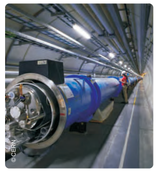
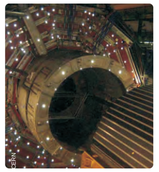
CRYOLIB LIBRARY

The CRYOLIB library is the result of collaboration between CERN and Empresarios Agrupados (EA) to create a specific library for the simulation of large cryogenic installations. The high complexity of these systems due to their non linearities and wide range of operation makes simulation an especially interesting tool for control engineers to develop/test control algorithms or perform virtual commisioning tasks. The library is also of great use to cryogenic engineers who wish to design new systems, and even to operators for training purposes.

The CRYOLIB library is delivered along with the source code. This allows the users both to modify and reuse any of the library components. Components have been validated with experimental data obtained from CERN installations.





OVERVIEW OF THE CRYOLIB LIBRARY

CRYOLIB allows the user to analyse in great detail transient aspects due to inertia, heat transfer or control processes. A fluid system connected with a control system can be easily represented and simulated.

CRYOLIB provides a standard set of cryogenic components that can be parametrized by the user:

- Several configurations of plate-fin multistream heat exchangers with 1D fluid model
- Turbo machinery: Oil lubricated compressor, cold compressor, turbines, etc
- Pipes 0D and 1D
- Tanks with level calculation
- Valves of different types
- Measurement instruments

Component formulation is independent of the working fluid.

Reverse flow, inertia and high speed phenomena are considered in pipes, volumes and junctions.

A complete database of fluid properties is offered for He, N_2, Xe, Ar and O_2. Liquid, superheated, two-phase and supercritical fluids are considered. Moreover, it also provides interface functions to connect directly with HEPAK (© copyright Cryodata Inc.), a computer program for calculating the thermophysical properties of helium-4 (4He) from fundamental state equations.

A specific library of control components compatible with the UNICOS (UNified Industrial COntrol System) framework developed at CERN is provided with the installation. UNICOS aims to provide components, methodology and tools to design, build and program industrial based control systems for CERN installations.

Interaction with other software is possible, especially in the following areas: optimization subroutines for design and test fitting, coupling to external software (e.g. MATLAB, Simulink, Excel...), etc.

CALCULATION OF FLUID PROPERTIES

CRYOLIB uses the FLUID_PROP library in order to calculate the physicochemical properties of fluids.

The FLUID_PROP library is a set of thermodynamic functions of the fluids: He, N_2, Xe, Ar and O_2. Real fluids properties are directly interpolated in external 2D properties files (user modifiable), obtained by running the HEPAK code in the case of Helium and the REFPROP code (NIST) for the other fluids.

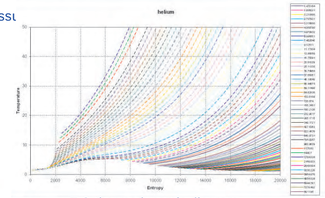
The library considers the homogeneous model that calculates mixtures of a real fluid with a non-condensable gas (quality, void fraction, etc) in case of two-phase, two-fluid flow. Phase calculation is automatic.

Functions calculating real properties interpolate in 2D property tables. Two kinds of interpolations are available:

- Direct interpolation using the parameters P-S or P-H and returning a property.
- Reverse interpolation using the parameters T-S, H-S or ñ -U and returning pressu

Real Fluids	Liquid Range		Gas Range	
	Pres. (bar) (Psat – Pcr)	Temp.(K) (Tsat – Tcrit)	Pres. (bar)	Temp. (K) (Tmin – Tmax)
Oxygen (O_2)	Psat – 50.43	Tsat – 154.6	0. – 820	54.4 – 1000
Helium (He)	Psat – 2.27	Tsat – 5.19	0. – 1000	**0.8** – 1500
Nitrogen (N_2)	Psat – 33.96	Tsat – 126.2	0. – 22000	63.15 – 2000
Argon (Ar)	Psat – 48.63	Tsat – 150.7	0. – 10000	83.8 – 700
Xenon (Xe)	Psat – 58.42	Tsat – 289.7	0. – 7000	161.4 – 750

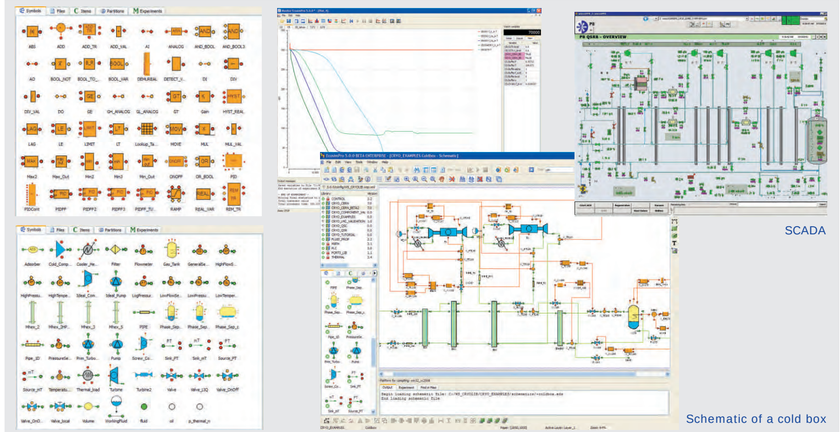
Real fluids ranges in terms of P/T



T-S thermodynamic diagram

MODELLING OF CRYOGENIC SYSTEMS

Cryogenic installations and its control system can be easily represented with this library, and the resulting model is very close to the actual physical system.

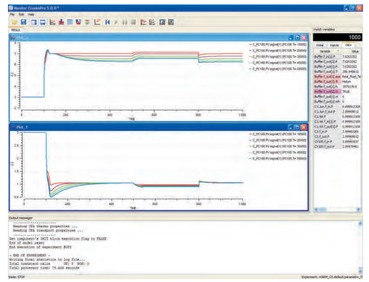


SCADA

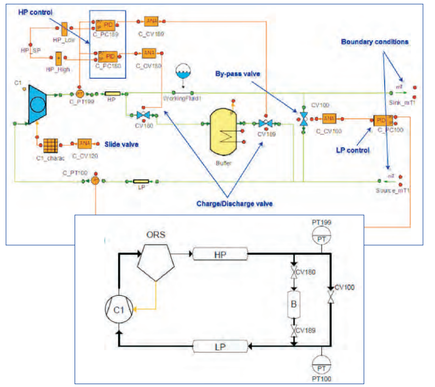
Schematic of a cold box

Models can be exported as a deck with an OPC client for connecting the model generated in EcosimPro with a real control system or to a SCADA system. Some of its domains of application include:

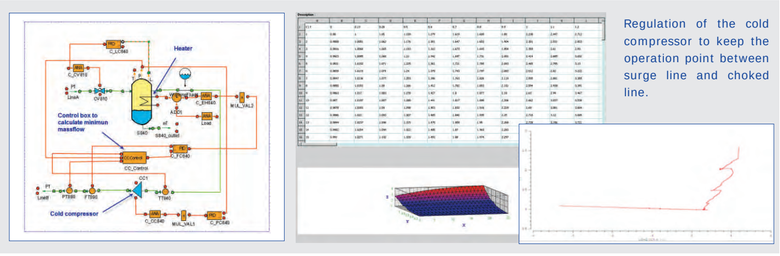
- Simulation of the complete cryogenic plant and its control system: virtual commissioning, control system development, etc.
- Design of specific cryogenic components
- Operator training. The model exported as a deck can be used in operator training simulators (e.g. PROCOS simulator at CERN)



The CRYOLIB library allows the user to analyse the response of the system with different parameter settings. The figure shows a parametric study to analyse the influence of the integration time of the low pressure controller on the system.

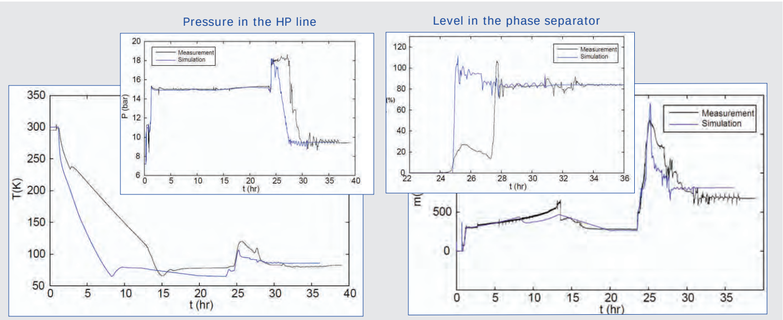


Specific cryogenic components such as cold compressors are included. A generic model is provided if the off-design characteristics are unknown to the user. The user can define specific tables for it, however.



Regulation of the cold compressor to keep the operation point between surge line and choked line.

The CRYOLIB library was validated with experimental data from CERN installations. The following screenshots show a comparison of some variables during coldbox cooling. The results of the simulation satisfactorily mimic the overall dynamic response of the actual plant.



Temperature in high pressure stream of HX1B

Massflow of LHC coldbox