Profile SFR-78

SNAKE

USA

GENERAL INFORMATION

NAME OF THE FACILITY	SNAKE
ACRONYM	S-CO_2, Na Kinetics Experiment
COOLANT(S) OF THE FACILITY	Sodium
LOCATION (address):	Argonne National Laboratory, Building 206 Lemont IL USA
OPERATOR	Argonne National Laboratory (ANL)
CONTACT PERSON (name, address, institute, function, telephone, email):	Dr. Craig Gerardi, Lead Experimenter Argonne National Laboratory, Building 206 Lemont IL 60439 USA +1 630-252-8736 cgerardi@anl.gov
STATUS OF THE FACILITY	In Operation
Start of operation (date):	2013

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 SNAKE facility is designed to study the chemical interactions that could occur between liquid sodium and gas injections. Sodium and gas temperatures up to 538 C and gas pressures up to 200 bar can be tested. The SNAKE facility primarily has been used to study the chemical interactions between supercritical carbon dioxide and sodium for sodium fast

reactor and CO2 Brayton cycle applications. Any gas could be used to replace the CO2 injection. The heat source heat exchangers for a Brayton cycle energy conversion cycle coupled with a sodium fast reactor are usually of the diffusion bonded heat exchanger type. These heat exchangers are considered to be very robust and their most likely failure mechanism is via micro-cracking at the header welds. The SNAKE facility studies gas injection through representative micro-cracks into sodium. Exhaust gases are analyzed using mass spectrometer and a gas analyzer. Solid reaction products are analyzed post-experiment with a variety of analytical chemistry techniques.

Acceptance of radioactive material

Yes, but does not currently. Would require safety review prior to addition of radioactive materials.

Scheme/diagram

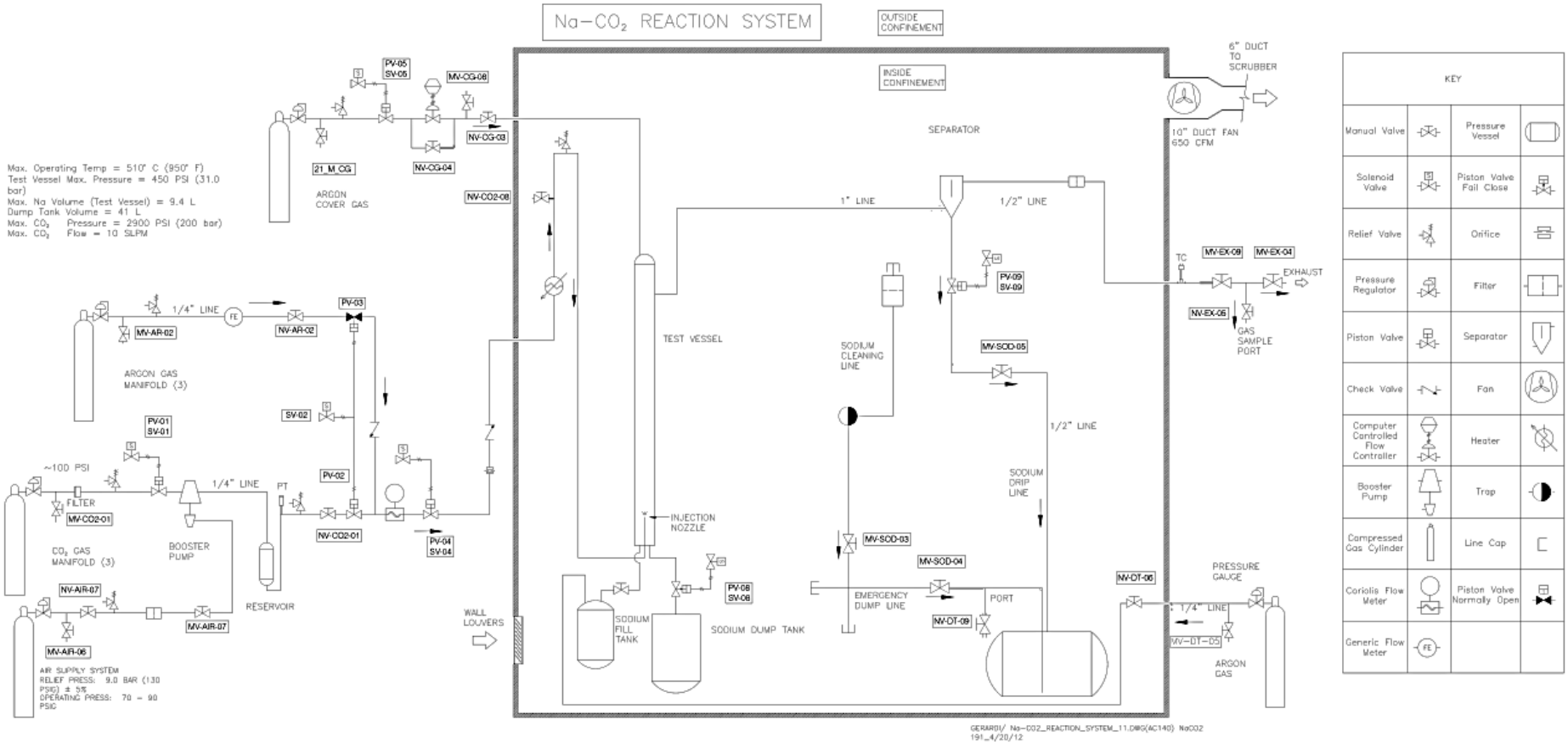

FIG. 1. Scheme of the SNAKE facility

3D drawing/photo

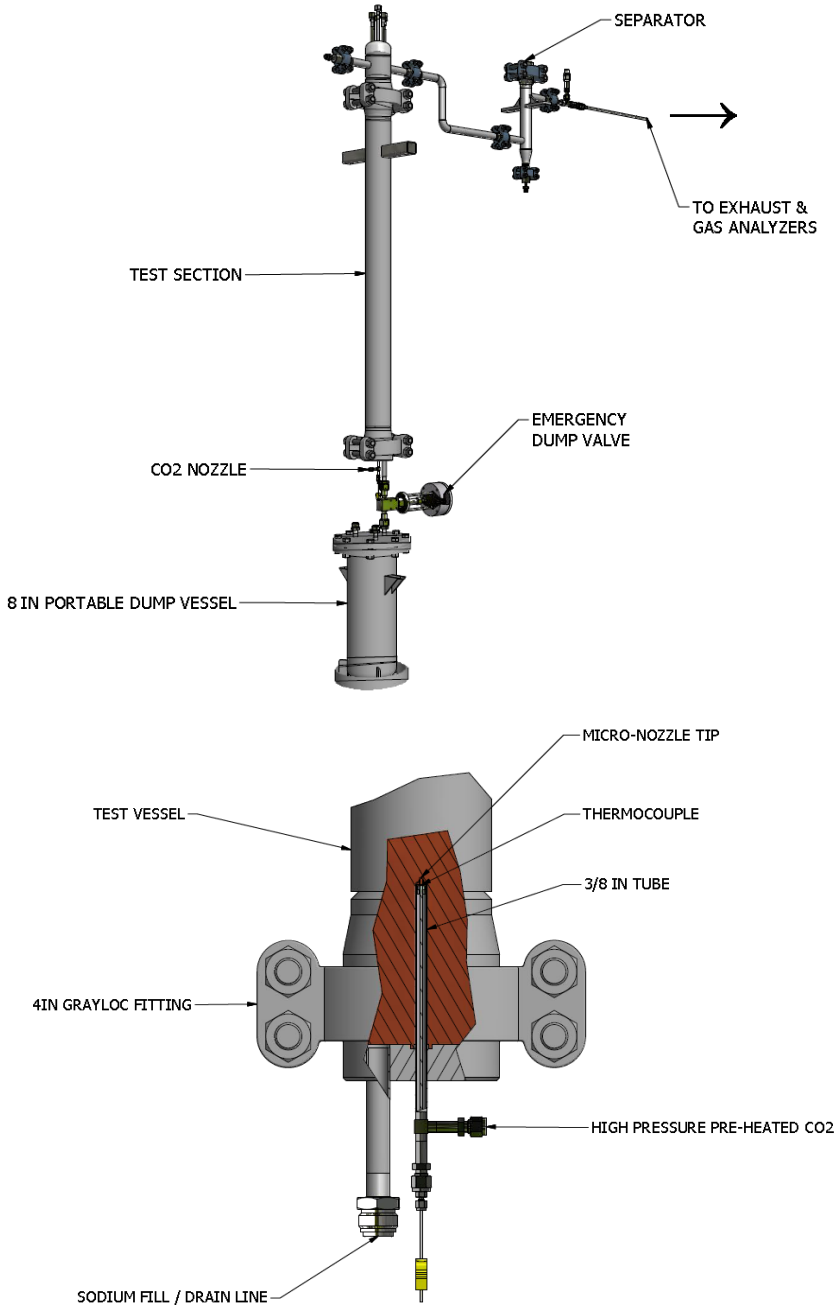

FIG. 2. Views of the SNAKE facility

Parameters table

Coolant inventory	Sodium, up to 9.5 L / 8.5 kg
Power	n/a
Test sections	
TS #1	*Characteristic dimensions* Sodium vessel is 100 mm diameter and up to 1.0 meters tall. Injection nozzle typically around 100 µm in diameter
	Static/dynamic experiment Dynamic
	Temperature range in the test section (Delta T) 150-538 C
	Operating pressure and design pressure Sodium test vessel rated to 31.0 bar at 538 C. Gas system rated to 200 bar at 538 C.
	Flow range (mass, velocity, etc.) Sodium is static but could add electromagnetic pumps for flow. Gas injection is around 10 slpm.
Coolant chemistry measurement and control (active or not, measured parameters)	No coolant chemistry measurement or active control. Clean, nuclear certified sodium is typically loaded before each experiment into clean test sections
Instrumentation	• Flow meters • Thermocouples at nozzle tip, near nozzle outlet in sodium, and throughout system • Distributed fiber optic temperature sensors near nozzle • Mass spectrometer for exhaust gases • MSA Chemgard Infrared Thermal Acoustic gas analyzer • Gas pressure transmitters

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

A series of sodium-CO2 interaction experiments were carried out in the SNAKE (S-CO2 Na Kinetics Experiment) experiment. These tests successfully injected supercritical carbon dioxide into a pool of sodium through a 64 µm diameter nozzle. A reaction between the CO2 and sodium was detected. The extent of this reaction was unexpected since the initial sodium temperature was 145 ˚C, a temperature range where previous researchers have detected little or no chemical reaction between these species. The important difference between the SNAKE experiment and previous research is that the SNAKE geometry and conditions promote high-interfacial area and mixing between the CO2 and sodium. These characteristics could be very important in promoting accelerated chemical reactions and will be studied further as the SNAKE test matrix is carried out.

Approximately 325 standard liters of CO2 were injected into a 45 cm (15 inch) high column of sodium at a nominal temperature of 150 ˚C over the course of 3 hours. The inlet CO2 pressure was gradually increased from 3 MPa to 11 MPa over these three hours in order to study the impact of pressure and flowrate on the sodium-CO2 interactions. For the first time in SNAKE, chemical reactions between the sodium and CO2 were observed. Sodium temperature increased from 150 ˚C to nearly 270 ˚C over the course of the experiments. Production of carbon monoxide was clearly detected, with up to 0.3 percent of the injected CO2 converted to CO over the course of the experiments. A significant amount of CO2 was converted into solids, approximately 37 percent. This reaction percentage is considered to be high given the sodium temperature of this experiment. It is possible that one or more mass flowmeters are out of calibration which would explain the surprisingly high conversion ratio. However, significant quantities of solid materials have been generated inside the test vessel and were observed using an inspection video camera. The reaction product particulates were removed, sampled, mounted, and analyzed via several chemical techniques. Sodium carbonate, and sodium oxide were clearly produced. No sodium hydroxide was detected which confirms that no substantial water or oxide was injected along with the carbon. Energy-dispersive X-ray spectroscopy (EDX) confirms that the only observed elements in all samples were sodium, oxygen, and carbon. An unidentified black substance was observed that dissolves in water so was not elemental carbon. Further investigations into this substance continue.

PLANNED EXPERIMENTS (including time schedule)

A number of experiments studying the injection of high pressure CO2 into sodium are planned to continue through September 2015. A wide range of conditions will be tested including pressures from 9 to 20 bars, sodium temperatures from 250-500 C, and sodium column heights above the injection nozzle from 10-80 cm.

TRAINING ACTIVITIES

N/a

REFERENCES (*specification of availability and language*)

All references are in English and available by request from Argonne.

1. FARMER M.T., KILSDONK D.J., SIENICKI J.J., GRANDY C., “Design of a Test Facility to Investigate Fundamental Na-CO_2 Interactions in Compact Heat Exchangers,” ANL-GENIV-164, (2010).
2. GERARDI C., FARMER M.T., KILSDONK D.J., SIENICKI J.J., GRANDY C., “Fundamental Na-CO_2 Interactions in Compact Heat Exchangers Experiment (SNAKE): Fiscal Year 2011 Status Update,” ANL-ARC-199, (2011).

3. GERARDI C., FARMER M.T., KILSDONK D.J., SIENICKI J.J., GRANDY C., "Na-CO_2 Interactions Experiment (SNAKE): Fiscal Year 2012 Update on Facility Assembly and Sodium Loading," ANL-ARC-230, (2012a).
4. GERARDI C., FARMER M.T., KILSDONK D.J., AESCHLIMANN R., SIENICKI J.J., GRANDY C., "Report on the Initial Fundamental Sodium-CO_2 Interaction Experiment," ANL-ARC-251, (2012b).
5. GERARDI C., SIENICKI J.J., MOISSEYTSEV A., FARMER M.T., GRANDY C., "Test Matrix for the Fundamental Sodium-CO_2 Interaction Experiment (SNAKE)," ANL-SMR-2, (2013).
6. GERARDI C., BREMER N., AESCHLIMANN R., SIENICKI J.J., GRANDY C., "Description of the First Observed Sodium-CO2 Reactions in the Sodium-CO2 Interaction Experiment (SNAKE)," ANL-SMR-7, (2013).