ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

ANU's high-temperature sodium laboratory

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The Australian National University (ANU) has developed a high-temperature sodium laboratory designed for operation at temperatures up to 850°C (Figures 1 and 2). The primary test apparatus is a liquid sodium loop, which can be operated either at constant temperature or in a heating/cooling mode with 15 kW_{th} capacity. An extension to this loop allows operation in boiling mode with 3 kW_{th} capacity.

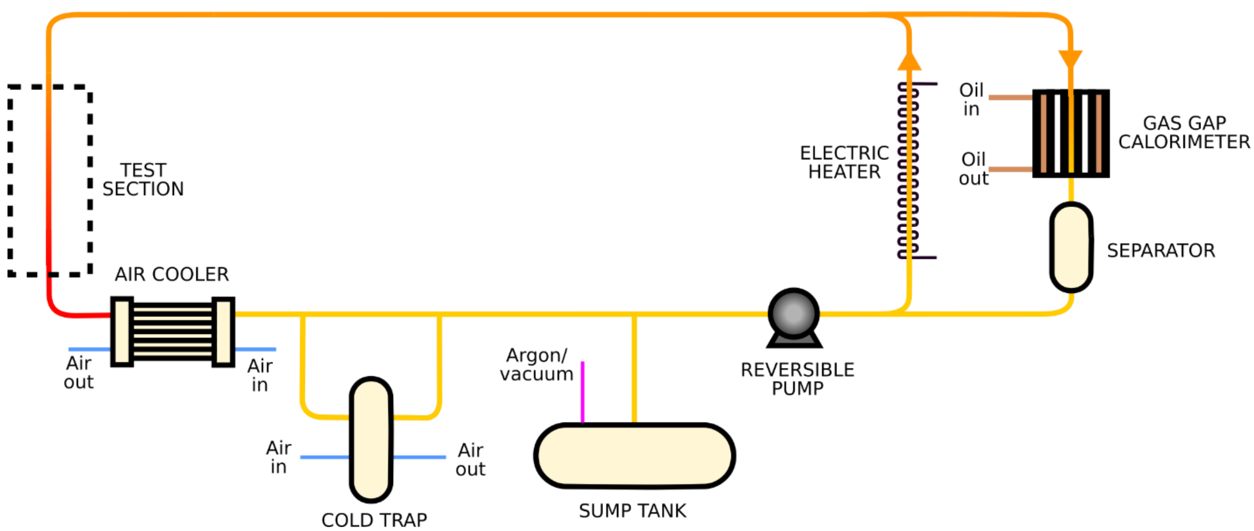

Figure 1. Process flow diagram for ANU sodium laboratory

Sodium Laboratory

The sodium laboratory is housed in a secure-access room adjacent to the 45 kW_e High-Flux Solar Simulator (HFSS) (Bader et al., 2015) at the Solar Thermal facilities located in the Craig Building on campus at ANU. The laboratory is a water-free area, with no sprinklers, and process cooling provided by air and oil loops rather than water. The fans and chillers are located in an adjacent plant room to minimise noise. In case of a leak and fire, the test apparatus sits on a stainless steel spill pan, and the room has a dedicated exhaust with an electrostatic precipitator to filter smoke. Equipment monitoring and control is via a National Instruments PLC with a LabVIEW interface.

Liquid sodium loop

The liquid sodium loop was developed in support of the Australian Solar Thermal Research Institute (ASTRI) program for testing components of a concentrating solar power (CSP) system configured around the supercritical CO_2 Brayton cycle operating with inlet temperature 700°C, and hence is designed for testing components at even higher temperatures, up to around 750-800°C. Component tests planned over the next two years include in the receiver subsystem (e.g. under controlled high-flux conditions in the HFSS), storage subsystem, including with both phase change and sensible storage materials, and corrosion tests of various different metal containment materials under both isothermal and variable temperature flowing conditions. A bespoke pump based on air-cooled permanant magnets allows operation in a constant temperature mode at the upper temperature. However, to emulate

Figure 2. Assembly drawing of the ANU sodium laboratory from front (left) and back (right)

operation of a CSP plant, for example, charging or discharging storage, or operating a solar receiver in the test area, the loop can employ either electric heating (3kW$_e$) or air cooling (a 15kW$_{th}$ shell-and-tube heat exchanger) to control temperaure zones. A calibrated flow meter that uses (uncooled) permanent magnets can be used up to 500°C. In certain modes of operation, the electric heaters will be used to trim inlet temperature. The sump tank can contain the entire sodium inventory (~9L), and is kept cold (solid) when not in use. The loop is assembled from 16mm OD Inconel 625 tubes, heat traced, and insulated with an inner layer of microporous insulation and outer layer of mineral fibre insulation. An argon/vacuum system blankets the loop and controls pressure up to 1.3bara. Purging, filling, and draining operations are via the argon/vacuum network. In the event of power failure or emergency, the loop drains sodium by gravity to the sump tank. The cold trap is designed to maintain sodium purity levels at around 1 ppm oxygen.

Boiling sodium extension

In support of an ARC Linkage project to investigate sodium boiling flows, an extension to the loop has been implemented. In boiling flow, the entire loop is at constant temperature, which is controlled by a device known as a gas-gap calorimeter (Moreno and Andraka, 1989). This is an oil-cooled heat exchanger, where the heat transfer rate is varied by varying the ratio of two gases (argon and helium) in a small gap located between the condensing sodium and the oil. Liquid sodium is pumped from the bottom of a separator in a reverse pumping mode to a sodium boiler located in the test area.

Conclusion

Although there is much previous experience globally with sodium test loops, the authors believe this facility is unique in its very high-temperature capability. The sodium laboratory is under final assembly and commissioning, and is planned to be ready for use from November 2019.

Acknowledgement

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References

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Moreno, J.B., Andraka, C.E., 1989, ‘Test results from bench-scale sodium-pool-boiler solar receiver‘, Sandia Report, SAND89-0899