IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

CHIP Research Programme
[Iodine chemistry in the primary cooling system]

The CHIP programme aims to reduce the level of uncertainty on radioactive iodine releases during a core meltdown accident in a nuclear reactor. The programme results will also be used to better define the means and measures to be implemented in order to limit such releases.

Content and objectives

This programme is dedicated to studying iodine chemistry under thermal non equilibrium (impact of chemical kinetics) in the primary cooling system in the event of a core meltdown accident in a water reactor. The programme uses two experimental lines:

- A "phenomenology" line (LP) designed to quantify the fraction of gaseous iodine and to characterise the aerosols produced for complex chemical systems;
- An "analytical" line (LA) designed to collect kinetic data on simple chemical systems involving iodine.

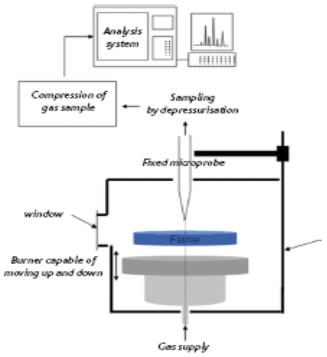
The data collected will be used to validate the transport models for iodine in the primary cooling system, which are integrated in the ASTEC software. This software is developed by the DPAM to predict the different types of possible accidents and the related radioactive product releases.

The CHIP programme is run by IRSN/DPAM and is part of the International Source Term Programme co-funded by the CEA, EDF, IRSN, the European Commission, the US Nuclear Regulatory Commission (NRC), the Atomic Energy of Canada Limited (AECL), the Korea Institute of Nuclear Safety the Paul Scherrer Institute and SUEZ-Tractebel over the 2005-2012 period.

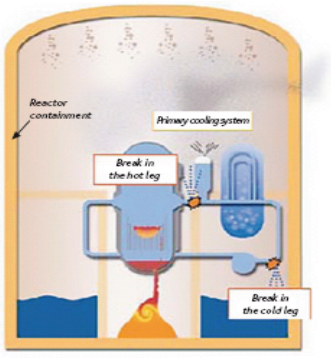
Collaboration

The CHIP programme relies on several scientific partnerships both on a national and international level. The "analytical" line tests are performed in Lille at the CNRS/ PC2A[1]. Part of the "phenomenology" line loop was designed and developed by the Finish Research Institute VTT[2]. A research programme has been launched in collaboration with the CNRS/LASIR[3], focusing on the molecular composition (speciation) of aerosols produced in the CHIP phenomenology loop.

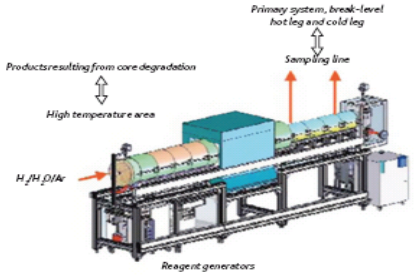
Other collaboration agreements may be signed to improve the performance of experimental devices, particularly in terms of separating iodine into aerosol and gas forms.



CHIP LA device: kinetic studies using the flame technique



Core meltdown accident in a nuclear reactor



CHIP LP device: reduced-scale model of the primary cooling system

1 - *CNRS/PC2A: Physico-chemistry of Combustion Processes and the Atmosphere, CNRS UMR 8522, University of Lille 1.*
2 - *VTT: Technical Research Centre of Finland, Espoo.*
3 - *CNRS/LASIR: Infrared and Raman Spectrometry Laboratory, CNRS-UMR 8516, University of Lille 1.*

Budget

The total cost of the CHIP programme is about €8.5 million, including €1.5 million for investment over a period of 6 years.

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CHIP Facility
Phenomenology line
[Iodine chemistry in the primary cooling system]

The CHIP programme aims at improving the assessment of iodine quantities (source term) released in the event of a core meltdown accident in a nuclear reactor. The "phenomenology line" is designed to reproduce the thermal-hydraulic and chemical conditions existing in the primary cooling system during a loss-of-coolant accident. The aim is to represent the homogeneous and heterogeneous chemical reactions occurring during the transport of iodine from the damaged reactor core to the reactor containment.

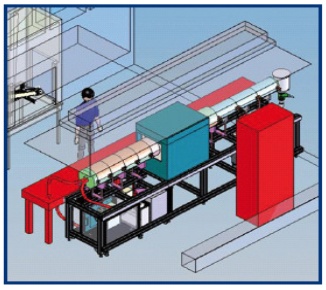
Test objectives

The experiment involving the phenomenology line will be performed over the 2008-2012 period and will help to:
- Quantify the fraction of volatile iodine in the primary cooling system for chemical reaction systems representative of those existing in a reactor. The speciation of the aerosols generated in the CHIP facility will also be studied to provide important data on the molecular forms of iodine condensed in the primary cooling system;
- Validate software developed by IRSN and used to simulate the behaviour and transport of iodine under accident conditions (SOPHAEROS model in the ASTEC software).

Experimental device and test conditions

The device is composed of:
- Several generators to produce chemical species in vapour or gas form (I_2, H_2/H_2O, Cs, B, Mo, Ag, In, Te, Cd and Rb);
- A line designed to heat the different reagents to temperatures between 1,500°C and 1,600°C. This temperature level corresponds to those encountered in the upper part of a core undergoing melting;
- A transport line made from the same material as that used for the primary cooling system, and including two types of sampling devices designed and developed by the VTT[1] Research Institute:
  - High-temperature sampling between 700°C and 900°C to study hot-leg break conditions;
  - Low-temperature sampling at around 150°C to study cold-leg break conditions.

The parameters studied are the temperature at the sampling points, the concentration ratios of the chemical reagents, and the hold time in the system. They are representative of the different ranges encountered under accident conditions in the primary cooling system of a pressurised water reactor. The pressure in the CHIP facility is that existing in a primary system with a large break, equivalent to an absolute pressure of about 2 bar.



CHIP test loop

1- Technical Research Centre of Finland, Espoo.

2 - *CNRS/LASIR Infrared and Raman Spectrometry Laboratory, CNRS-UMR 8516, University of Lille 1.*

Collaboration

Some of the equipment is developed by the Finish Research Institute VTT[1]. The experimental study on aerosol chemistry is conducted in collaboration with the CNRS/ LASIR[2].

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CHIP Facility
Analytical line
[IODINE CHEMISTRY IN THE PRIMARY COOLING SYSTEM]

The CHIP programme better quantifies the amount of iodine that may be released (source term) during a core meltdown accident in a nuclear reactor. The "analytical" line studies the chemical mechanisms involved in the formation of iodine species for homogeneous gas-phase reactions of quaternary systems (X, I, O, H) by means of pre-mixed flame configurations.

Test objectives

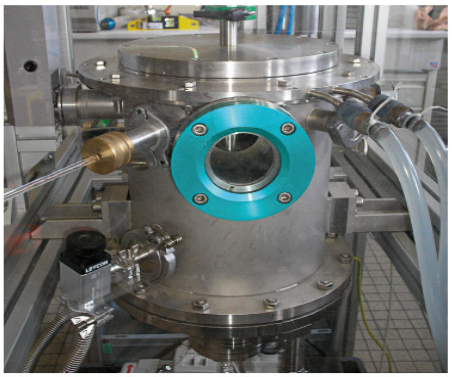
This programme will make it possible to:
- Ascertain basic kinetic data for mixtures containing iodine, hydrogen, another fission product (X = Cs), or a control rod element (X = Cd), and steam;
- Supplement the databases (chemical speciation of gaseous iodine species and basic kinetic data) needed to model the behaviour of radioactive fission products in the primary cooling system of a pressurised water reactor (ASTEC software developed by IRSN/ DPAM).

Experimental device and test conditions:

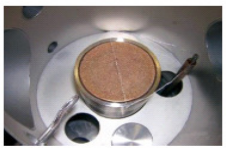
The device includes:
- Several reagent feed pipes (iodine from a hydrogen iodine (HI) cylinder, hydrogen/ steam generator, O_2 oxidising agent from a gas cylinder, other reagents such as Cs, Cd, etc.);
- A burner supplied with a prepared gas mixture ensuring the formation of a 1D flame in which the reagents can react;
- A low-pressure combustion chamber;
- On-line gas sampling systems;
- Analytical devices for identifying and quantifying the species under investigation (molecules, atoms and radicals).

This device is used to determine quantitative profiles of change in chemical species as a function of the temperature profile in the flame. The experimental data are used to develop complex reaction mechanisms.

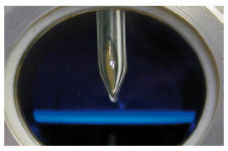
The experimental parameters are the temperature (500 - 2,000 K) and the concentration ratios of the chemical reagents. They are representative of the different ranges covered under accident conditions in the primary cooling system of a pressurised water reactor.



Experimental device



Burner in translation position



Quartz microprobe taking a sample from the flame

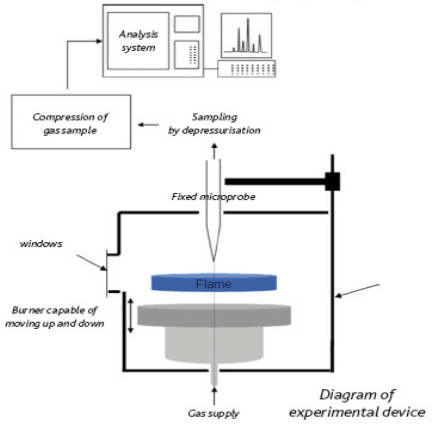


Diagram of experimental device

1 - CNRS/PC2A: Physicochemistry of atmospheric and combustion processes, CNRS UMR 8522, Univ. Lille 1.

Collaboration

These tests are performed at the CNRS/ PC2A in Lille as part of IRSN PhD studies.

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