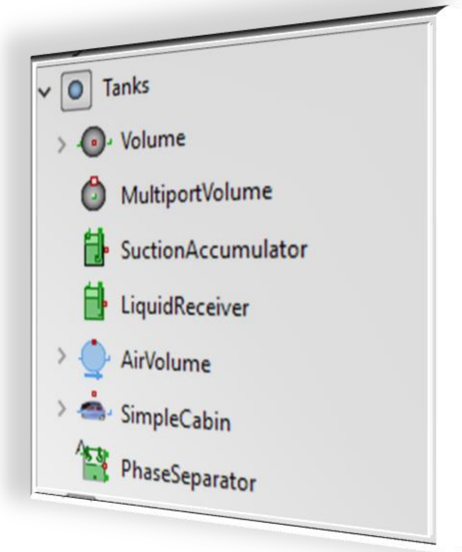


LIBRARY CONTENTS

Tanks

- Ideally mixed volume of fixed size with scalar port
- Ideally mixed volume of fixed size with vector port
- Suction accumulator with an U-shaped tube and bleed orifice
- liquid receiver assuming complete de-mixing of phases and including pressure drop due to friction
- Ideally mixed air volume of fixed size
- Simple cabin
- Phase Separator

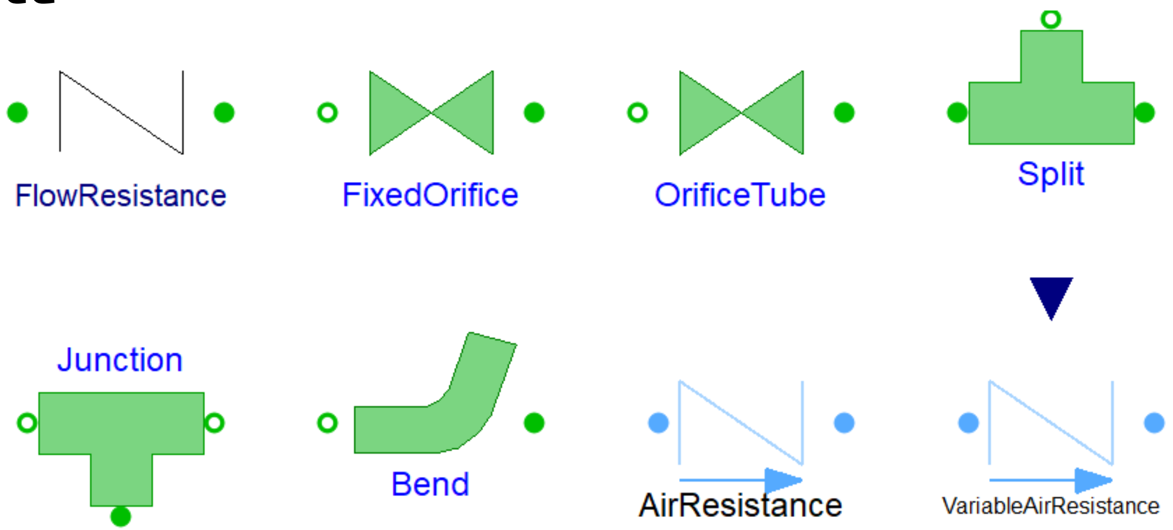




LIBRARY CONTENTS

Flow Resistances

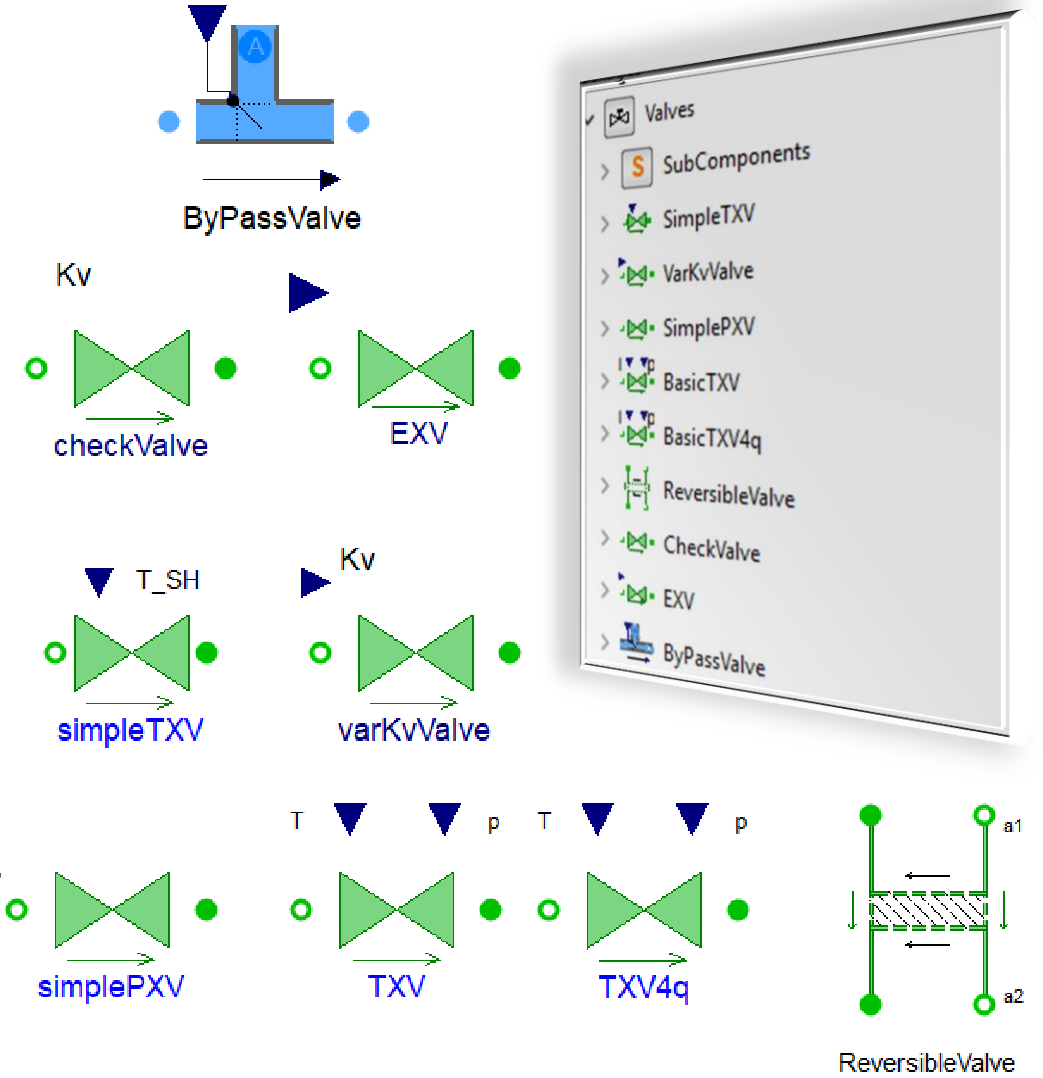
- Generic flow resistance
- Fixed Orifice
- Orifice Tube
- Split
- Junction
- Bend
- Air Resistance
- Variable Air Resistance



LIBRARY CONTENTS

Valves

- Modelling approach
  - Quasi-steady state, isenthalpic behaviour
  - Mass flow is determined by algebraic equations using valve specific data, e.g. the flow coefficient KV and the critical differential pressure ratio x
- Thermostatic expansion valves
  - Modelled in a simplified manner using a PI-Controller or with 4-dimension diagram (supplier data)
- Short orifice tube
  - Based on state-of-the art correlation



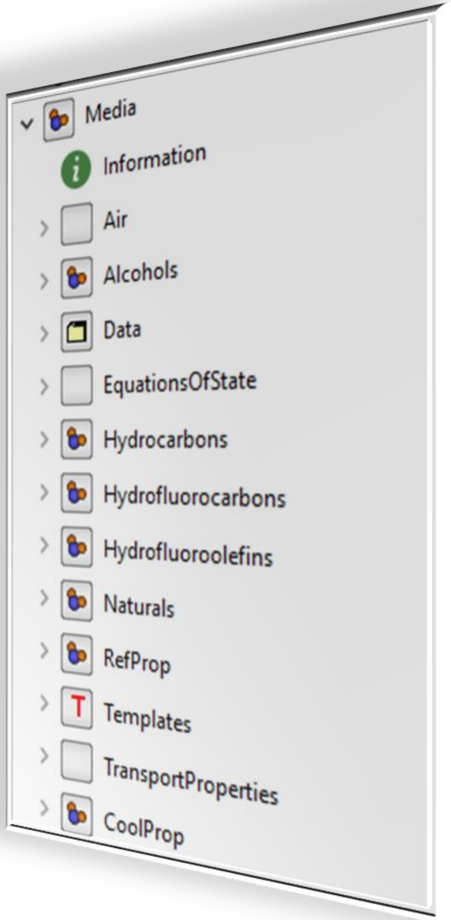
Valve with Kv-value as signal input or constant loss factor (flow resistance)

LIBRARY CONTENTS

Media

High accuracy equations of state in Helmholtz function form

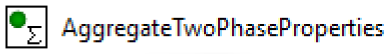
- Natural working fluids
  - R744 (carbon dioxide), R728 (nitrogen), R702 (hydrogen), R732 (oxygen), R717 (ammonia)
- Hydrocarbons
  - R290 (propane), R600a (isobutane)
- Alcohols
  - Ethanol
- Hydrofluorocarbons
  - R125, R134a, R143a, R152, R245fa, R404a, R407c, R410a, R507a, R236fa
- Hydrofluoroolefins
  - R1234yf

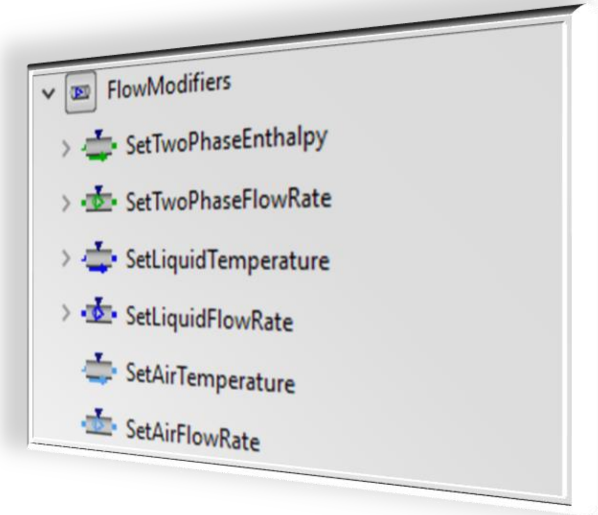


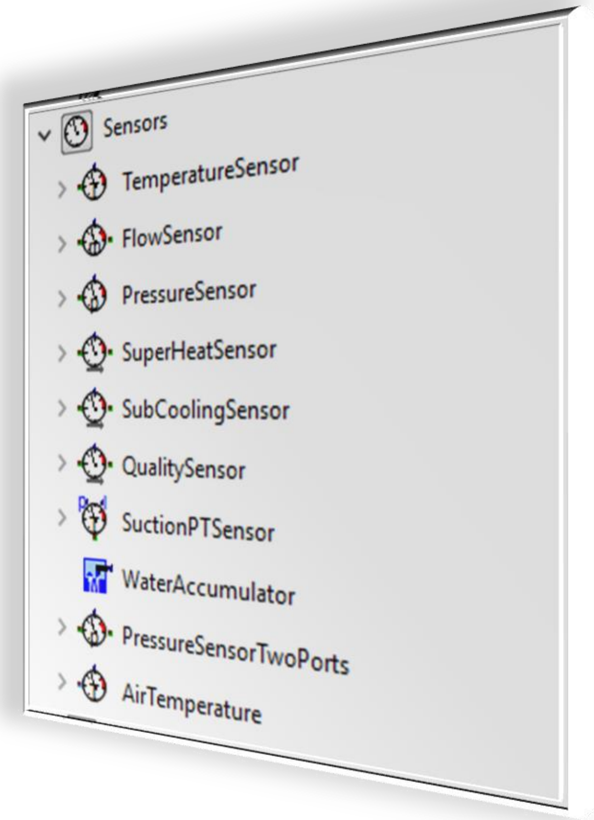
LIBRARY CONTENTS

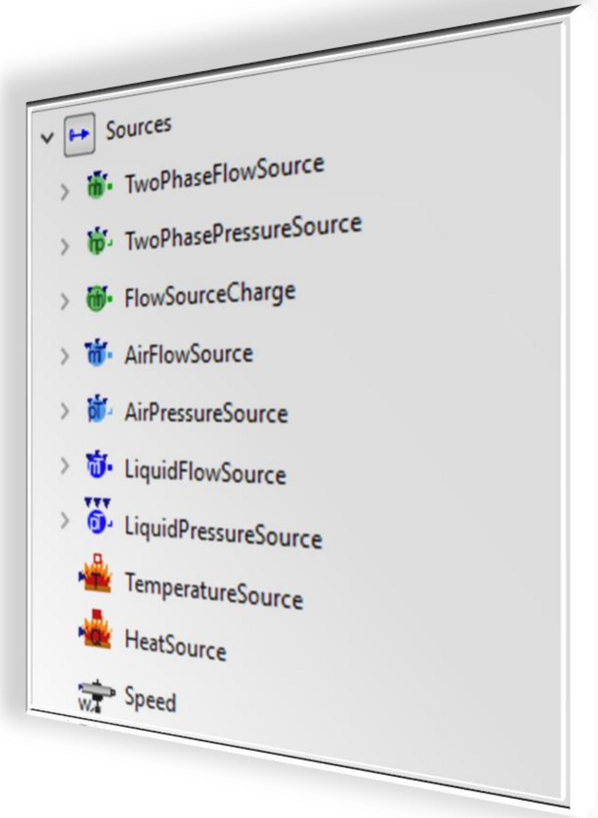
Basic Components

- The AggregateVolume object calculates the total TwoPhase volume in the system – useful for dimensioning





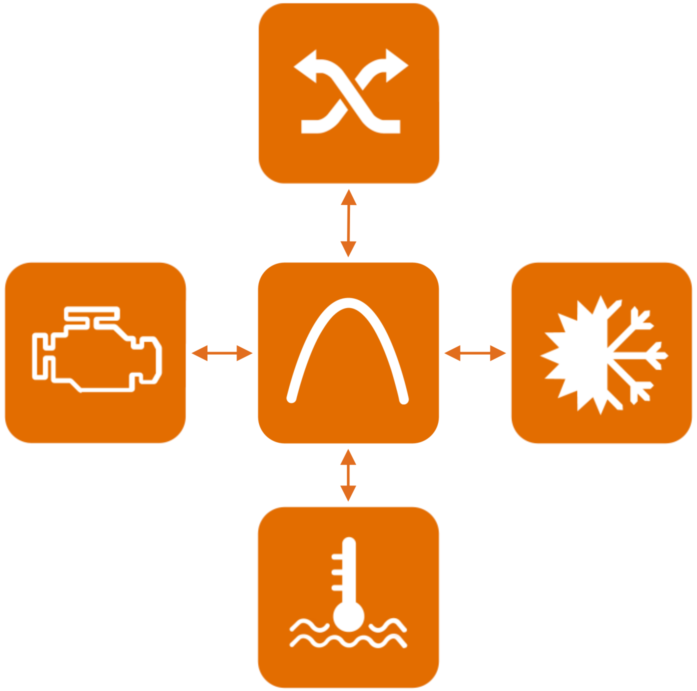




MODELON COMPATIBILITY

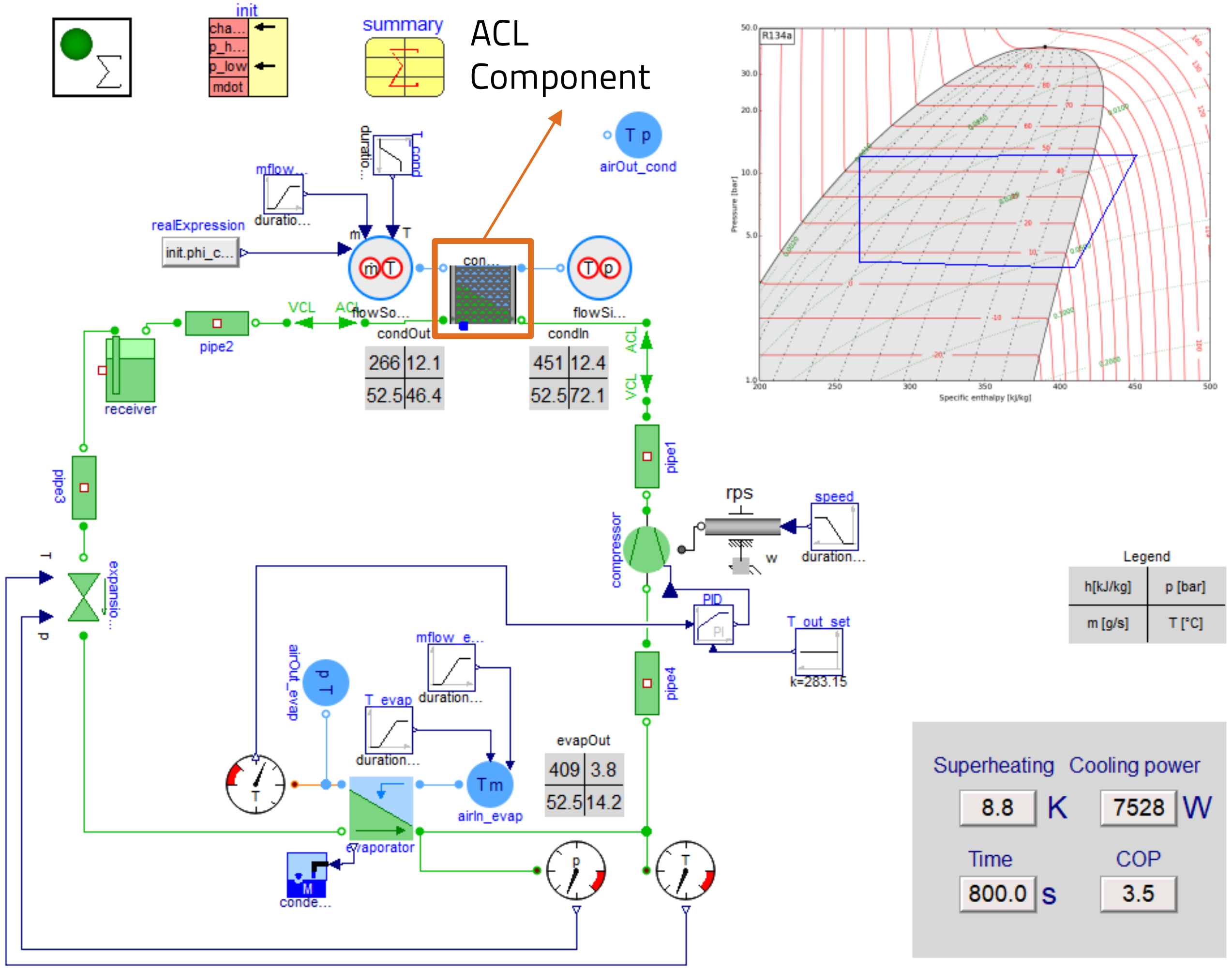
RECOMMENDED MODELON LIBRARY COMPATIBILITY

- VaporCycle Library components are seamless compatible with HeatExchanger Library, Liquid cooling Library, Engine Dynamics Library and Also with Air Conditioning Library via special adapter.



EXAMPLE: VCL - ACL INTERACTION

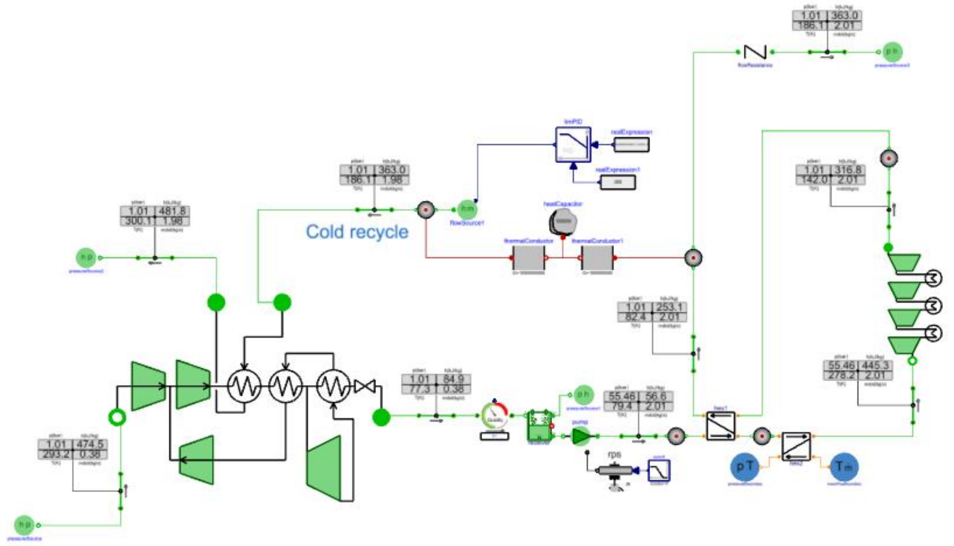
This air-conditioning system experiment is a copy of the class VaporCycle.Experiments.AirConditioning, with the modification that a condenser component model from Air Conditioning Library is used.



LATEST RELEASE

RELEASE:2021.2

New Features

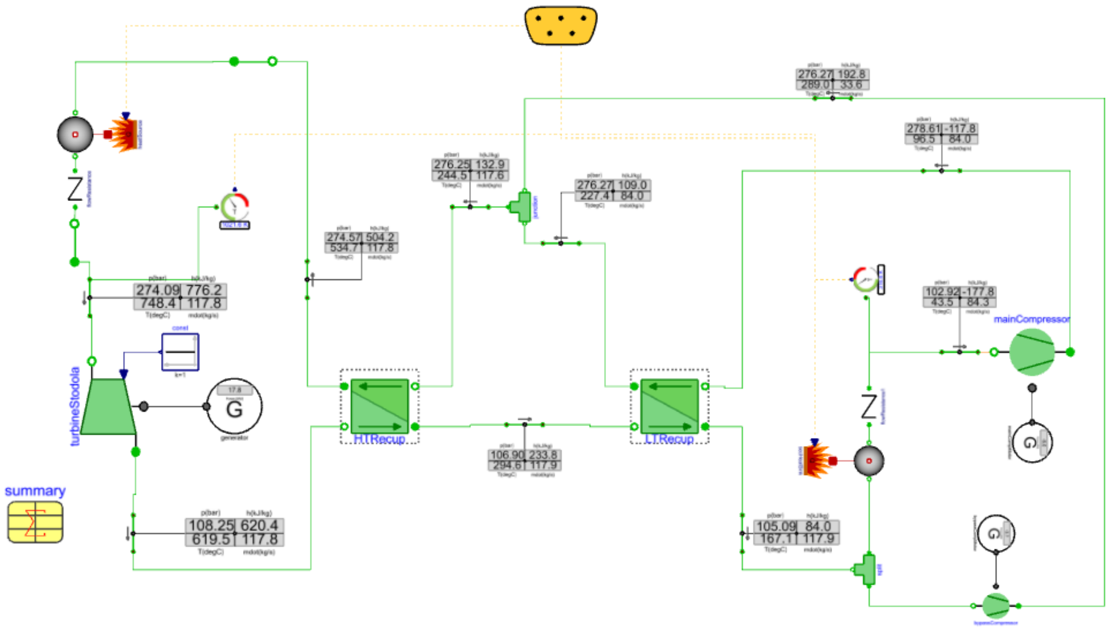


- Liquefied air energy storage (LAES) example added, a thermo-electric energy storage system that uses liquid air as the energy storage media. The stored energy is used to cover electricity consumption peaks or for balancing of the power grid

RELEASE:2021.2

New Features

- An example of recompression Brayton power cycle system with supercritical CO_2 as fluid added. The model is set up to provide 15 MW turbine output. Primary heater or external heat source can be used for providing heat to the fluid after compression based on the turbine inlet temperature target



RELEASE:2021.2

New Features

- Improved the SBTL media to support generating analytic Jacobians, but not yet for the system models

Enhancements

- Improved the R1234yfSBTL coefficients with extended range
- Improved the CoolProp volume experiment model
- Robustness improvements for the FlowModifier models
- Corrected coefficients used for surface tension calculation in R1234yf SBTL model implementation
- Changed the default component name for the SetTwoPhaseEnthalpy model