Superconductor Thermohydraulical and Resistive Electrical Analytical Model (STREAM)

Scientists of CEA have developed this code used to model superconductors cooled in static superfluid bath. Analytical Model (STREAM) has been successfully developed for the analysis of WEST TFC09 Quench in a helium bath. STREAM offers a detailed simulation of superconductors' stability functioning to avoid any quench issues. This code can find several applications such as medical (MRI) or hydrogen batteries.

Description of the technology

Superconductor Thermohydraulical and Resistive Electrical Analytical Model (STREAM) has been developed to model superconductive coils cooled in a static helium bath. This model comprises the electrical equations (magnetic field, current sharing temperature, quenched length evolution, Joule energy, resistive voltage, resistance and current) and a thermodynamical and an hydraulical evolutions in two following sequences.

The first one comprises the helium pressure evolution with an isentropic compression (closed volume) of a cold volume by a hot (and heated) volume; the second one comprises the determination of expulsed helium mass flow in the exhaust circuit (from a given pressure threshold) with a limit at atmospheric pressure or Mach number equal to 1.

The thermal–hydraulic codes can be used in two main kinds of applications and studies:

- *The first application is the operation/commissioning analysis in quasi steady state between the operating temperature and the current sharing temperature. This application permits to determine the operation domain and magnets stability determining if the superconductors temperature remain under the current sharing temperature. These quasi-steady-state models can also be used for commissioning and for cool-down assessment.*
- *The second application is the safety analysis, when the energy deposited is higher than the minimal quenching energy and when the conductor is quenching.*

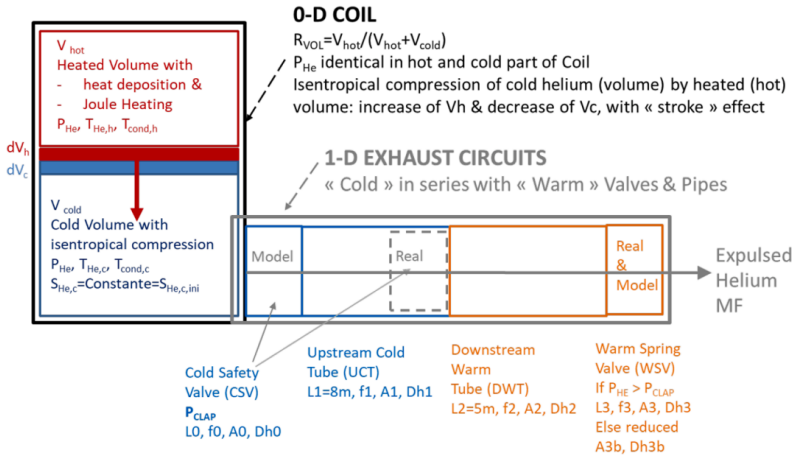
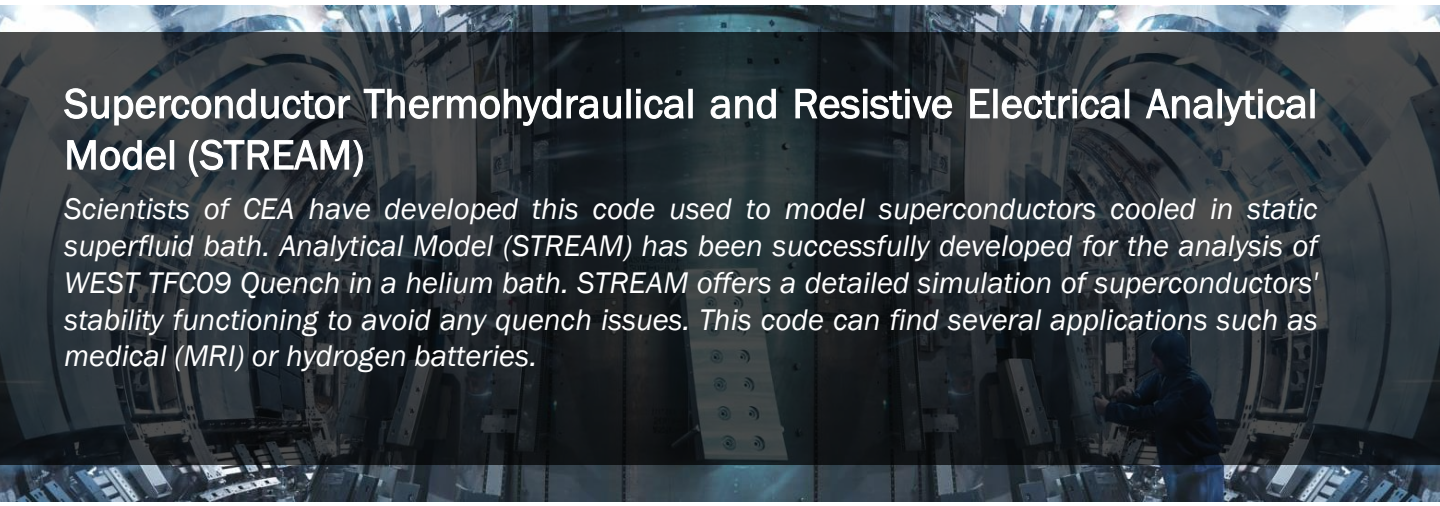


Fig. 7. WEST STREAM model hydraulical scheme



Superconductor Thermohydraulical and Resistive Electrical Analytical Model (STREAM)

Scientists of CEA have developed this code used to model superconductors cooled in static superfluid bath. Analytical Model (STREAM) has been successfully developed for the analysis of WEST TFC09 Quench in a helium bath. STREAM offers a detailed simulation of superconductors' stability functioning to avoid any quench issues. This code can find several applications such as medical (MRI) or hydrogen batteries.

Innovation and advantages of the offer

The solution offered even for different settings, presents several advantages, here are listed the main ones :

- *STREAM provides a significant gain in computation duration compared to another model*
- *The computer code can be adapted to the system (helium replaced by hydrogen)*
- *State of the art of thermal–hydraulic models*

Non-fusion Applications

For non-fusion applications, this code offers the possibility to model this superconductor's characteristics cooled in a static superfluid bath. Such a solution could find applications in Hydrogen batteries, Health sector (RMI for quench safety), or in any application requiring a safety analysis of a superconductor.

EUROfusion Heritage

Some previous analyses were made with SuperMagnet to find that the quench is induced by a neutron and gamma flux caused by highly energetic runaway electrons (30 MeV) colliding the outboard plasma facing components. Then STREAM has been developed and applied to WEST TFC09 Quench. The comparison between the measured and STREAM calculated expulsed helium pressure and temperature upstream the Cold Safety Valve (CSV) is performed, as well as with previously determined SuperMagnet results. This STREAM analytical model and related know-how is useful for other tokamak magnets safe operation and protection such as in JT-60SA, notably considering that the execution time is rather small due to the set of solved equations.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.