PLATEAU FACILITY IN SUPPORT TO ASTRID AND THE SFR PROGRAM: AN OVERVIEW OF THE FIRST MOCK-UP OF THE ASTRID UPPER PLENUM, MICAS

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ABSTRACT

The CEA and several industrial partners are involved in the development of a 4th generation reactor cooled by sodium, ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration). It is a 600MWe pool type reactor integrating cutting edge technologies.
Developments are in progress especially for the vessel and the apparatus. Experiments are needed for both validation of numerical codes and special studies. In this way, a thermal-hydraulic loop, the PLATEAU facility, has been developed and built at the CEA Cadarache. Different mock-ups can be connected to this loop to study different issues at various reactor conditions. Currently, 4 mock-ups are identified: the internal vessel, the entire pool reactor, the link between the external and the internal vessel, a part of the internal vessel at a higher scale to study specific issues.
The MICAS mock-up at 1/6 scale is dedicated to study the flow regime of the internal vessel (hot plenum), both for code validation and also engineering design developments.
This mock-up has been built in transparent polymer to carry out some optical measurements as laser velocimetry. Numerical studies have been performed to determine the general flow pattern in a way to identify the area of interest for detailed phenomenological studies.

KEYWORDS
Sodium, fast neutron reactor, mock-up, code validation

1. INTRODUCTION

ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration) is a project of construction of a 4th generation reactor cooled by sodium. CEA is the leader of this project involving many partners (EDF, AREVA, BOUYGUES…). Because of its large experience in SFR (Sodium Fast Reactor), this coolant has been chosen. The design integrates this know-how and the feedback of the previous French SFR (PHOENIX, SUPER-PHOENIX) but also cutting edge technologies. We are currently at the end on the pre-conceptual design stage and new developments need to be validated. Experiments with sodium are complicated, mainly because of its high reactivity with water and its opacity. Part of the studies is performed on small scale mock-ups using water using the dimensional analysis. A hydraulic loop has been designed and built to provide hydraulic conditions to those mock-ups: PLATEAU. Depending on the issue, different dimensionless numbers are considered. They are characterized by a dimensionless number, such as the Froude or the Richardson. Four mock-ups have been identified: the internal vessel, the entire pool reactor, the link between the external and the internal vessel, a part of the internal vessel at a higher scale to study specific issues. The first one to be studied will be the hot plenum: MICAS.
This article is dedicated to present the PLATEAU facility and the experimental program on the MICAS mock-up. In the first part, the ASTRID reactor concept is briefly presented. Then the PLATEAU

experimental facility is described in detail. The issues of the internal vessel are summed-up and the MICAS mock-up and its experimental program are presented. Then some numerical calculation results are shown to illustrate the flow in the internal vessel.

2. ASTRID REACTOR CONCEPT

ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration) is a technological demonstrator reactor. The main objective of ASTRID is to prepare the industrial deployment of 4th generation sodium fast reactors (SFR) by demonstrating at a sufficient scale the technical options chosen, mainly in the field of the safety and the operability. The industrial deployment has not been scheduled and depends on many trends. Nevertheless, years of operation on ASTRID will be necessary to have an overall feedback to design upper scale industrial plants. The forecast power will be up to 1500 MW. The safety level is based on the 3rd generation PWRs, and has to follow the recommendations of the WENRA (Western European Nuclear Regulators Association). Sixty years of service life are expected for the ASTRID reactor. However, based on the current knowledge, only 40 years are guaranteed; life extension will be studied during the operation. From the economical point of view, ASTRID will give an idea of investment and operating costs. ASTRID is a 600MWe pool reactor cooled by sodium. This scale has been chosen to be representative enough and to reduce the cost. The main advantage of pool type reactor is to maintain the primary sodium in one main vessel. It reduces the risk of primary sodium leakage. The figure 1 is a sketch of the actual design. The sodium flows from the external vessel to the internal vessel through the core where it is heated. From the hydraulic point of view, the core design has been optimized to limit the pressure loss. Around 90% of the sodium is ejected from the core to the internal vessel. The other part flows across the Upper Core Structure (UCS), then to the internal vessel. This structure aims at monitoring the core state by the use of thermo-velocimetry probes above each fuel assembly. The UCS also contains the control rode mechanisms inside its sheaths. The hot sodium (550°C) of the internal vessel enters inside the Intermediate Heat Exchangers (IHX) to heat a secondary sodium circuit. This latter is connected to a steam generator. This scheme avoids the primary sodium to be in contact with water in case of leakage. The outlet of the IHX is connected to the external vessel where the sodium is pumped and sent back to the core. Detail presentations of ASTRID and the project are given in [1] and [2].

From the feedback of France great experience in SFR and international reactors, four main areas of progress have been identified:

- Improvement of the core efficiency and safety, especially regarding the prevention of severe accident [3];
- Prevention from the severe accident by the use of innovative systems such as decay heat removals;
- Reduction of the risk of the interaction between sodium and water;
- Implement inspection and maintenance devices.

For qualifying the design options, and for validating the simulations, experimental tests are needed [4], [5]. For convenience, most experiments are carried out with water instead of sodium. The GISEH platform gathers all the hydraulic loops used for the qualification of the ASTRID components. The PLATEAU (PLATeforme en EAU/water platform in French) facility, belonging to the GISEH platform, is dedicated to large components such as the vessels.
The ASTRID project is at the end of the pre-conceptual design step. For most components, the geometry is defined and some new concepts have to be validated before continuing on the conceptual design. For this task, mock-ups of the various components have to be tested on the PLATEAU facility.

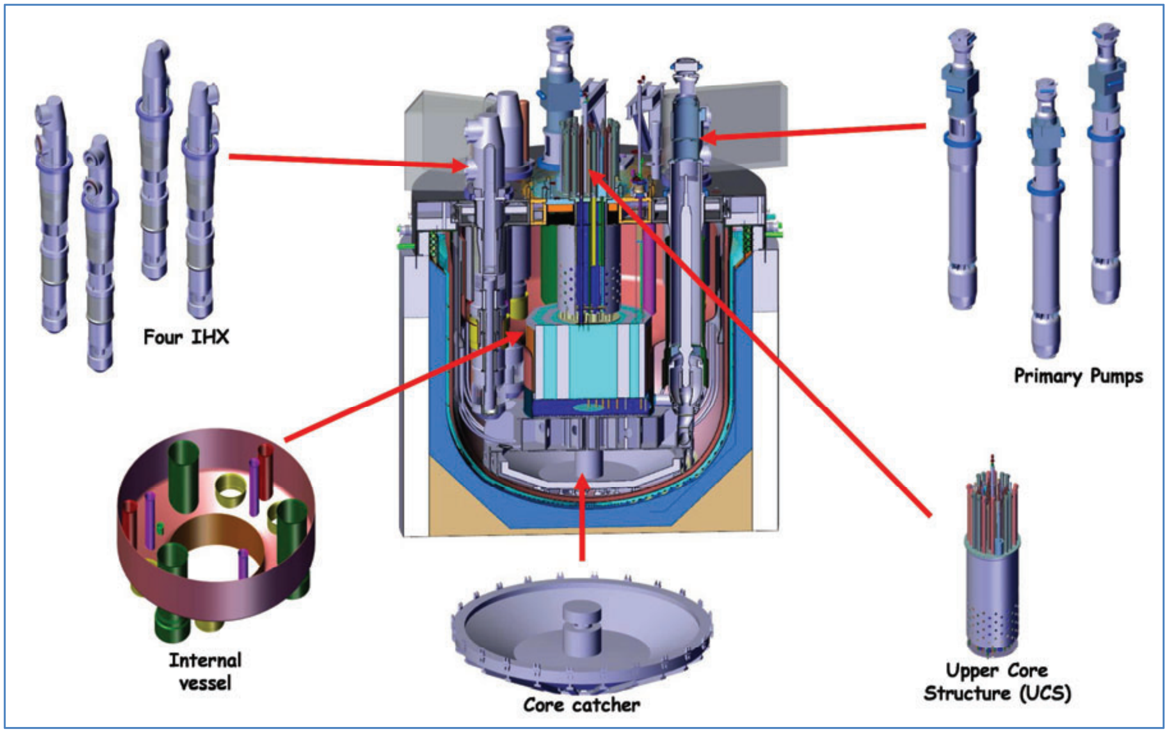

Figure 1. Cut view of the ASTRID primary circuit

3. THE PLATEAU FACILITY

A sketch and a photo of the PLATEAU facility are presented respectively on the figure 2. This facility has to accommodate various mock-ups and must be as versatile as possible. The entire circuits are shown on the figure 3. The loop enables three injection points (named 1, 2 and 3 on the figure 3) in the mock-up at different temperatures and flow-rates. Without the utility networks (not drawn on the figure 3), the PLATEAU facility presents four main circuits (cf. the figure 3):

- The main circuit (MCM in green in the figure 3);
- The hot secondary circuit (HSC in red in the figure 3);
- The cold secondary circuit (CSC in blue in the figure 3);
- The transitory injection circuit (TIC in light blue in the figure 3).

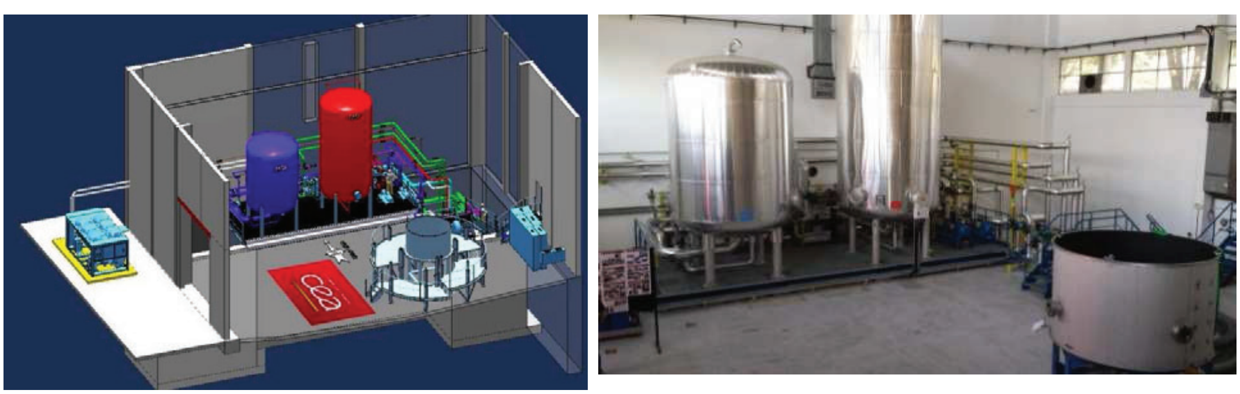

Figure 2. Global view and photo of the PLATEAU facility

This network enables three operating methods:

- Hydraulic mode: only the MCM is used. The temperature is identical in the three injection points, but the flow rate is controlled independently for each one. The temperature is regulated by the mean of the heater HEAT01 and the exchanger EX01 linked to a cooling system.
- Thermohydraulic mode: the MCM, HSC and CSC are used. As in the hydraulic mode, three different flow-rates can be imposed on the injection points. But, that case two temperatures can be used; outlet 1 (cf. figure 3) with hot water and the two others with cold water. The MCM water is cooled in the mock-up by injection of cold water from the CSC. The heater HEAT01 cannot be used because the needed power to heat such a flow-rate is too high. The hot water from the HSC is mixed with the water from the MCM to reach the setpoint temperature. As the level in the mock-up is kept steady, the water overflow is flushed to a tank (not shown on the figure3).
- Transitory mode: it begins from the thermohydraulic mode and stabilized conditions. All the circuits are used (CIT, CSC, CHC, MCM). It aims at realizing a temperature step (manly cold, but also hot) at the injection point 1 (cf. fig. 3). Water from TA01 (in case of hot step) or from TA02 (cold step) is injected downstream the pump P03. The temperature change rate is controlled by regulated valves.

The different working ranges of the flow-rate and temperature are listed in the Table I.

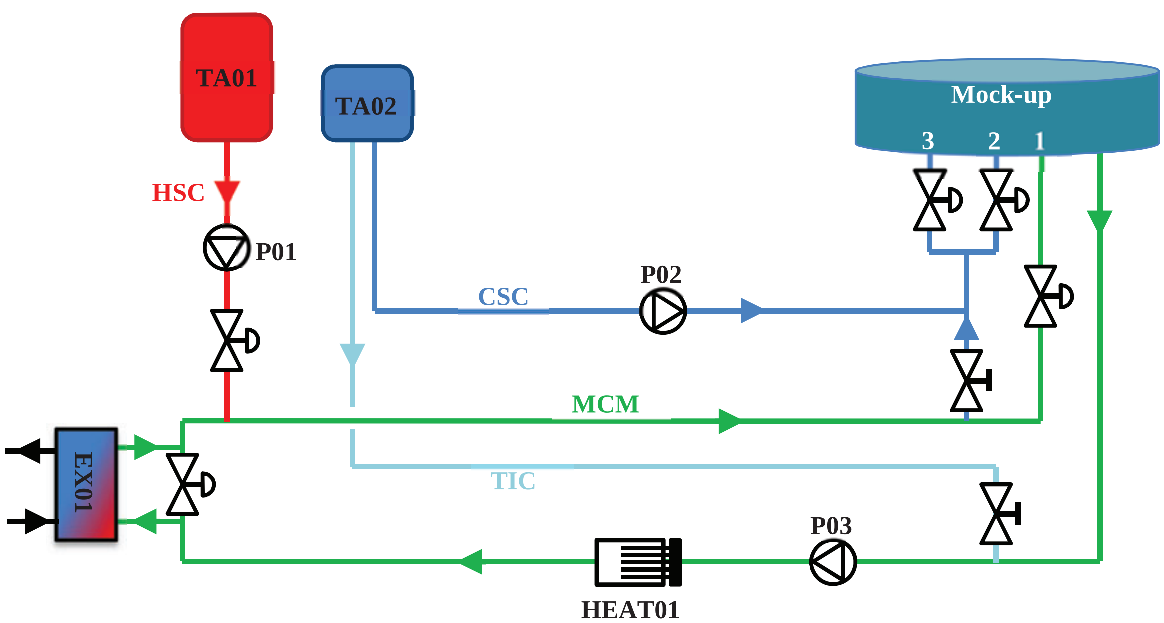

Figure 3. Diagram of the PLATEAU hydraulic circuits

Table I. Operating ranges of the different modes of the PLATEAU facility

Mode	Injection zone	Flow rate	Temperature
Hydraulic	All	From 50 to 350 m^3/h split between the 3 zones	From 10 to 60°C uniform for the 3 zones
Thermohydraulic	2 and 3	From 0 to 50 m^3/h split between the 2 zones	From 10°C to the room temperature
	1	From 50 to 350 m^3/h	From 10 to 55°C
Transitory	2 and 3	Constant from 0 to 50 m^3/h split between the 2 zones	Constant from 10°C to the room temperature
	1	Variable	Variable between 10 to 55°C

4. THE UPPER PLENUM MOCK-UP, MICAS

4.1. Issues of the Internal Vessel

From the state of art of the previous mock-ups built in the 90s in the framework of the EFR program (European Fast Reactor), new needs for experimental means have been listed for the ASTRID program. Several issues have been identified for the internal vessel and studies have to be carried out on a reduced scale mock-up. The feedback cannot help to validate the innovative systems implemented on ASTRID and calculations need validation data. Four main issues have been listed:

- Thermal interface behavior

It is created around the core and it is due to the thermal losses between the internal hot vessel and the external cold vessel. In function of its location and, moreover, if it oscillates, it can damage the internal vessel by thermal fatigue.

- Free surface flow state

The oscillation of the surface flow can induce thermal oscillations on the immersed components (UCS, IHX…). This can damage those components by the thermal fatigue. Also, some gas can be carried inside the IHXs if vortexes are created at the surface. In this case, it may happen that the gas creates a big bubble under the core. This one can be transported into the core. But gas getting into the inner core is highly unallowable because of neutron instability.

- Thermohydraulic stability and flow distribution at the IHX inlet

At low reactor powers, the hot jet coming from the core is lifting up and oscillating rather than getting down. This behavior can introduce new thermal loads to the IHX and the other components immerged in the sodium.

- Thermal and flow pattern in the UCS.

Due to its location, just above the core, the UCS is exposed to high thermal stresses. The knowledge of the inside flow pattern at nominal and reduce reactor powers is an essential datum to characterize these thermal stresses.

4.2. Geometry

The MICAS mock-up is dedicated to study the issues listed above. A cross-view of this one is shown on the figure 4. Its dimensions are about 2.5 m in diameter and 1.7 m in height. It is a 1/6 scale of the ASTRID reactor and some geometrical simplifications were made. For example, the hexagonal fuel assemblies in the core have been replaced by cylindrical pipes. Nevertheless, the IHX are represented in

detail due to the great impact of their geometrical configuration on the flow pattern as the fluid is exiting the vessel. The opening height and width of the IHXs outlet can be modified by adding tubes around the exit. It allows parametric studies. Due to its location just above the core, the UCS highly influences the flow pattern; for this reason, its geometry in MICAS is highly detailed.
The flow distribution in the ASTRID core is quite complex [6]. The center core is constituted by the fuel assemblies and the control rods. One layer of reflector assemblies, surrounded by another layer of neutron shielding assemblies are placed around the fission zone. The outer core is composed by few layers of neutron shielding and internal assembly storage. It would be difficult to reproduce exactly this pattern on the MICAS mock-up. It has been simplified into 3 zones. The injection room is shown at the bottom of the figure 4; the central zone corresponds to the core at high temperature (yellow zone on the figure 4); the intermediate one is related to the reflector; and the external zone represents the internal fuel assembly storage. These two external zones are supplied with low temperature water. Those 3 zones are connected to the PLATEAU facility (inlets 1 to 3 on the figure 3).

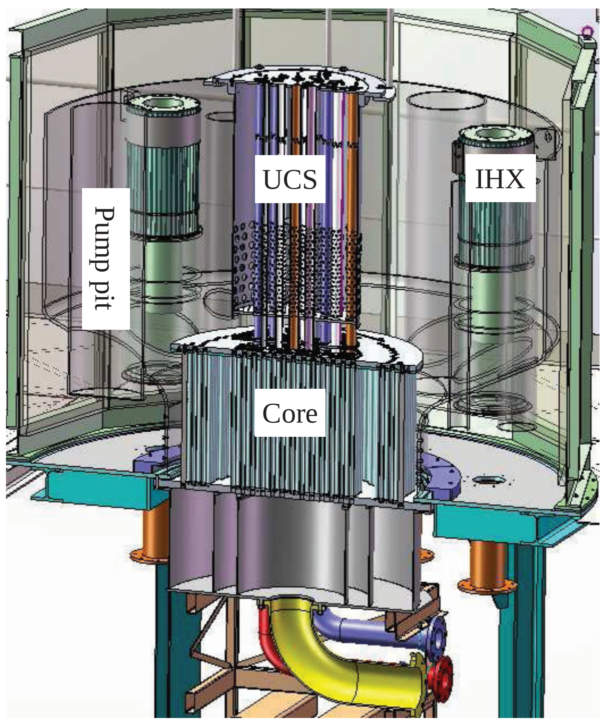

Figure 4. Cross view of the MICAS mock-up

Regarding the measurements, the fluid temperature is measured by using thermocouple poles (+/-1°C of accuracy). It allows the knowledge of the temperature at different depths versus the location. The bottom part of the internal vessel wall is equipped with PT100 (+/-0.1°C of accuracy). It aims at characterizing the thermal interface around the core.
Most of the components are built in transparent polymer for visualizations (high speed video) and measurements (Laser Doppler Velocity, Particle Imaging Velocity). The mock-up is placed in an external vessel made of 12 plane walls to enhance the optical access. To increase the accessible laser domain (velocity measurement), the pump pits include a plane face.
The flow-rate crossing the UCS is evaluated using 3 methods:

- By integrating the velocity field around the UCS outlet; the velocity field being determined by laser techniques.

- By measuring the difference of the water levels between each sheath and the internal vessel; an abacus of the pressure loss versus the flow-rate for each sheath has to be built.
- By introducing micro-fan flowmeters inside each sheath; this method is rather intrusive and has to be reserved to the large sheaths.

The gas carried into the IHXs is determined qualitatively and quantitatively. Rapid imaging focused on the IHXs inlet helps to characterize if vortexes are absorbed into the IHXs. Two cameras are used: one facing the external vessel wall to measure the vortexes depth, the other above the free surface flow to measure the vortexes diameter. From those measurements, the birth probability of the vortexes versus their characteristic (in term of depth, diameter and lifetime) will be established. For the whole IHXs, the carried gas volume has to be evaluated. A possible measurement technique to quantify the whole gas entrained is to introduce a liquid/gas separator downstream the P03 pump. This solution is being studied

4.3. Dimension Analysis

The inlet conditions of the MICAS mock-up experiments are calculated using the ASTRID reactor conditions in terms of flow-rate and temperature at nominal power. Depending on the study, different similitudes are used; regarding the free surface behavior, the Froude number is employed; for the thermal flow aspects, the Richardson number is used. We define the dimensionless quantity X* by the ratio between the variables of the mock-up and ASTRID: $X^*=X_{mock\text{-}up}/X_{ASTRID}$
Then, for each type of study (hydraulic or thermohydraulic), the dimensionless numbers characterizing the flow (Re, We, Pe) can be calculated by setting Fr*=1 or Ri*=1. They are presented in the Table II where ρ is the density, L is the characteristic length, β is the thermal expansion, μ is the dynamic viscosity, α is the thermal diffusivity, σ is the surface tension and ΔT is the maximal temperature difference at the outlet core.

Table II. Dimensionless numbers depending on the study

Dimensionless number	Hydraulic – Fr*=1	Thermohydraulic – Ri*=1
Re*	$\sqrt{Fr^*}\frac{\rho^* L^{*1.5}}{\mu^*}$	$\frac{1}{\sqrt{Ri^*}}\frac{\sqrt{\beta^*\Delta T^*}}{\mu^*}L^{*1.5}$
Pe*	$\sqrt{Fr^*}\frac{L^{*1.5}}{\alpha^*}$	$\frac{1}{\sqrt{Ri^*}}\frac{\sqrt{\beta^*\Delta T^*}}{\alpha^*}L^{*1.5}$
We*	$Fr^*\frac{\rho^* L^{*2}}{\sigma^*}$	$\frac{1}{Ri^*}\frac{\rho^*\beta^*\Delta T^*}{\sigma^*}L^{*1.5}$
Q*	$\sqrt{Fr^*}L^{*2.5}$	$\frac{1}{\sqrt{Ri^*}}\sqrt{\beta^*\Delta T^*}L^{*2.5}$

The dimensionless physical properties (ratio between the water and the sodium properties) are presented in the table III. To calculate the sodium properties, we use the average outlet core temperature, 550°C. The water temperature is taken between 20°C and 60°C. In the Table III, L* is the scale of the MICAS mock-up. According to the Table III, we can calculate the characteristic numbers and the flow-rate for each study. The flow-rate is calculated with the ASTRID data at nominal power.
For the hydraulic study, the characteristic numbers are shown in the Table IV depending on the mock-up water temperature. First of all, the flow-rate is independent from the temperature and is in the range of the P03 pump (cf. figure 3) of the PLATEAU facility. Regarding the dimensionless numbers, Re*, Pe* and We*, we notice they increase versus the water mock-up temperature. It means the similitude is more observed at high temperature and it's better to carry out the experiments at 60°C.

The Table V shows the dimensionless numbers and the flow-rate for the thermohydraulic study. The temperature difference (between the cold and the hot injection) for the mock-up is set in function of the PLATEAU facility scope, i.e. 50°C. The water physical properties are calculated at the mean temperature at the inlet of the mock-up, i.e. 35°C. The flow-rate is in the range on the P03 pump (cf. figure 3) and is lower than in the hydraulic study. The Re* and the We* are close to the values of the hydraulic study.

Table III. Dimensionless physical properties in function of the water temperature

T(°C)	ρ*	μ*	Cp*	β*	σ*	ΔT*	α*	L*
20	1.19	4.22	3.31	7.42×10^{-1}	4.57×10^{-1}	3.5×10^{-1}	2.44×10^{-3}	1/6
35	1.19	3.03	3.31	1.23	4.47×10^{-1}		2.51×10^{-3}	
40	1.19	2.75	3.31	1.38	4.37×10^{-1}		2.57×10^{-3}	
60	1.18	1.96	3.31	1.85	4.16×10^{-1}		2.68×10^{-3}	

Table IV. Dimensionless numbers and flow-rate depending on the temperature for the hydraulic study

T(°C)	Re*	Pe*	We*	Q (m^3/h)
20	1.92×10^{-2}	1.48×10^{-1}	7.19×10^{-2}	323
40	2.94×10^{-2}	1.55×10^{-1}	7.51×10^{-2}	
60	4.10×10^{-2}	1.62×10^{-1}	7.80×10^{-2}	

Table V. Dimensionless numbers and flow-rate for the thermohydraulic study

Re*	Pe*	We*	Q (m^3/h)
1.47×10^{-2}	17.8	7.89×10^{-2}	212

4.4. Experimental Program

From the scaling analysis and the cumulative abilities of the PLATEAU facility and the MICAS mock-up, a brief experimental program has been built to respond to the issues listed at the beginning of the paragraph 4:

- Preliminary studies: as intrusive instrumentations, such as the sticks of thermocouple, are put inside the pool, their influence on the flow behavior will be assessed. Comparisons of velocity measurements carried out with and without the sticks of thermocouple will be performed.
- Hydraulic study: the Table VI presents the parameters of the study and the measurement means to answer to the issues of the free surface flow behavior, the supply of the IHXs, and the UCS hydraulic. The flow-rate range investigated will be between 50 and 110% of the nominal flow rate calculated in the table IV. During the pre-conceptual studies of the ASTRID project, a neutron shielding has been added around the IHXs opening. Its impact on the flow behavior will be determined. The water level affects the free surface flow stability, especially the vortexes. Tests will be carried out to assess this influence in the range of +/-150 mm of the nominal level. The hydraulic PLATEAU mode, and mainly the MCM circuit, will be used (cf. the figure 3 and the Table I).

Table VI: Parameters and measurement of the hydraulic study

Parameters studied	Measurements
- Water level - IHXs geometry (elevation and opening of the flow window) - Influence of the neutron shielding	- Rapid imaging of the free surface flow - Velocity field at the outlet of the core, around the IHXs and the UCS. - Flow-rate through the UCS. - Flow-rate of the entrained gas.

- Thermohydraulic study: the table VII shows the parameters of the study and the measurement means to answer to the issues of the thermal interface and the themohydraulic stability. Experiments will be carried out in the flow-rate range of 45 to 100% of the nominal flow-rate defined in the Table V. According that the ASTRID differential temperature (between the hot fission zone and the cold external core areas) ranges from $60<\Delta T_{ASTRID}<150°C$, the MICAS differential temperature (between the hot and the cold injections into the mock-up) is set from $20<\Delta T_{MICAS}<50°C$. As in the hydraulic study, the influence of the IHXs parameters (geometry and neutron shielding) will be considered. The critical Richardson number (starting of the jet oscillations) will be investigated in term of core flow-rate. The PLATEAU facility will run in the thermohydraulic mode using the MCM, HSC and the CSC circuits (cf. the figure 3 and the Table I).

Table VII: Parameters and measurement of the thermohydraulic study

Parameters studied	Measurements
- IHXs geometry (elevation and opening of the flow window) - Influence of the neutron shielding	- Velocity field at the outlet of the core, around the IHXs and the UCS. - Temperature field at the bottom of the internal vessel, around the core, the UCS and the IHX. - Temperatures along the wall internal vessel.

- Cold transitory: this study is the trickiest. It simulates a cold shock during an automatic reactor stop. The transitory mode of the PLATEAU facility is used for this study (cf Table I). Starting from a thermohydraulic steady state ($Ri^*= 1$) is the logical manner to do this experiment. The capacity of TA01 and TA02 tanks allows around 30 minutes of test. Nowadays, since no experiment has been carried out, we have no datum on the length to establish the steady state. From the feedback of the previous studies performed in the 90s, it is estimated to about 15 minutes. But if it is too long, the duration of the cold transitory test would be too short. Moreover, at $Ri^*=1$, the dimensionless time is $\tau^*=1.1$; it implies a longer duration of the transitory on the MICAS mock-up. Thermohydraulic results are needed to state on the initial conditions of this test. However, if they are unfavorable to start at a thermohydraulic steady state, we would chose, as initial conditions, a 60°C homogeneous temperature for all the mock-up inlets (1 to 3 on the figure 3). As, this case doesn't need the use of the tanks TA01 and TA02, a well-established steady state can be reached.
  During the cold transitory, the flow-rate and the temperature are varying simultaneity. To

simplify the test steering, the variation of the temperature and the flow-rate will be carried out one after one. First, the temperature will be decreased, then the flow-rate.

All those tests will begin in September 2015. We will start with the hydraulic tests, will followed by the thermohydraulic experiments and we will finish with the cold transitory. The whole experimental program on the MICAS mock-up is planned to last approximatively one year.

4.5. Numerical Study

The initial scaling analysis was useful to define the mock-up experimental parameters ranges according the scale reduction and the use of water instead of sodium. From this study, CFD calculations have been performed on the MICAS geometry. They aim at understanding the flow pattern to place the instrumentation at the better locations. The 3D simulations have been carried out using StarCCM+ v9 on a 13.4 million polyhedral cells mesh. The entire geometry has been considered without any simplification; for example, the grid above the core has been meshed explicitly, every hole has been taken into account. The free surface is modeled by a symmetric condition; it assumes to be flat, the vortexes are not taken into account. A 1 bar outlet pressure boundary condition is set at the IHXs. Inlet velocity conditions are set in the core location. The ASTRID core flow-rate and temperature distributions are observed. Those first calculations aim at studying the thermohydraulic flows. The water temperature at the inner core inlet condition is set at 60°C and 10°C at the outer core. The changes of the water physical properties (viscosity, density…) in function of the temperature are taken into account. All external walls are assumed adiabatic. The turbulence is modeled using the k-ε model and the gravity is taken into account. This article is not devoted to discuss about the whole study, some test case results are shown on the figure 5. It presents the velocity and the temperature fields in the internal vessel of MICAS for an equivalent 100% reactor power. Calculations are run to reach the steady state.

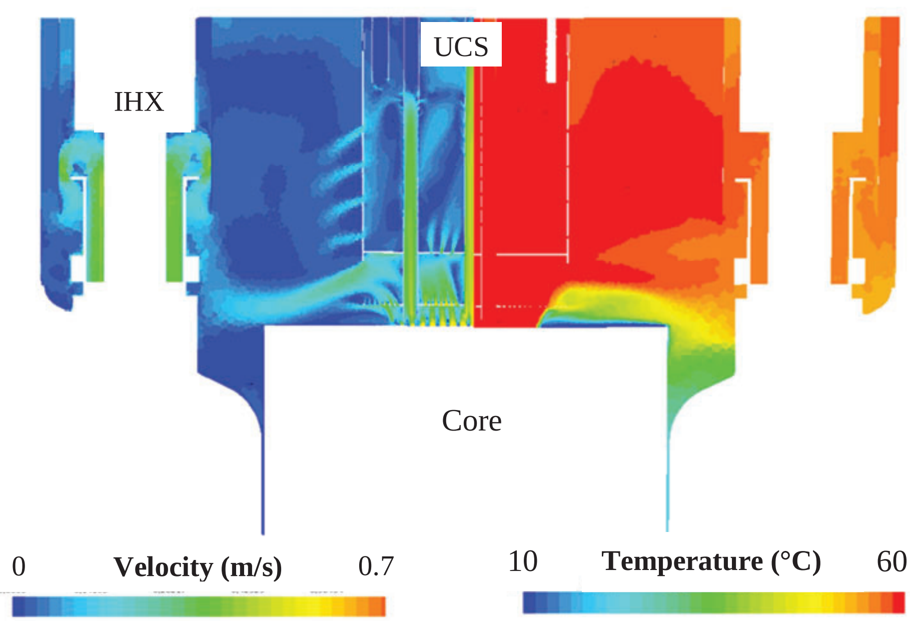

Figure 5. Cut view of the velocity (left side) and the temperature (right side) field at Ri*=1

On the figure 5 (left side), we can observe that the outgoing jet from the core is firstly impinging the UCS and then is deflecting down. This behavior is expected since the sodium simulations on the ASTRID reactor exhibit the same flow pattern. A part of the flow is crossing the UCS through the sheaths. Twenty

percent of the core flow-rate is entering in the UCS while only 11% is expected in the ASTRID reactor; this difference because pressure losses in the sheaths have been neglected. Those latter are generated by in particular the control rod mechanisms. Calculations are in progress to take into account those pressure losses to correct the flow-rate crossing the UCS. Except around the IHXs, the other part of the domain are quite dead zones with low velocity. Measurements have to be focused on the jet coming from the core and the flows around the UCS and the IHXs.
On the right side of the figure 5, the image shows that the temperature field is quite homogeneous in the internal vessel. The temperature is close to 60°C in a great part of the domain. In particular the entire UCS is at 60°C. Only around the core, the temperature is near 10°C. It corresponds to non-fissile zone of the core. It creates high temperature gradient by the mixing of the cold and the hot jets. Instrumentation has to be adapted to this specific thermal pattern. The instrumental mesh has to be refined in this area. Another area of interest is at the bottom of the internal vessel. A thermal interface is developed at the outlet core elevation. Temperature sensors have been placed along the wall of the vessel to determine the location of this interface.

5. CONCLUSIONS

The ASTRID 4th generation reactor concept includes French and International feedbacks and main advances on the safety and operative point of view. As the numerical codes are not yet able to model correctly all the physical phenomena, the new designs of the components have to be validated with specific experiments. The PLATEAU loop has been designed for this purpose and it is dedicated to study big components such as the vessels. This facility uses simulant fluid, water, instead of sodium for convenience and cost. It has been designed very versatile to study mock-ups as varied as possible. The first mock-up tested on PLATEAU will be MICAS. It is a 1/6 reduced scale of the ASTRID internal vessel built in transparent polymer for both visualization of the flow and laser velocimetry. The main issues concern the free surface flow stability and the thermal stability. They are studied using dimensional analysis. The Froude number is used to study the free surface and vortices issues, and the Richardson number for the thermal flow instabilities. From this dimensional analysis and the ASTRID data about the core flow-rate and the temperature, operating conditions of MICAS in terms of water flow-rate and temperature are calculated. They are in the range of the ability of the PLATEAU facility. As it induces less distortions to the We and the Re numbers, experiments will be performed at 60°C for the hydraulic studies. An experimental program is built considering the different issues. Preliminary studies are planned to check the non-intrusive behavior of the instrumentation. The hydraulic studies will analyze the influence of geometrical parameters (IHX height and opening, water level…) on the free surface behavior. The effect of IHX geometry on the thermal flow stability will be investigated during the thermohydraulic studies. The critical Richardson number, corresponding to the transition between a stable and an oscillating jet, will be determined versus the total core flow-rate. The last experiment will try to simulate an automatic stop of the reactor. It corresponds to a fast decrease of the temperature and the flow-rate. This test will be carried out from initial conditions corresponding of a steady state thermohydraulic flow if the tanks capacity ensures a sufficient experimental duration. Some CFD calculations have been carried out to determine the measurement locations of interest. Regarding the velocity, measurements have to be emphasized around the core exit and the IHXs. The temperature measurements have to focus at the bottom of the vessel and around the core. The flow-rate across the UCS is overestimated because the pressure losses due to the control rod mechanisms are neglected. This lack will be corrected in the further studies. Experimental results will be presented in further articles.

REFERENCES

1. P. Le Coz, J.-F. Sauvage and J.-P. Serpantie, “Sodium-Cooled Fast Reactors: the ASTRID Plant Project”, *Proceeding of ICAPP 2011*, Nice, France, 2-6 May, (2011).

2. "4TH-Generation Sodium-Cooled Fast Reactors - The Astrid Technological Demonstrator", http://www.cea.fr/content/download/131897/2449556/file/4th-generation-sodium-cooled-fast-reactors.pdf (2012).
3. P. Lo Pinto et al., "The Safety orientations during ASTRID conceptual design phase", *Proceeding of FR13, Paper CN-199-267, IAEA CN-199,* Paris, France, (2013).
4. G. Rodriguez et al., "Development of experimental facility platform in support of the ASTRID program", *Proceeding of FR13, Paper CN-199-122, IAEA CN-199*, Paris, France (2013).
5. O. Gastaldi et al., "Experimental platforms in support of the ASTRID program: Main experimental needs and devoted existing or planned facilities", *Proceeding of ICAPP 2015, Paper 15126, SFEN*, Nice, France (2015).
6. F. Varaine, P. Marsault, M-S. Chenaud, B. Bernardin, A. Conti, P. Sciora, C. Venard, B. Fontaine, N. Devictor, L. Martin, "Pre-conceptual design study of ASTRID core", *Proceeding of ICAPP '12,* Chicago, United States, 24-28 Jun (2012).