Sodium Handling and Chemical Compatibility for Active Cooling of Fusion Components

Jocelyn Pellegrino[1], Dr. Carlos Rpmero-Talamás[2], and Ethan Bowers[2]

[1]Department of Physics, Morgan State University, Baltimore MD 21251, and [2]Fusion Energy Sciences Laboratory, University of Maryland, Baltimore County, Baltimore MD 21250

Background

Fusion components experience extreme heat fluxes and require coolants capable of rapid efficient heat removal. Liquid sodium has been previously used as a coolant in fusion due to its:

- High thermal conductivity
- Very low viscosity
- Wide liquid operating range
- Fast thermal response

These properties enable compact heat exchangers and efficient high-heat flux removal.

Research Questions

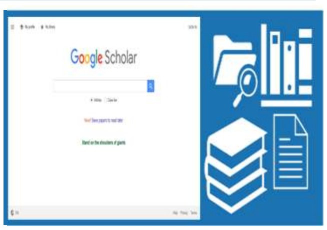
Having pre-established how the lab will be using liquid sodium as a coolant the remaining questions are as follows:

- ❑ What are the major safety concerns?
- ❑ Where do we buy it and how do we ship it?
- ❑ How do we store it?
- ❑ Is it radioactive and what licenses are required?
- ❑ What is its chemical/thermo-physical properties?
- ❑ What materials are compatible with it?
- ❑ What steps should the lab take when ordering the material?

From these questions a literature review was created on liquid sodium and a flow chart on its percurrent.

Methods

1. Collect documents related to liquid Na.
2. Check credibility of documents.
3. Gather information relating to research questions.
4. Write literature review on the gathered information.
5. Find procurement of sodium.
6. Create flow chart of percurrent steps.
7. (Time permitted) Design a way to hold the sodium in its liquid state/ design a way to eject liquid sodium into a vacuum.



Acknowledgments

This work is made possible by Maryland Space Grans Consortium.

Key Findings (Results)

Chemical Reactivity Information

Sodium is highly reactive with:

- Oxygen: forms oxides though an exothermic reaction
- Water: violent reaction → NaOH + H_2 (hydrogen ignition possible)
- Sodium is also reactive to alcohol and liquid ammonia. Which is why in the case of a sodium fire dry powders or inert gas must be used as a fire suppressant
- Halogens: explosive reactions

Sodium Fires

3 types of sodium fires:

- Sodium "air" pool; when sodium leaks and forms a pool. The pool ignites via exothermic oxidation.
- Sodium spray increases flammability due to greater surface area and ignites via exothermic oxidation.
- Sodium & water reaction fires; contact with water generates hydrogen fires and potential explosions

Thermo-physical properties of Sodium

- Melting point: 97.8 °C
- Boiling point: 881 °C
- Solid density at 20 °C: ~0.97 g/cm^3
- Liquid density decreases linearly with temperature
- Very low viscosity; decreases with temperature.
- Surface tension decreases with temperature

Storage

Solid-state sodium is stored using an **argon** blanket

Steel drums (280–440 lb)

Large tank cars (~80,000 lb) for industrial quantities

Licensing

No license required for non-radioactive sodium

Activated sodium (Na-24) requires NRC + state licensing

Transportation

Bricks or cast solids in sealed containers

Drums that double as melt pots

Procurement

Available from suppliers (e.g., Sigma-Aldrich)

Sold in various sizes and purities

Closing Remarks

Based on the found information the following flow chart is how I would recommend acquiring liquid sodium:

1. Define purpose
2. Determine quantity
3. Check licensing requirements
4. Identify supplier
5. Verify purity
6. Place order
7. Prepare inert storage
8. Prepare melting setup
9. Receive shipment
10. Store under argon
11. Begin system use

Bibliography

[1] Benedict, C. F. (Ed.). (1955). Liquid metals handbook: Sodium (NaK) supplement. U.S. Bureau of Mines, U.S. Department of the Interior.

[2] Natesan, Krishnamurti, Li, Meimei, Momozaki, Yoichi, & Rink, David L. (2009). Sodium Compatibility of Advanced Materials.

[3]Taylor, N., Merrill, B., Cadwallader, L., Di Pace, L., El-Guebaly, L., Humrickhouse, P., Panayotov, D., Pinna, T., Porfiri, M.-T., & Reyes, S. (2017). Materials-related issues in the safety and licensing of nuclear fusion facilities. Nuclear Fusion, 57(9), 092003.

[4] Brehm, W. F. (1978). Materials compatibility in liquid sodium . Hanford Engineering Development Laboratory. (HEDL SA 1559; CONF 781071 2).

[5] Foust, O. J. (1978). Sodium–NaK engineering handbook: Volume III. Sodium systems, safety, handling, and instrumentation (TID 28754). U.S. Department of Energy.

[6] Pozzo, M., Desjarlais, M. P., & Alfè, D. (2011). *Electrical and thermal conductivity of liquid sodium from first-principles calculations*. **Physical Review B, 84**, 054203

[7] Fink, J. K., & Leibowitz, L. (1995). *Thermodynamic and transport properties of sodium liquid and vapor* (ANL/RE-95/2; DE95016401). Argonne National Laboratory