AIR CONDITIONING LIBRARY

Overview

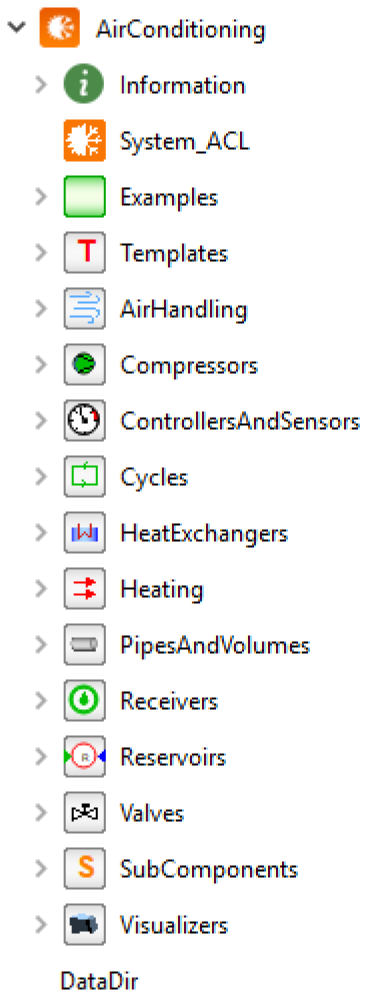
AGENDA

- ❑ About Air Conditioning Library
- ❑ Key Features
- ❑ Key Capabilities
- ❑ Key Applications
- ❑ Library Contents
- ❑ Modelon Compatibility
- ❑ Latest Release

Modelon

ABOUT AIR CONDITIONING LIBRARY

- Library for refrigeration systems based on the open Modelica Standard with access to model source code
- Release of Air Conditioning Library 1.0 in December 2004 with strong focus on automotive applications
- Standard for model exchange process between automotive OEMs and Tier 1 suppliers
- Well proven and further maintained for existing user group, can be combined with newer modular libraries HXL, LCL and VCL.



KEY BENEFITS

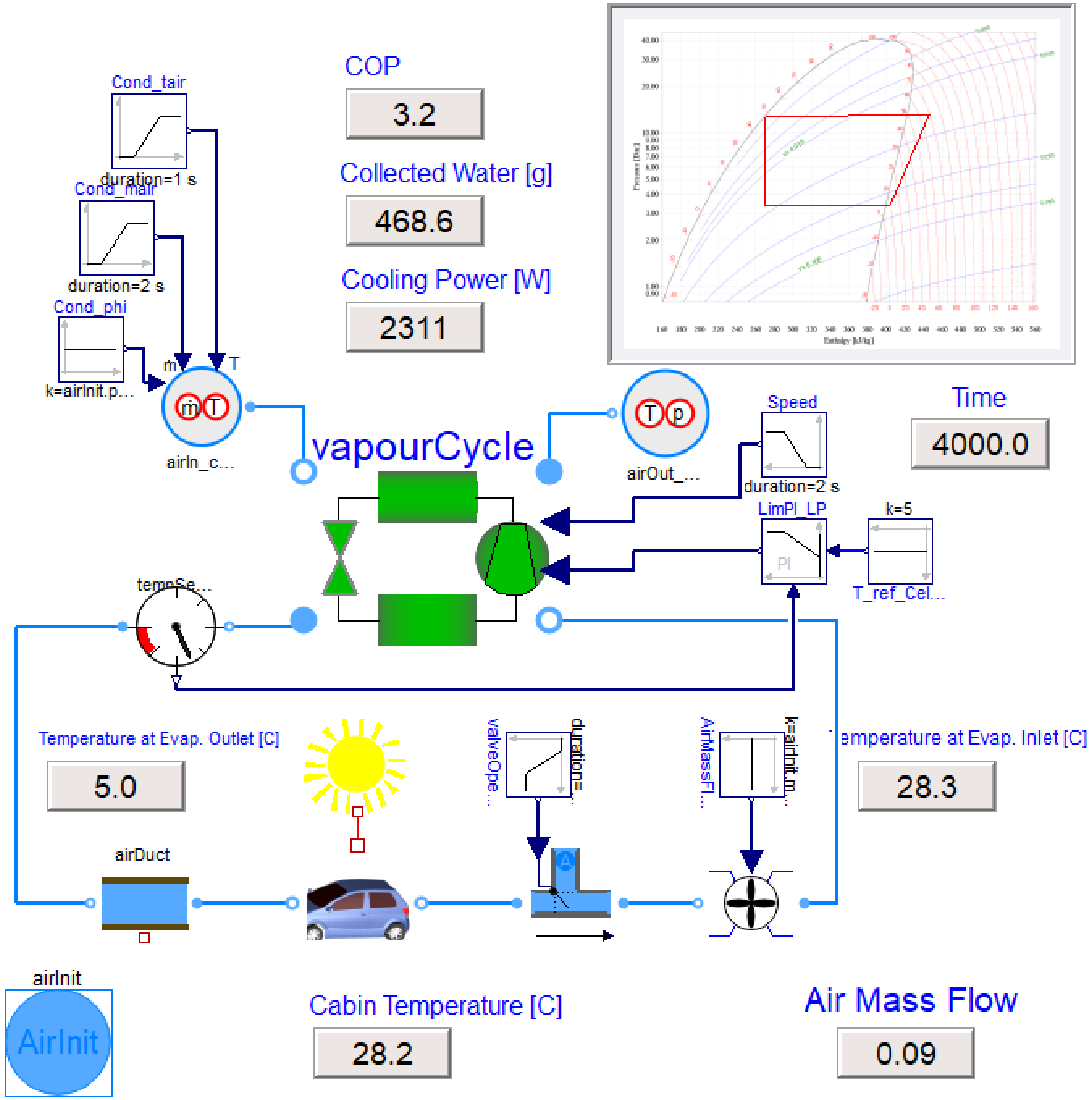
KEY BENEFITS

- Modelica library by Modelon with access to source-code
- Model library for refrigeration applications and other vapor compression cycles, focus on automotive Air-conditioning systems
- Both transient and steady-state simulation with the same model
- Easy-to-use templates that can be adapted for custom needs
- Supreme coverage of different refrigerants

KEY CAPABILITIES

KEY CAPABILITIES

- Domains
  - Automotive and residential air-conditioning
  - Stationary refrigeration and heat pumps
- Applications
  - System integration, incl. model exchange between supplier and OEM
  - Controller design
  - Virtual testing – e.g. fuel consumption in standard driving cycles
  - Heat exchanger design studies and model calibration



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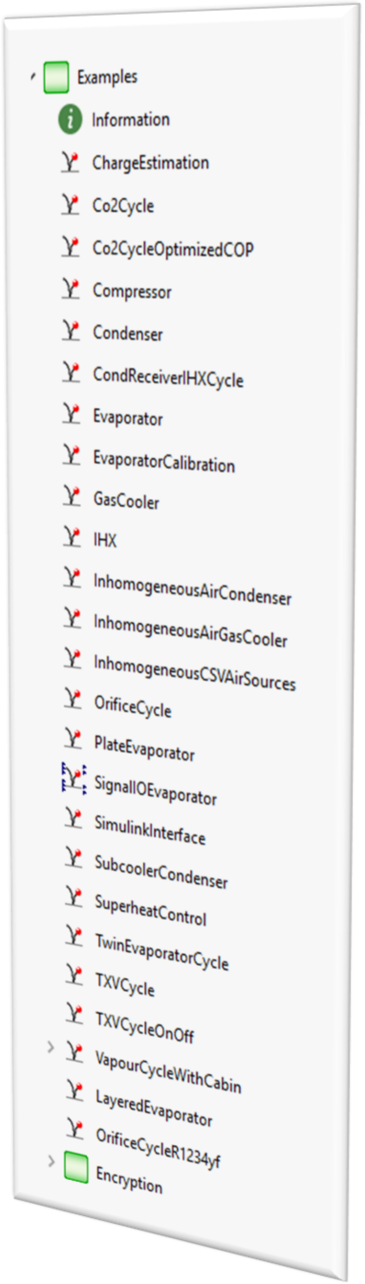
KEY APPLICATIONS

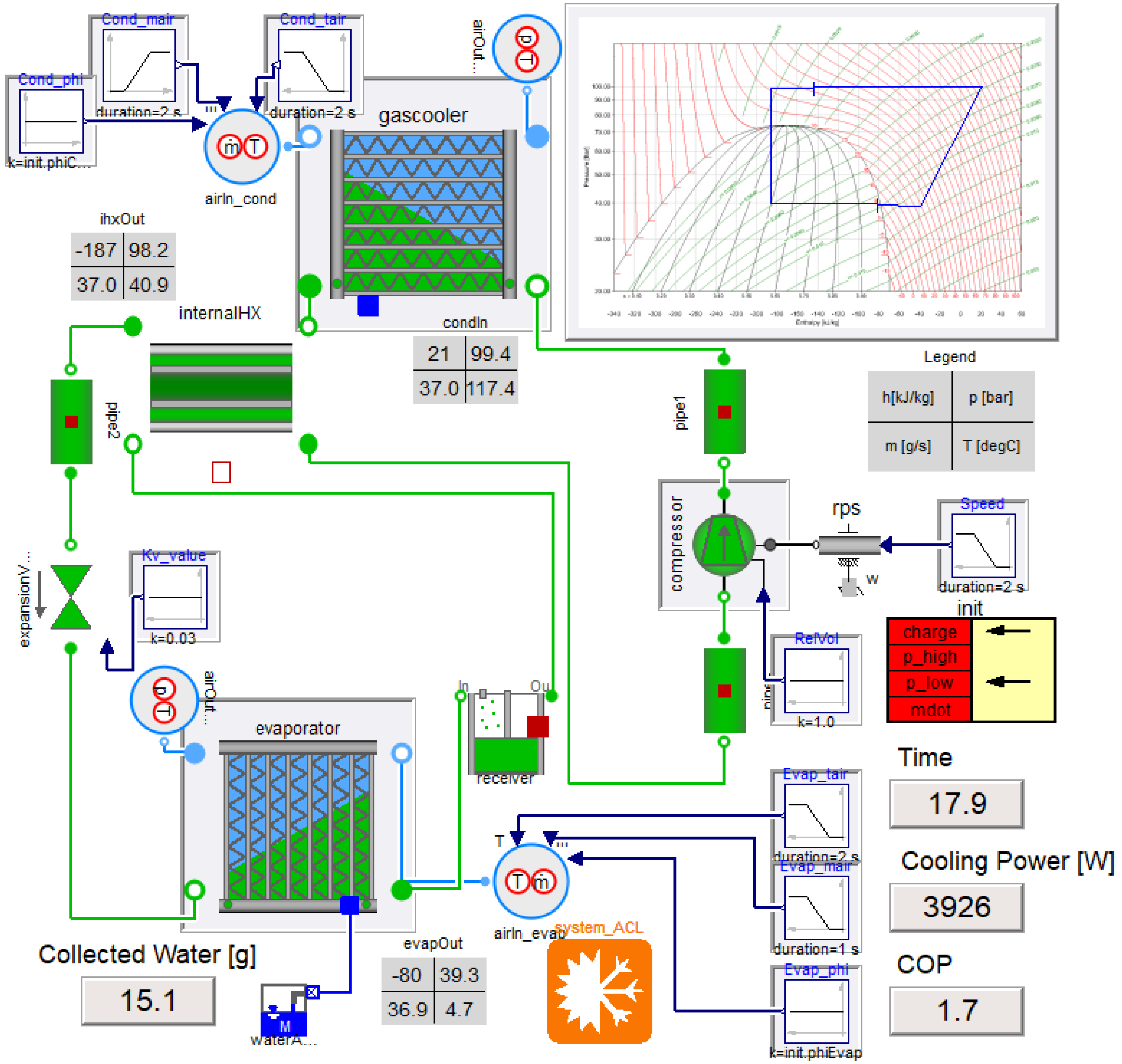
KEY APPLICATIONS

- Vapor Compression Cycle
- Twin Evaporator Cycle
- Vapor Cycle with Cabin
- Component Test Rig



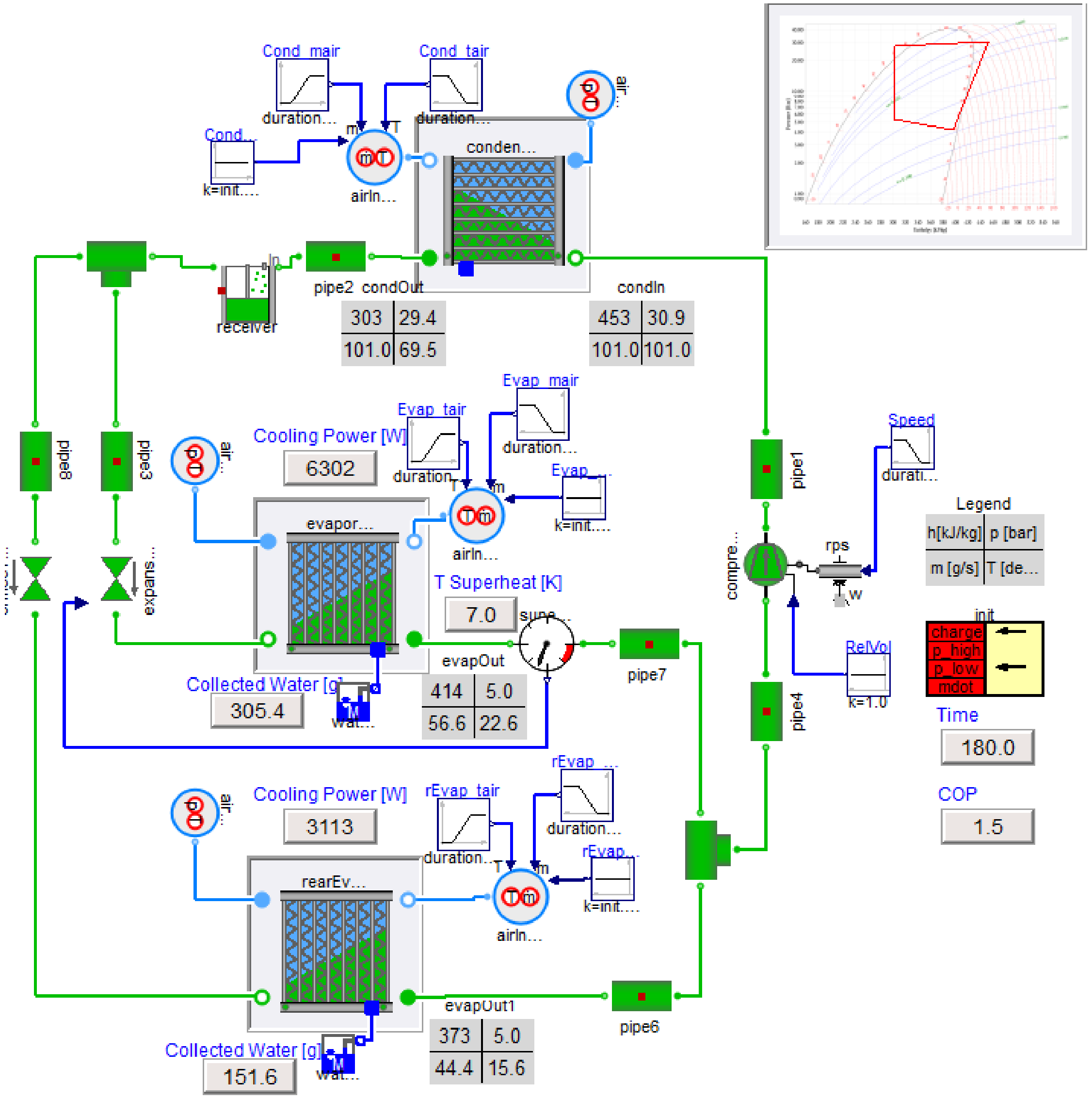
EXAMPLE: VAPOR COMPRESSION CYCLE

Transcritical refrigeration circuit with low pressure side accumulator and internal heat exchanger. The refrigerant is CO_2 (R744). The system can be run with different transient air and compressor boundary conditions and used as a starting point to add controls.



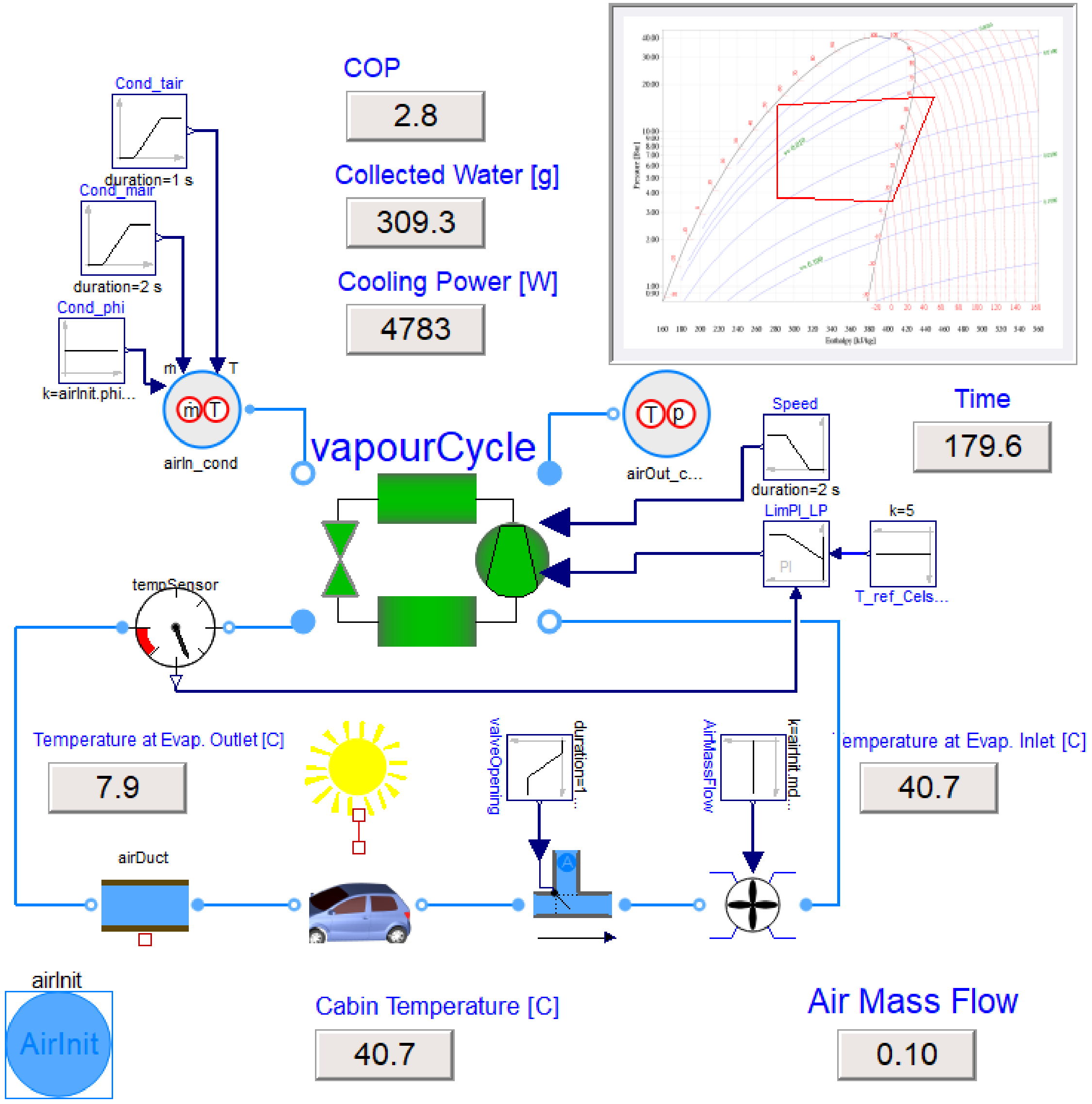
EXAMPLE: TWIN EVAPORATOR CYCLE

A splitter divides the refrigerant flow between two cooling capacity consumers depending on valve positions. Working fluid is R134a. In a similar way more complex systems with more branches can be set up



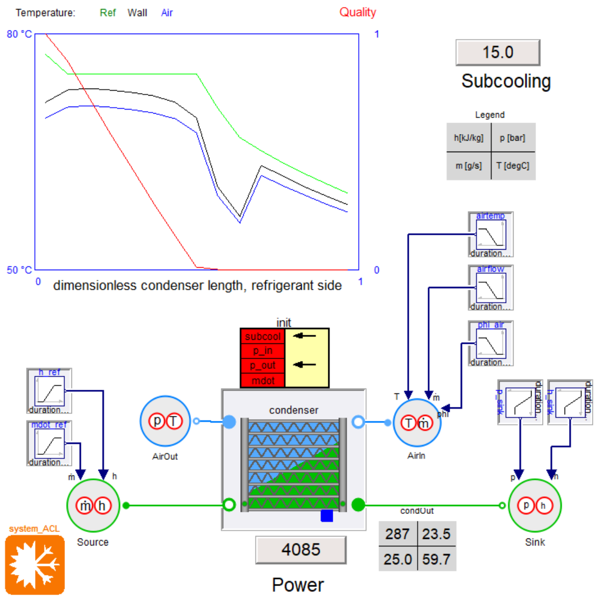
EXAMPLE: VAPOR CYCLE WITH CABIN

A complete vapor compression system is included as a component in an air conditioning system with a simple cabin model. The compressor displacement is controlled to obtain the set-point value of the outlet air temperature from the evaporator.

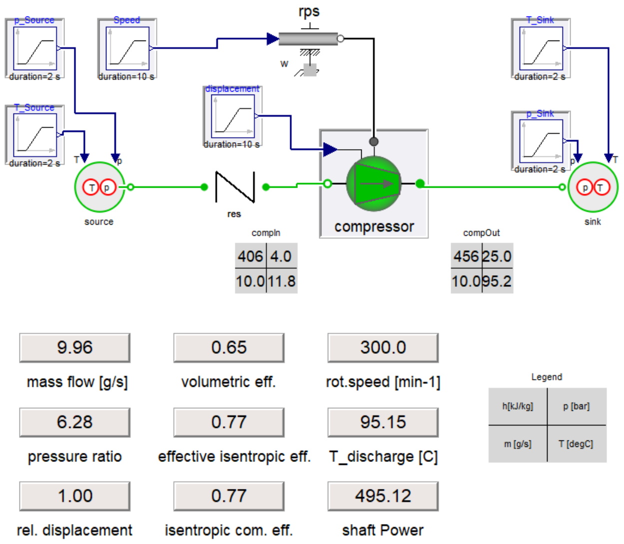


EXAMPLE: COMPONENT TEST RIG

- Starting point for component experiments – e.g. for calibration or validation with experimental data
- Test component can be replaced with customized component
- Easy to perform typical design scenarios with FMI Add-in for Excel, or run multiple simulations and compare with measurements



CondenserTestbench

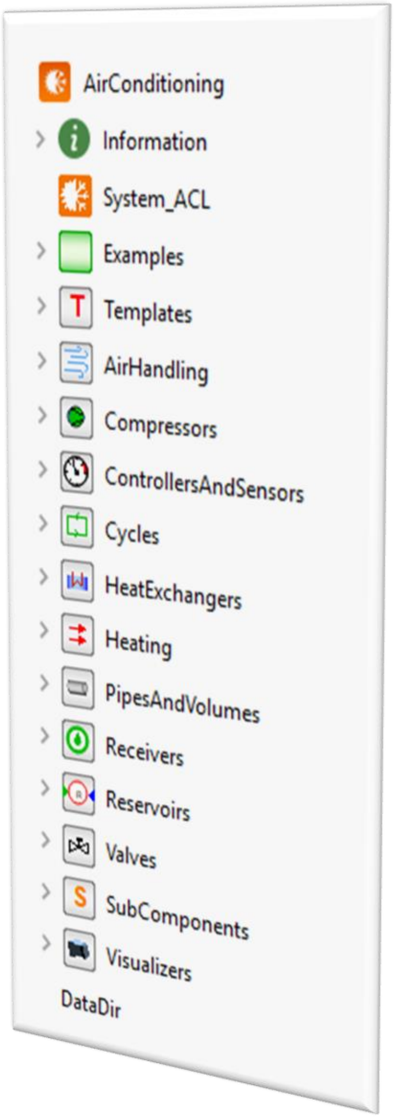


CompressorTestbench

LIBRARY CONTENTS

LIBRARY CONTENTS

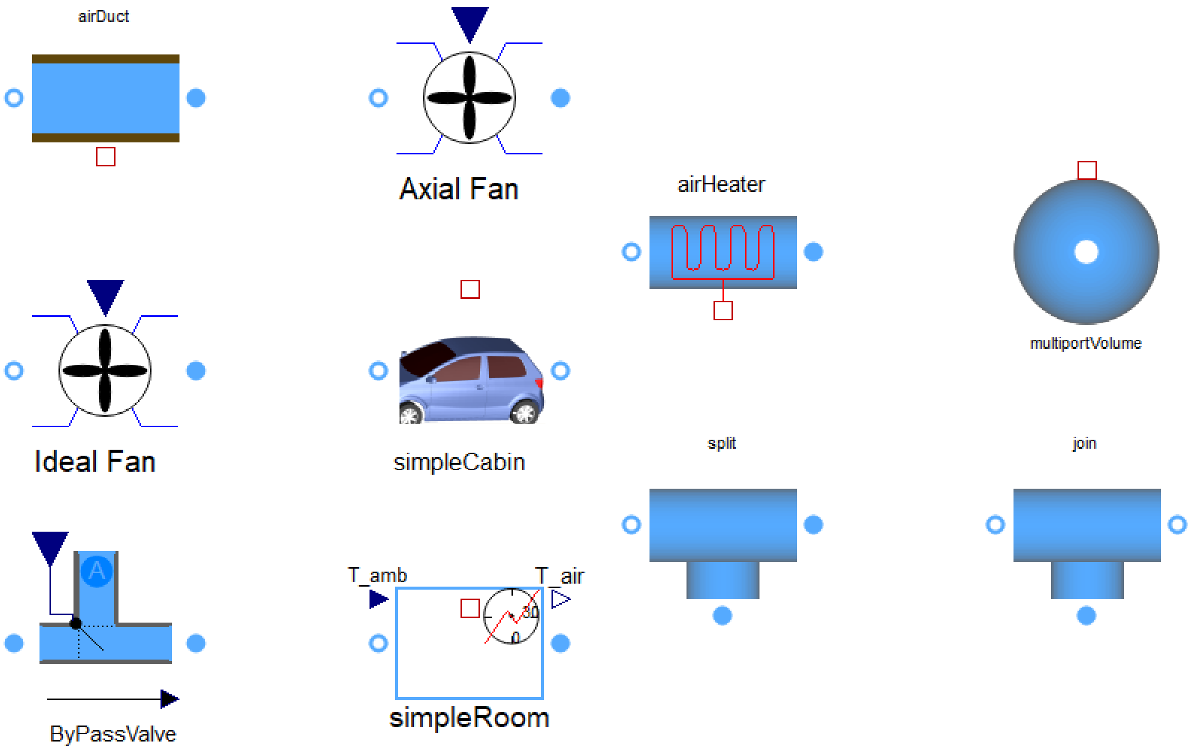
- Pre-defined system and component experiments
- Heat exchangers
- Pipes and volumes
- Joins and splits
- Compressors and fans
- Valves and flow resistances
- Sensors
- Visualizers

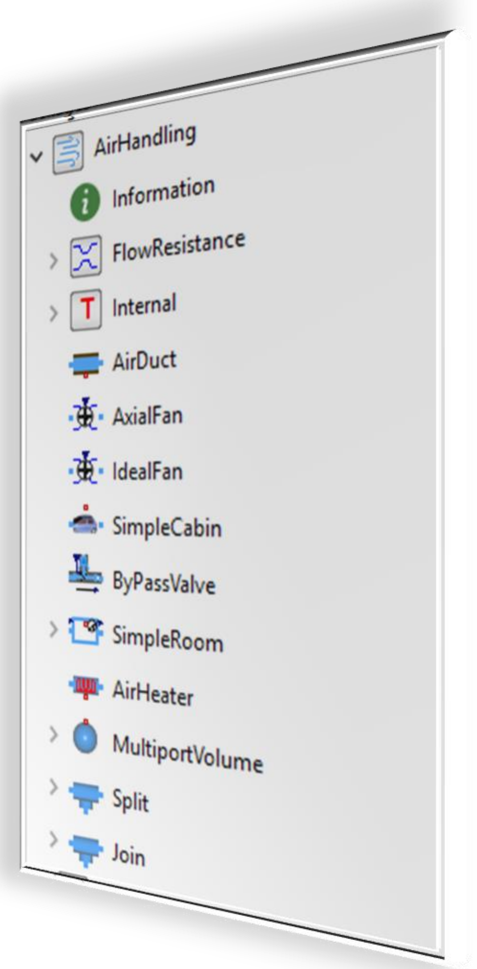


LIBRARY CONTENTS

Air Handling

- AirDuct
- IdealFan & AxialFan
- SimpleCabin
- ByPassValve
- SimpleRoom
- AirHeater
- MultiportVolume
- Split & Joint

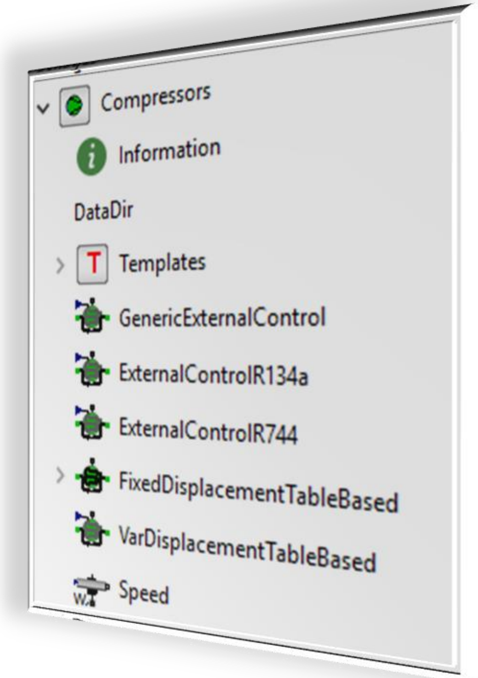


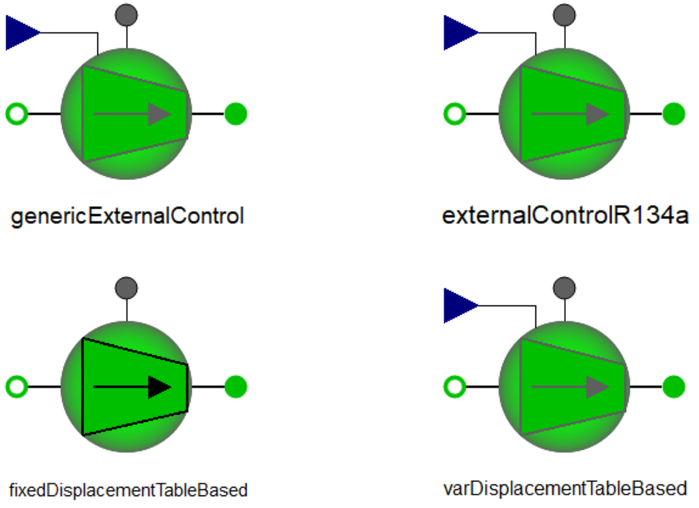


LIBRARY CONTENTS

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) $\lambda, \eta(\pi, n, x) = f(\pi, n) \cdot g(x, n)$





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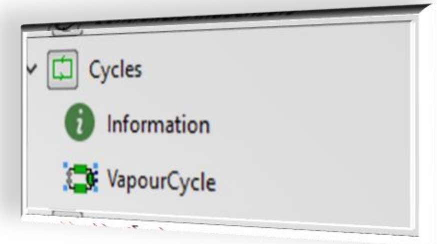
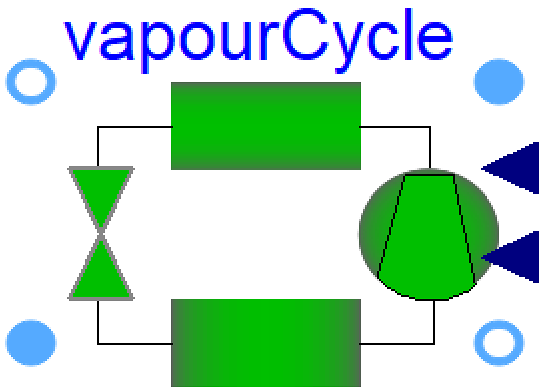


Cycles

- VapourCycle
  - This model contains a complete R134a AC-system cycle with controlled superheating. The model contains an init record, used for initialization and boundary condition data. All air flow connectors and the signal connectors to the compressor are used as external connectors and must be defined in the inheriting model.



LIBRARY CONTENTS

HeatExchanger

Microtube compact heat exchangers with louvered fins

- Refrigerant – Air
  - Evaporator, Condenser/GasCooler, Condenser with integrated receiver
- Coolant – Air
  - Radiator, Heater core (AirCoolantHXHorizontal/Vertical)

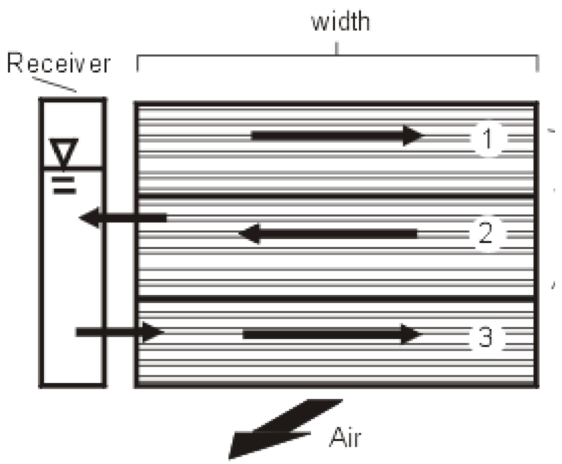
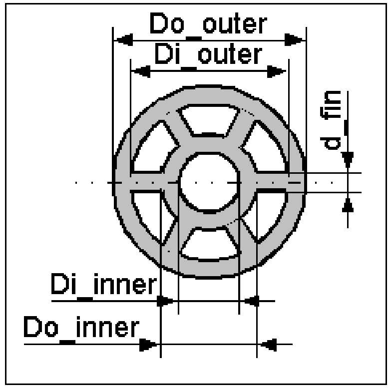


Plate heat exchangers incl. Chevron type

- Refrigerant – Coolant
  - Evaporator *(PlateRefCoolantHX or ChevronPlateHX)*
  - Condenser *(PlateRefCoolantHX or ChevronPlateHX)*

Tube – in – tube

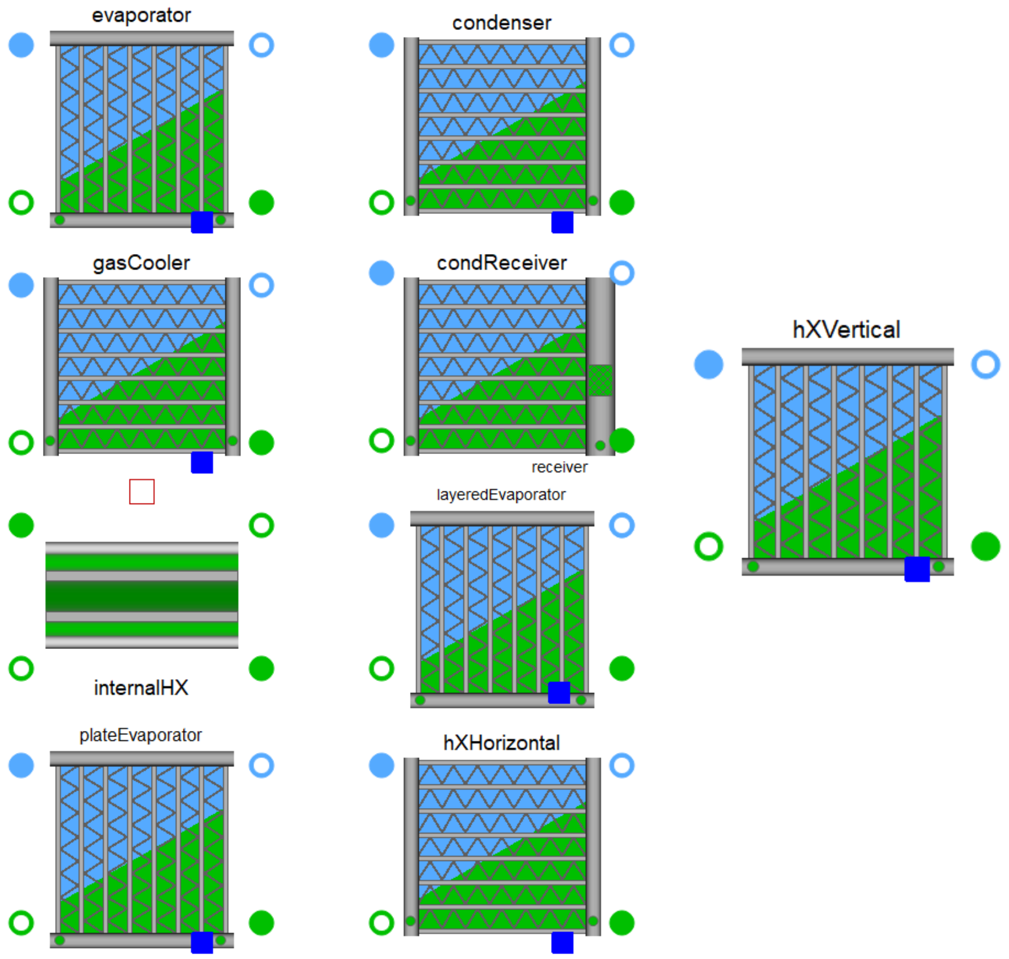
- Internal heat exchanger in refrigeration circuit

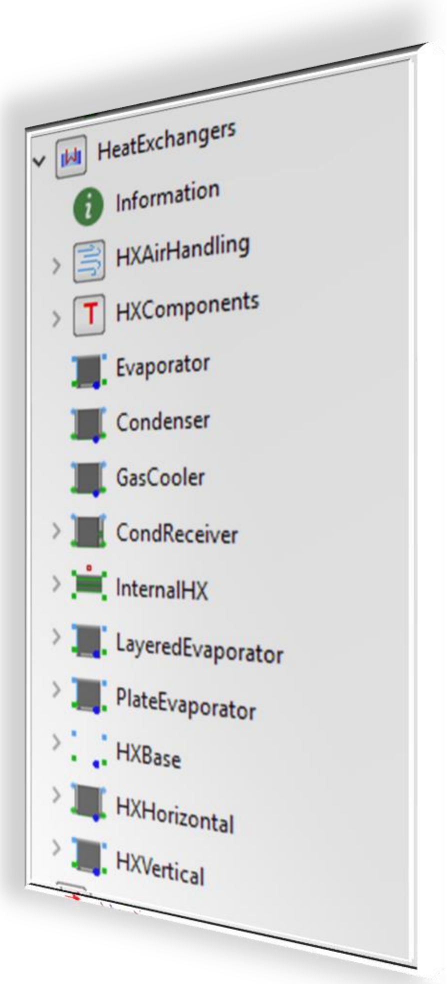


LIBRARY CONTENTS

Heat exchanger

- Evaporator
- Condenser
- GasCooler
- CondReceiver
- InternalHX
- LayeredEvaporator
- PlateEvaporator
- HXHorizontal
- HXVertical





LIBRARY CONTENTS

Heat exchanger – Layering

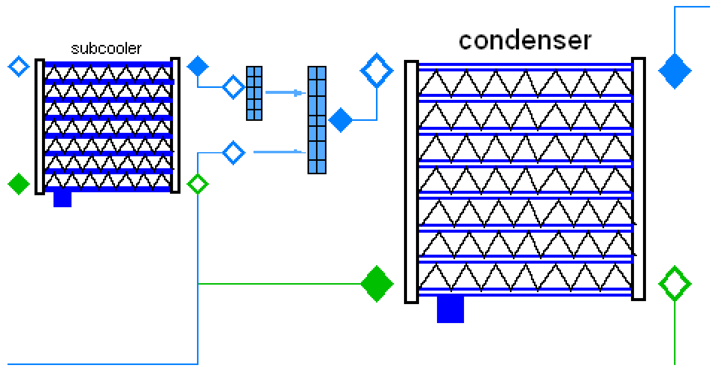
Non-standard and complex heat exchangers can be composed layer by layer

Two examples in library:

- A condenser with a separate subcooler of smaller face area
- An evaporator composed from layers that are not aligned in air flow direction

Heat exchangers with refrigerant passes that are not aligned in air-flow direction

1



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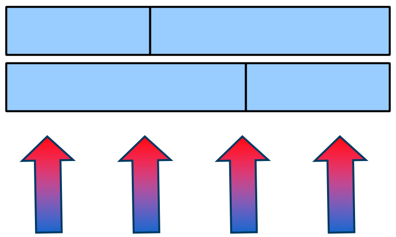


LIBRARY CONTENTS

Heating

HeatExchangers

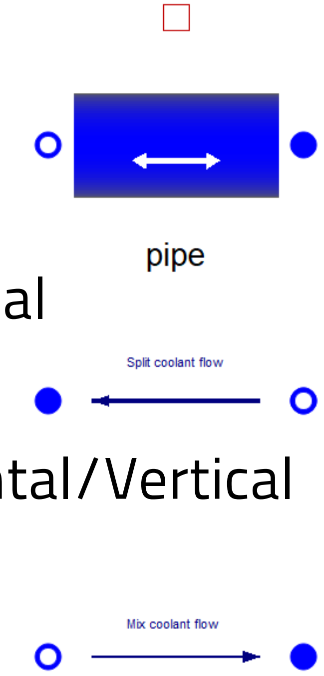
- AirCoolantHXHorizontal/Vertical
- PlateAir/RefCoolantHX
- CoolantRefrigerantHX/Horizontal/Vertical
- ChevronPlateHX

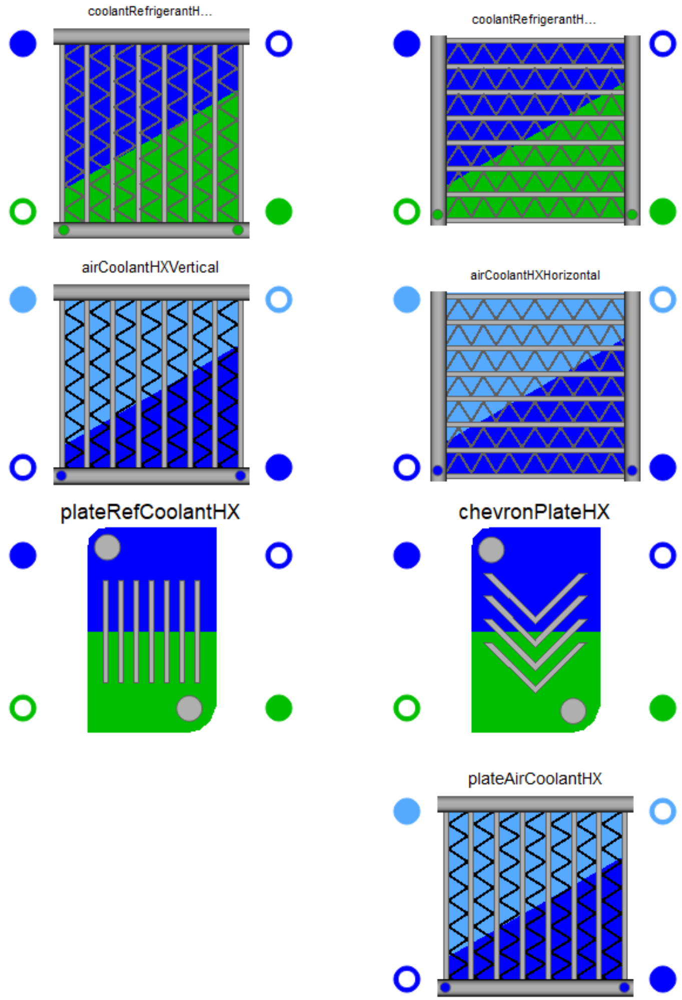
PipesAndVolumes

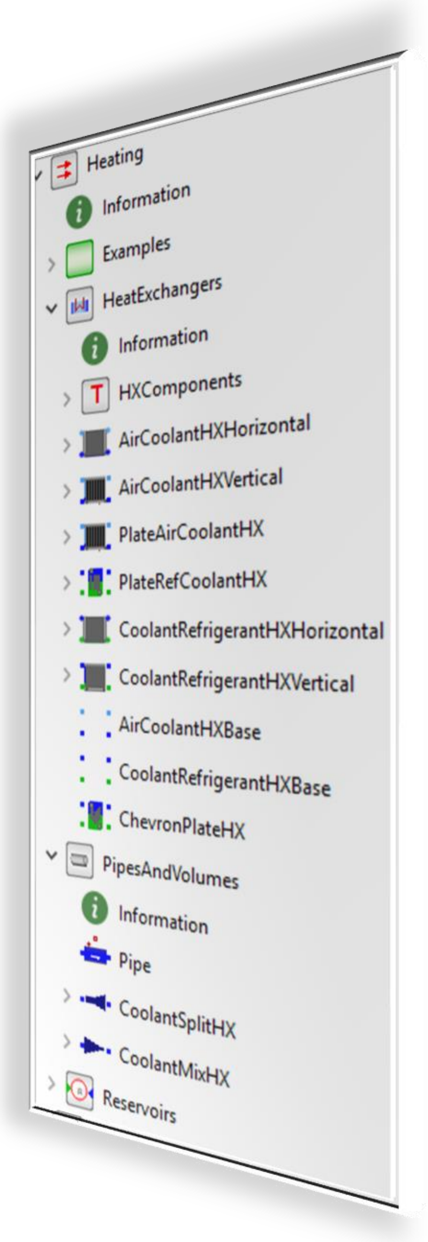
Pipe

- CoolantSplitHX
- CoolantMixHX

Reservoirs



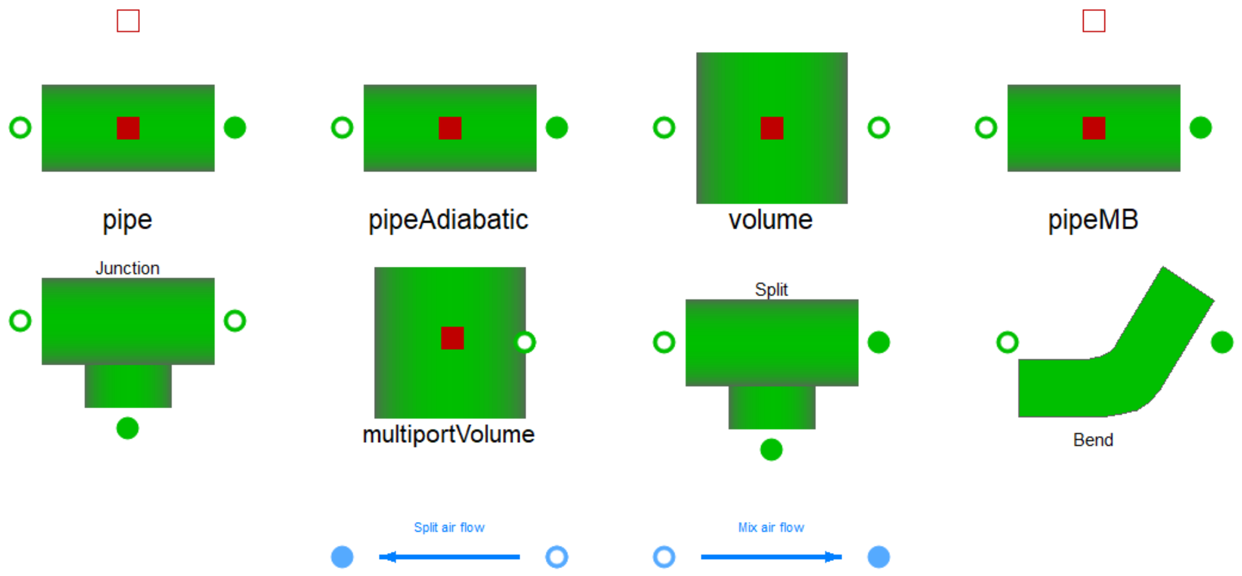


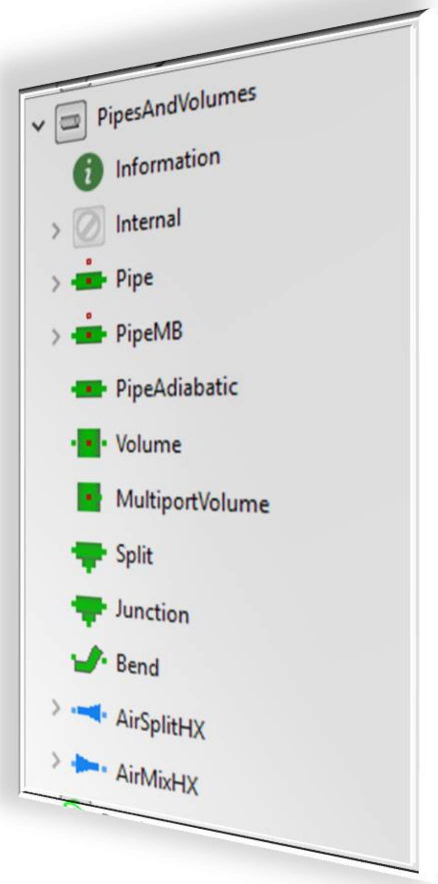


LIBRARY CONTENTS

PipesAndVolumes

- Pipe
- PipeMB
- PipeAdiabatic
- Volume
- MultiportVolume
- Split
- Junction
- Bend
- AirSplitHX
- AirMixHX

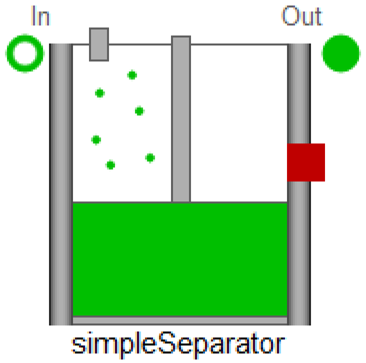


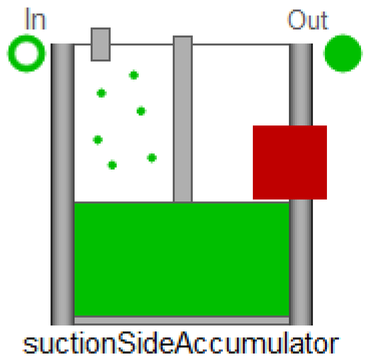


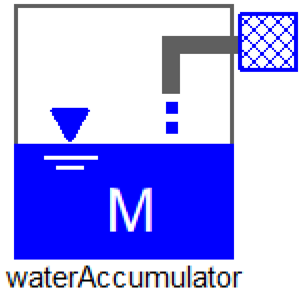
LIBRARY CONTENTS

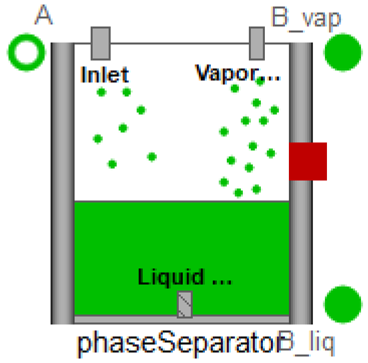
Receivers

- SimpleSeparator
- SuctionSideAccumulator
- WaterAccumulator
- PhaseSeparator





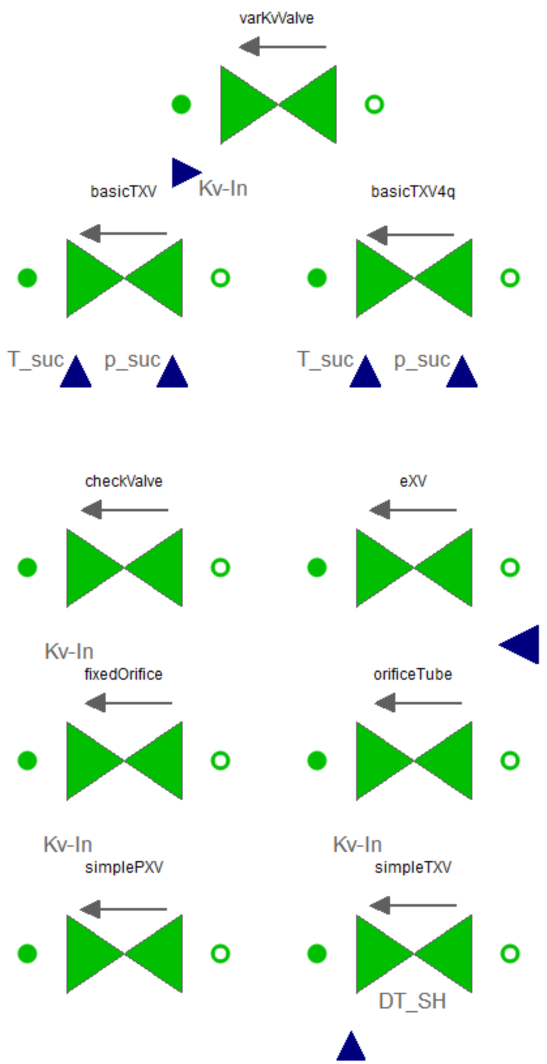




LIBRARY CONTENTS

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 (Some OEM and suppliers have detailed mechanical models)
- Short orifice tube
  - Based on state-of-the art correlation



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

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LIBRARY CONTENTS - FLUIDS

Refrigerants (two-phase)

- Reference properties, very high accuracy, high computational cost: R744(CO_2), R134a, R1234yf, R1234yf_smooth
- Technical, high accuracy, medium computational cost: R717 (ammonia), R744, R728 (nitrogen), R732 (oxygen), R702 (hydrogen), Ethanol, R290 (propane), R600a (iso-butane), R125, R134a, R134a_smooth, R143a, R152a, R245fa, R32, R404a, R407c, R410a, R507a, R236fa
- High performance table-based media for R1234a and R1234yf based on evaluated property models from the library

Coolants (liquid)

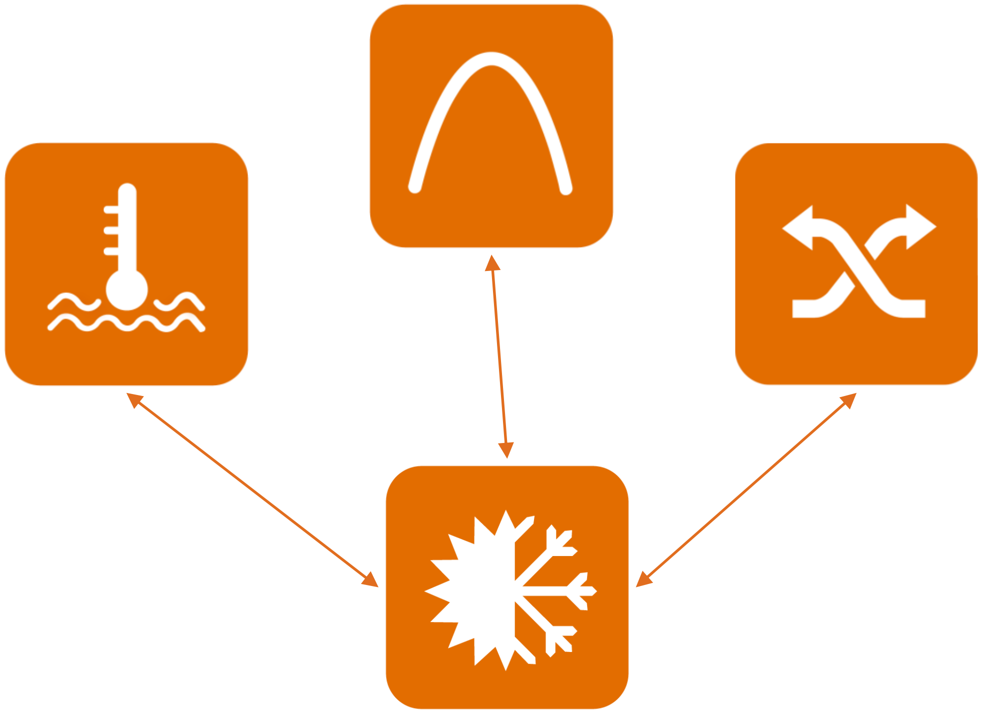
- Water
- Ethylene Glycol, 20%, 40% and 50% mixture with water
- 1,2-Propylene Glycol, 47% mixture with water
- Table template for user defined data

Moist air

MODELON COMPATIBILITY

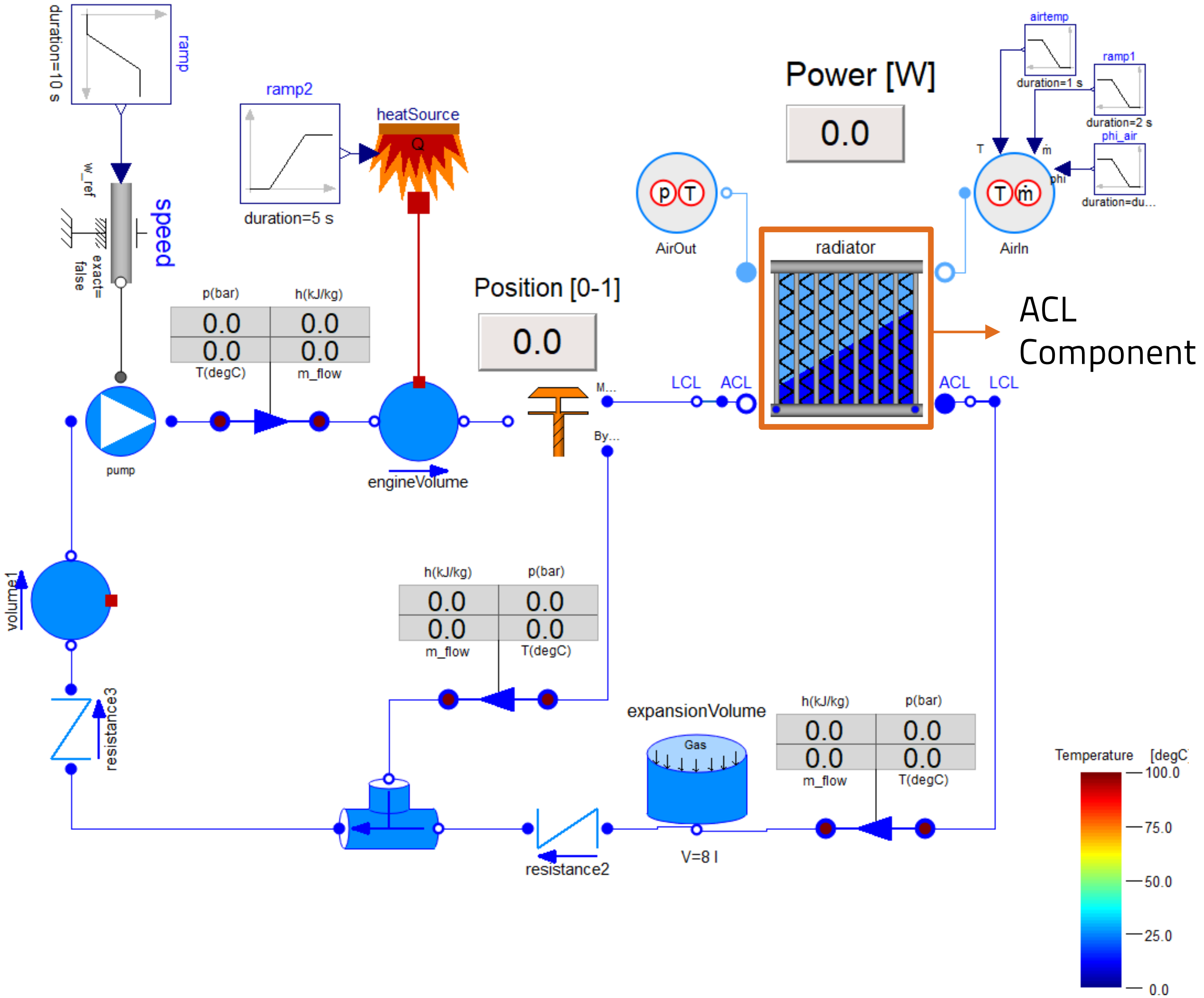
RECOMMENDED MODELON LIBRARY COMPATIBILITY

- Air Conditioning Library components are compatible with Liquid Cooling Library and Vapor Cycle Library (or Heat Exchanger Library) via adapters, which are available on demand.



EXAMPLE : LCL - ACL INTERACTION

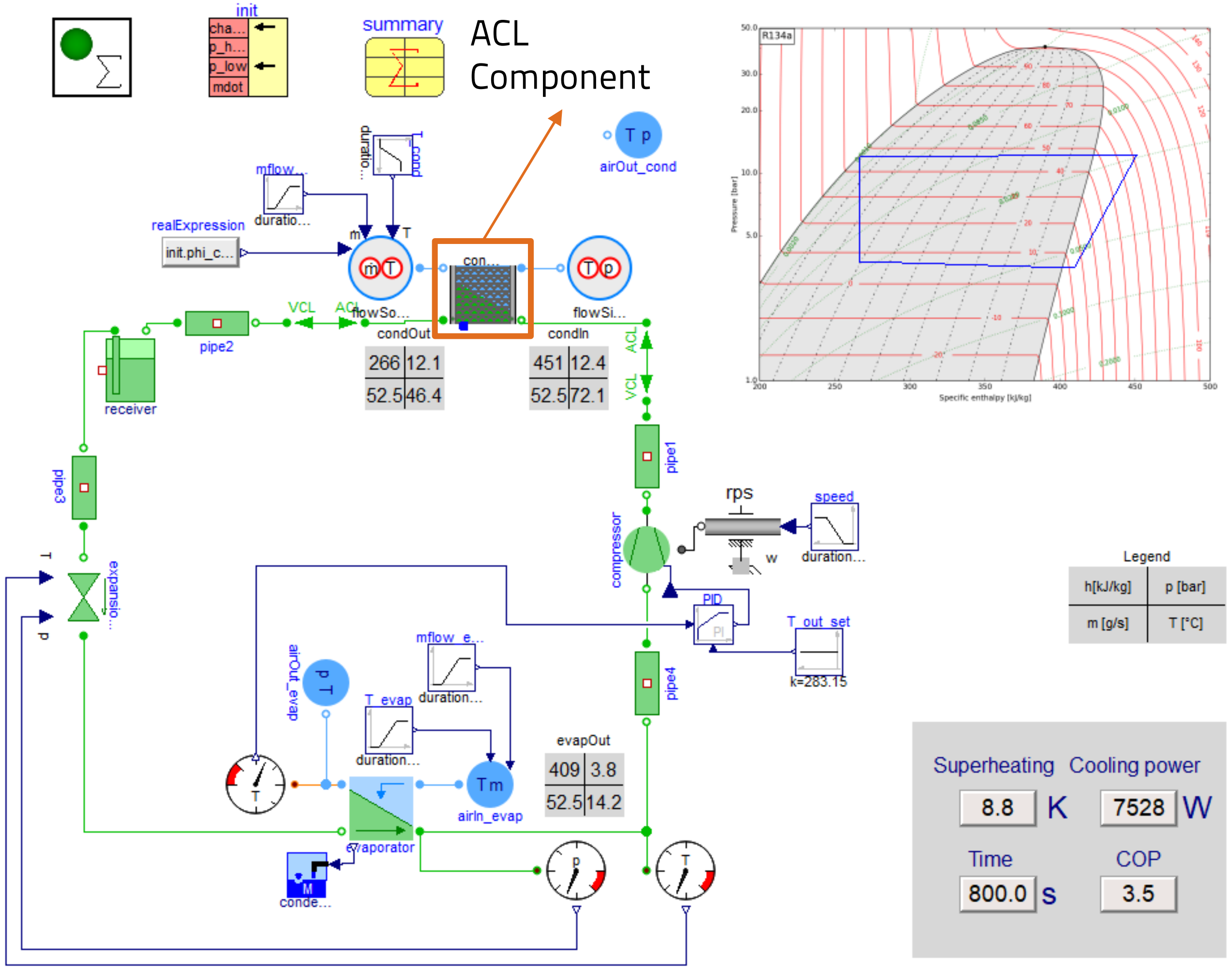
In this model, an engine cooling circuit from Liquid Cooling Library is combined with a radiator from the Air Conditioning Library. The flow is driven by a pump parameterized with a table format pump curve. The engine heat load heat load is described by a transient input signal. A radiator along with a thermostatic bypass valve maintains the required coolant temperature.



ACL Component

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.

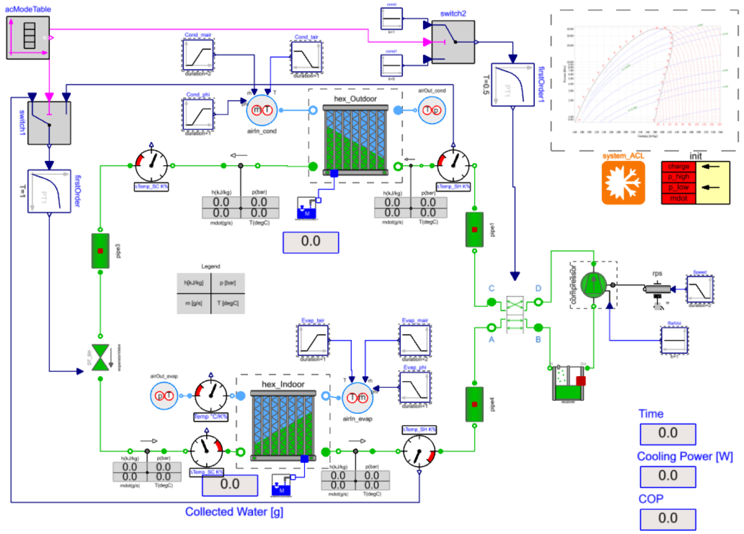


LATEST RELEASE

RELEASE:2021.2

New Features

- Major improvements for media using **spline-based table lookup** (SBTL)
  - All functions from the media interface are implemented, so that SBTL media can replace Helmholtz-energy based media in any model without changes to that model
  - Added derivatives, so that tools can generate analytic Jacobians
  - Increased range where media can be used
  - Improved robustness and better test coverage
  - Restructuring to reduce code duplication
- Two new system examples with and A/C cycle transiently changing to **heat pump** operation by reversing the refrigerant flow direction. It is possible to compile these with analytic ODE Jacobian for improved simulation performance



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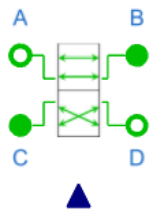
RELEASE:2021.2

New Features

- Added options for initial value propagation through connectors allowing to define pressure/enthalpy difference for initialization. Components then automatically propagate and calculate the inlet and outlet values depending on upstream or downstream choice

- Four-way valve to simplify the modeling of reversing refrigerant flow direction developed



RELEASE:2021.2

Enhancements

- Initialization value for Kv for valves in cycle initialization records with default value calculated from high and low pressure
- analyticInverseTfromh parameter in the AirTransport and AirTemperature models to compute temperature for given specific enthalpy and vice versa
- Derivative to functions h_T and h_T_low in ThermoFluidPro.Media.IdealGases.Common
- Corrected the derivative annotations in ThermoFluidPro.Media.Air.MoistAir and ThermoFluidPro.Media.Air.NoncondensingAir
- Example model to illustrate the usage of Analytic Jacobians in the component level Evaporator_SBTL_AnalyticalJacobians
- Example model to illustrate the usage of Analytic Jacobians in the system level TXVCycleOnOff_0_flow_SBTL_AnalyticalJacobians
- Example model to illustrate the usage of Analytic Jacobians in the system model with air path models VapourCycleWithCabin_SBTL_AnalyticalJacobians.
- Changed calibration factors in InternalHX from parameter to input