Profile SFR-49

MELT

JAPAN

GENERAL INFORMATION

NAME OF THE FACILITY	MELT
ACRONYM	MELT
COOLANT(S) OF THE FACILITY	Liquid sodium, Water (as the simulant of liquid sodium in simulated experiments)
LOCATION (address):	Oarai Research and Development Institute, Japan Atomic Energy Agency (JAEA), 4002 Narita, Oarai-machi, Ibaraki-ken, 311-1393, Japan
OPERATOR	JAEA
CONTACT PERSON (name, address, institute, function, telephone, email):	Shuji OHNO, Reactor Systems Design Department Sector of Fast Reactor and Advanced Reactor Research and Development Japan Atomic Energy Agency (JAEA) 4002 Narita, Oarai-machi, Ibaraki-ken, 311-1393, Japan Tel: +81 29 267 4141, email: ohno.shuji@jaea.go.jp

STATUS OF THE FACILITY	In operation
Start of operation (date):	2014

MAIN RESEARCH FIELD(S)

- ☐ Zero power facility for V&V and licensing purposes
- ☒ Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
- ☒ Thermal-hydraulics
- ☐ Coolant chemistry
- ☐ Materials
- ☐ Systems and components
- ☐ Instrumentation & ISI&R

TECHNICAL DESCRIPTION

Description of the facility

The MELT was built to perform out-of-pile experiments relating to the molten core material behaviour in Sodium-cooled Fast Reactor (SFR) severe accidents. This facility basically consists of the melting section and the test section. In the melting section, about 20 ℓ of materials such as alumina and stainless steel can be melted at the highest temperature of

2300 °C by the induction heating furnace, which is installed inside the cylindrical containment vessel. In order to avoid the oxidization of the materials during the experiments, argon gas can be charged in the containment vessel. The molten materials can be poured into the test section through a nozzle by pulling out a plug at the furnace bottom. The test section is located in the pit to prevent the external escalation of potential abnormal events accompanying the experiments. An X-ray imaging system is available for the visualization of transient phenomena in the test section. The MELT has been utilized to investigate structure erosion by the melt-jet impingement, fuel-coolant interaction (FCI), et cetera.

Acceptance of radioactive material
No

Scheme/diagram

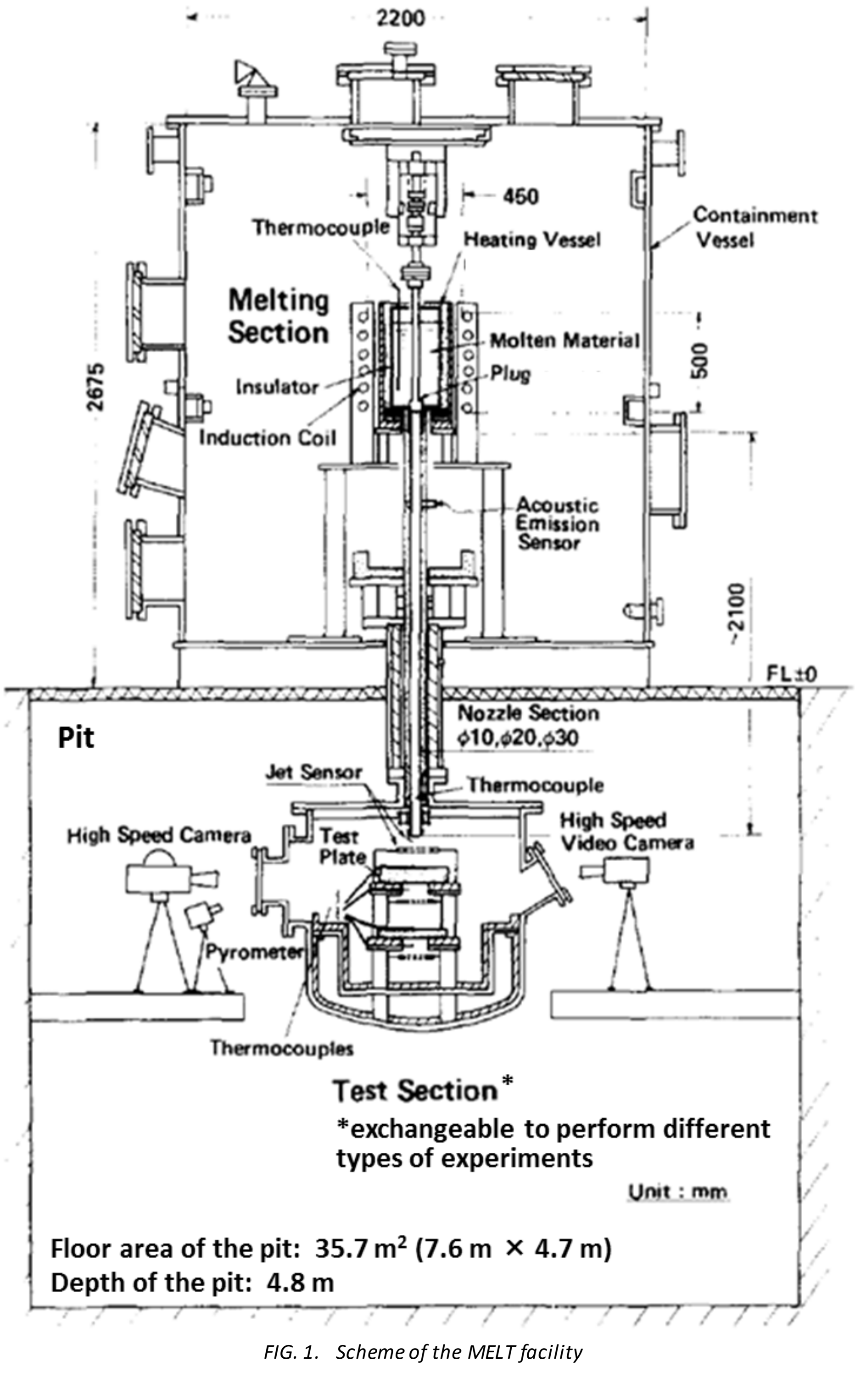

FIG. 1. Scheme of the MELT facility

3D drawing/photo

FIG. 2. View the MELT test section for sodium experiments to study fuel-coolant interactions

Parameters table

Coolant inventory	Liquid sodium: 250 kg
Power	Induction heating power: 100 kW (max)
Test sections	
TS #1	*Characteristic dimensions* Outer diameter of the sodium vessel: 114 mm Overall height of the sodium vessel: 1000 mm
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) Delta T: 0 °C (about 10 kg of stagnant liquid sodium) Design temperature: 600 °C
	Operating pressure and design pressure Operating pressure: 0 kPa (gauge) Design pressure: 500 kPa (gauge)
	Flow range (mass, velocity, etc.) Stagnant liquid sodium (Replaceable by sodium loop)
Coolant chemistry measurement and control (active or not, measured parameters)	The MELT facility is equipped with an inert gas (e.g. argon) supply system to prevent the oxidization of the liquid sodium. Besides, in order to separate potential impurities from the liquid sodium, filtering devices are installed in the sodium vessel.
Instrumentation	X-ray imaging system (maximum continuous voltage/current: 300 kV/10 mA, X-ray decay time: <100 μs), High-speed video camera (typical recording rate: 10000 frames per second at a resolution of 1000×1000 pixels), Thermocouple, Pressure sensor, Pyrometer, Flowmeter

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

In the early experimental campaign, a series of simulation experiments was performed to study the melting behaviour of a steel structure by a molten fuel jet. In the post-accident material relocation phase of SFR severe accidents, one of the greatest concerns is potential downward release of the molten core material through control rod guide tubes (CRGTs) which have weaker thermal resistance in the core region, and the subsequent direct contact of molten fuel jets with structures located underneath. In the experiments, to investigate the erosion rate of solid plates by a high temperature molten jet and the effects of crust forming at jet-structure interface, simulation materials such as salt (NaCl) and tin (Sn) were employed as the jet material and the solid structure, respectively. Furthermore, to check the effects of thermo-physical properties on the erosion behaviour, a molten alumina (Al_2O_3) jet impinging on a stainless steel plate was covered in the experiments. The erosion rates obtained in the experiments were far less than the values predicted by an analytical solution that neglects the existence of a crust layer and its thermal resistance. Based on the experimental results, a

Nusselt number in the impingement region of a molten jet was correlated by a Reynolds number and a Prandtl number.

After the completion of the early experimental campaign, a series of experiments to study molten fuel-coolant interactions (FCIs) in a jet contact mode was performed. In the experiments, a molten alloy with a low melting point (composition: Bi 60 %, Sn 20%, In 20%, density: 8.4×10^3 kg/m^3, melting point: 79 °C) and water were employed as the molten fuel and the liquid sodium, respectively. Several distinct interaction behaviours were observed for various combinations of the initial temperature conditions of the two fluids. A semi-empirical model for a minimum film boiling temperature criterion was developed in this study. The model reasonably explained different FCI behaviours observed in the experiments. Based on the experimental results and the developed model, it was concluded that energetic FCIs are possible only under relatively narrow initial thermal conditions where the film boiling could be sustained at the contact interface between two fluids. In recent years, this series of experiments has been followed by a new experimental campaign using the MELT to reinforce the experimental evidence for In-Vessel Retention (IVR) of molten core materials during SFR severe accidents. The new campaign was initiated by a series of fundamental experiments using water as the simulant of sodium to gain further understanding on the mechanisms of FCIs under the sodium-cooled conditions. In the fundamental experiments, up to about 400 kg of a molten alloy with a low melting point was injected into a large water pool through a nozzle with a diameter of up to about 150 mm. The experimental results revealed that the local vaporization and resultant vapour expansion accelerated the fragmentation of the molten alloy and thereby inhibited the deep jet-penetration in the pool. In conclusion, these experimental campaigns provided valuable data for the establishment of evaluation methods to predict the consequences of FCIs in SFR severe accidents.

Another recent experimental campaign was conducted to study the fuel discharge behaviour through in-core coolant channels such as CRGTs. While in-core channels with a relatively large flow area are potential effective flow paths for fuel discharge which reduces the reactivity of the degraded core, the liquid coolant in the channels might facilitate the freezing and plugging inside the channels and thus disturb the effective fuel discharge. Besides, the local FCI and resultant pressure buildup, which might occur within the molten fuel pool at the time of the CRGT wall failure, is considered to be a potential initiator of the reactivity increase induced by the pool sloshing. In the experiments, to investigate the fundamental characteristics of the fuel discharge, a molten alloy with a low melting point was ejected into a simulated in-core channel which was initially filled with water. The experimental results showed that immediately after the ejection, the simulated channel was entirely voided due to the vaporization of a part of the water. Based on the experimental results, an evaluation method to predict the effects of the coolant on the fuel discharge behaviour was developed. Preliminary evaluation using the developed method suggested that the coolant has limited disturbing effects on the fuel discharge, and therefore in-core channels will provide effective fuel discharge paths. An experimental study was also conducted using the MELT to investigate the local FCIs and resultant pressure buildup in a simulated molten fuel pool. The experimental results suggested the existence of a unique inhibitory mechanism against the pressure buildup.

PLANNED EXPERIMENTS (including time schedule)

Since 2012, a series of sodium experiments with a visual observation by X-ray imaging system has been conducted under the experimental campaign which has been launched to reinforce the experimental evidence for the IVR of molten core materials during SFR severe accidents. Their particular emphasis is placed on the investigation of the consequences of FCIs (e.g. fragmentation, jet breakup, coolablity, etc.) under sodium-cooled conditions. These experiments will take several or more years to be completed.

TRAINING ACTIVITIES

Training activities for the operators are regularly conducted under the supervision of JAEA qualified staff.

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