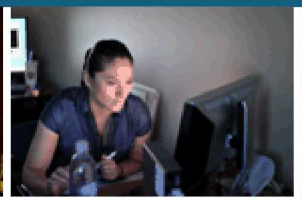
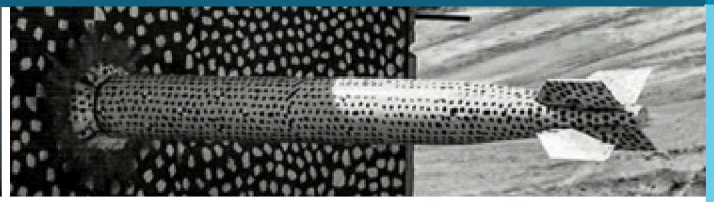
SAND2020-9945C

Permitting for a Gen 3 Pilot-Scale Sodium and Molten Salt System





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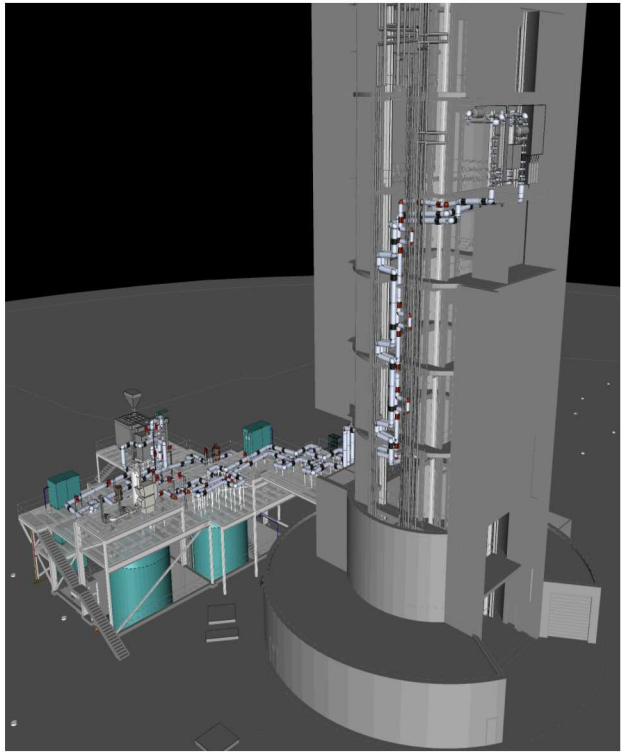
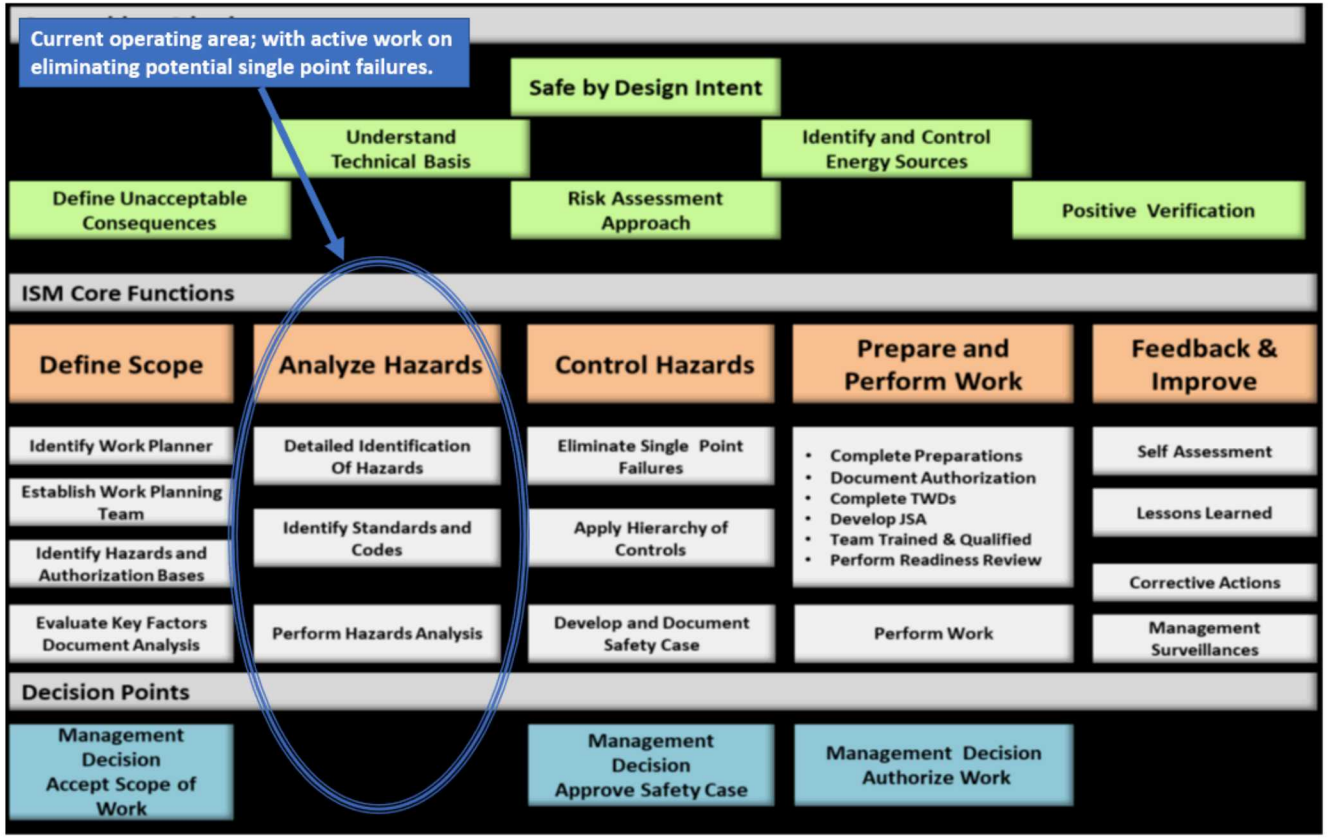
Gen 3 Pilot-Scale Pathway

- A Generation 3 liquid-pathway, pilot-scale sodium and molten chloride salt concentrated solar power (CSP) system is in development at Sandia National Laboratories (SNL).
- The project will be developed at SNL's National Solar Thermal Test Facility (NSTTF), residing on U.S. Kirtland Air Force Base (KAFB).
- The 2 MW_{th} system will consist of a sodium receiver in conjunction with a ternary chloride salt loop for up to 6 hours of thermal energy storage (TES). The TES is connected to an sCO2 power block.



ES&H WPC Process

- Work Planning & Controls (WPC) – ES&H hazard identification and mitigation.
  - WPC – Intent is to de-risk a project to an acceptable level of risk.
  - SNL risk management to avoid unacceptable consequences.
- Permitting and ES&H WPC are on track to date.
- SNL WPC Integrated Safety Management (ISM) process
  - For defining, analyzing & controlling project hazards.



Permitting

- Several permitting requirements are necessary to proceed with pilot-scale construction, pertaining to both the DOE and the U.S. Air Force.
- AF813 forms are a requirement for environment and hazard analysis.
- SNL NEPA controls include Air Quality Permits, Hazwaste stream & Stormwater requirements, and biological survey requirements.
- NFPA code requirements must be met including adherence to NFPA requirements (e.g. NFPA 400), Life Safety Systems Analysis, and Fire Hazard Analysis
- Primary Health Screening (PHS) is the primary beneficiary from staged sodium fires. The risks of sodium fires must be demonstrated for proper NFPA hazard analysis.

NEPA Additional Requirements

- Air Quality Requirements
  - Fugitive Dust Control Permit required prior to operations start.
  - Air Quality Control ES&H application with SNL & KAFB.

- Waste Stream & Stormwater Requirements
  - National Pollution Elimination Discharge System (NPDES) Construction General Permit (CGP) – Stormwater run-off.
    - For National Laboratories - requirements for waste removal from a project site.
      - Waste disposal description reports (WDDR) tool based on Safety Data Sheet (SDS).
    - Waste-related items: Salt sludge, waste construction debris, hazardous waste, emissions quantities, etc.
      - Managed in accordance with SNL Env. Compliance Coord. (ECC) & SNL Waste disposal program.

- Biological Requirements
  - Bio Survey required 3 wks. before project during breeding season (March 1- September 15)
  - Ecological open trenching/Hole excavation mitigation.
  - Notification of any bird mortalities to Ecology Program.

Purpose of Sodium Fires

- The Gen-3 project requires extensive permitting to ensure code and environmental safety & health (ES&H) compliance.
- In order to understand risks and hazard mitigation for permitting, a series of staged sodium fires has been conducted.
- The staged fires demonstrated the unique risks of molten sodium, mitigation practices, and the repeatability of data from previous sodium studies, all for ease of permitting.
- The fires also served as demonstrations to the KAFB Fire Departments and SNL Emergency Management.

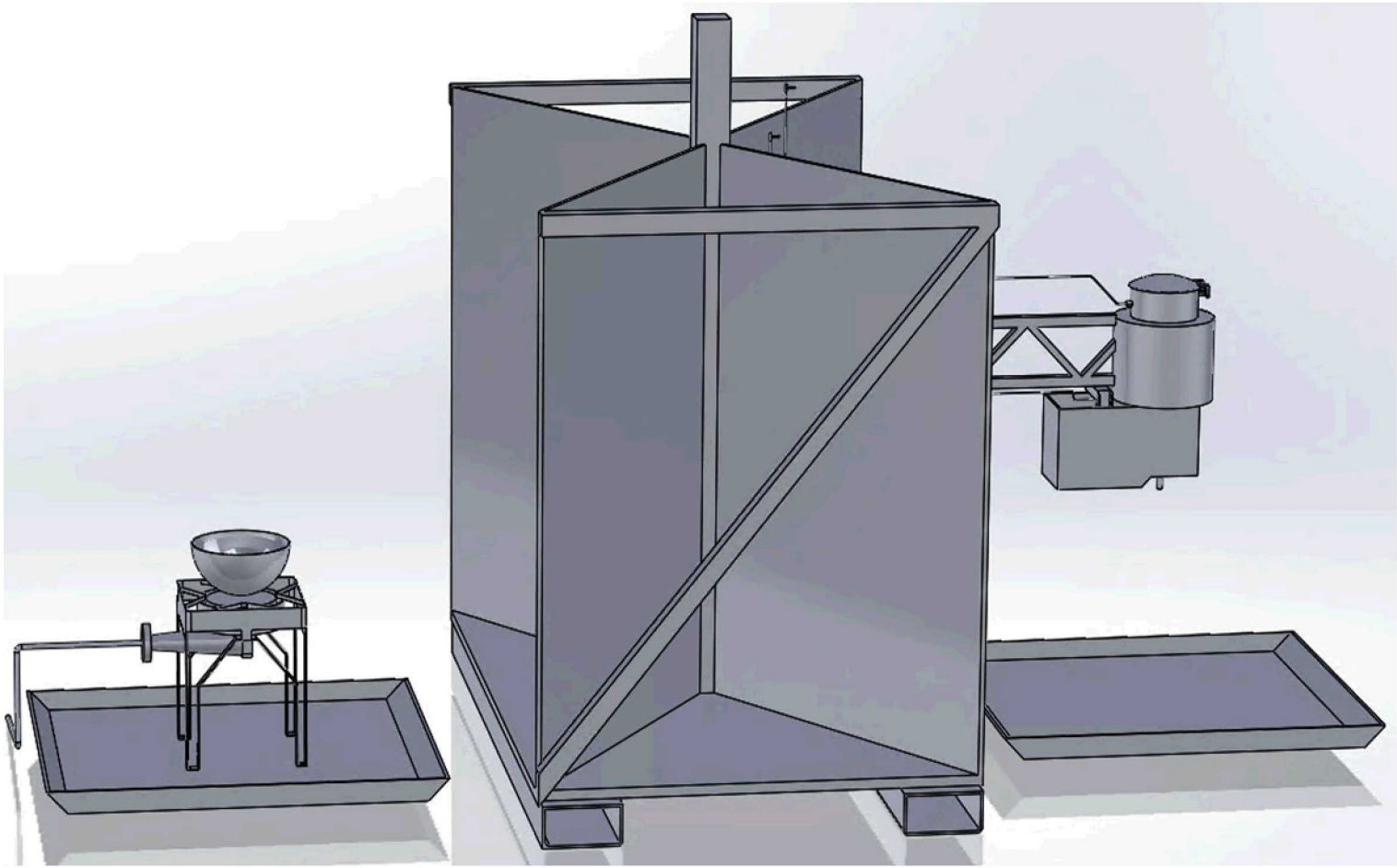
Sodium Tests Conducted

Test Date	Test #	Fire Type	Target Sodium Mass [kg]	Target Temperature (Celsius)	Fire Extinguishing Method	PPE	Instrumentation
Thurs, June 18	Shakedown A	Pool Fire	0.05	150	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Mon, June 22	Shakedown B	Pool Fire	0.05	150	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Mon - June 22	Shakedown C	Pool Fire	0.50	150	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Mon - June 22	Shakedown D	Pool Fire	1.00	500	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Mon - June 22	Shakedown I	Pool Fire with Concrete	1.00	500	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Tues- June 23	1	Pool Fire	2.00	500	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Tues- June 23	2	Pool Fire with Concrete	2.00	500	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Weds - June 24	3	Spray Fire	0.50	300	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity
Thurs - June 25	4	Solid Sodium Cutting	1.00	Room Temp	N/A	Safety Goggles, Chemical Handling Gloves	High-Speed Cameras, TCs, IR, Air Humidity
Thurs - June 25	5	Spray Fire with Concrete	2.00	500	Soda Ash	Alkali Metal "Space Suit" - Hazard Level B PPE	High-Speed Cameras, TCs, IR, Air Humidity

- Two variants of fires were staged, pool and spray fires.
- 9 fires were staged at varying temperature and sodium sample size.
- Fires were staged at a SNL explosive test pad, with all operations conducted remotely from within a bunker.

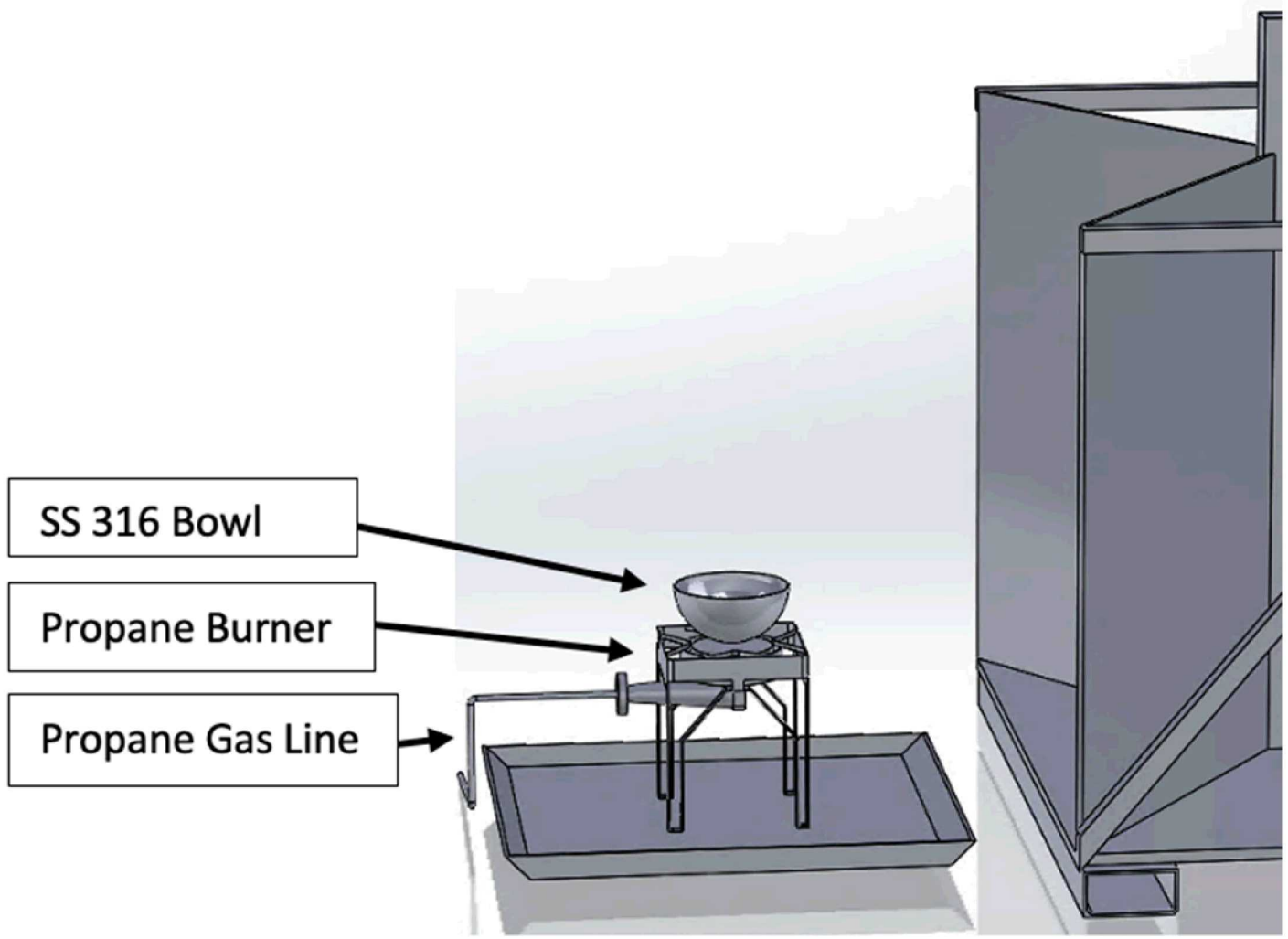
Test Rig

- For safe, remote conduction of the fire variants, a test rig was developed at the NSTTF allowing for both spray and pool fires.
- The test rig is divided in half with a system for pool fires on the left and a system for spray fires on the right.



Pool Fire Test Rig

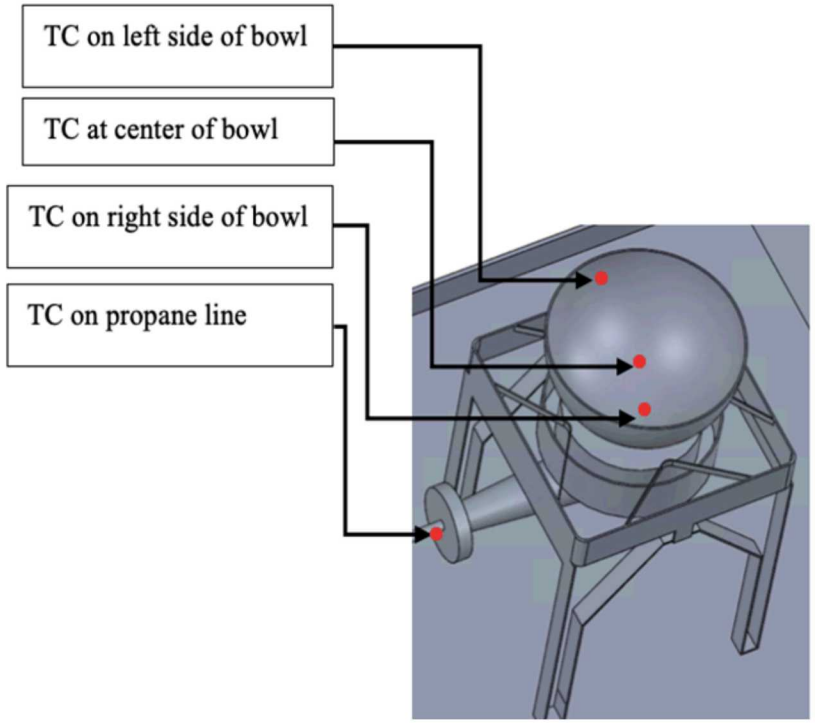
- Pool fires were staged using a propane burner, a 316 S.S. bowl, and a catch pan. Thermocouples were placed on the walls and center of the bowl.
- Desired quantities of sodium were cut, weighed, and placed in the bowl. Concrete was added to the bowl for certain tests.
- The bowl was centered on the propane burner, which was ignited and used to melt the sodium into a thick pool. After ignition, the molten sodium was left in the bowl to completely react out.

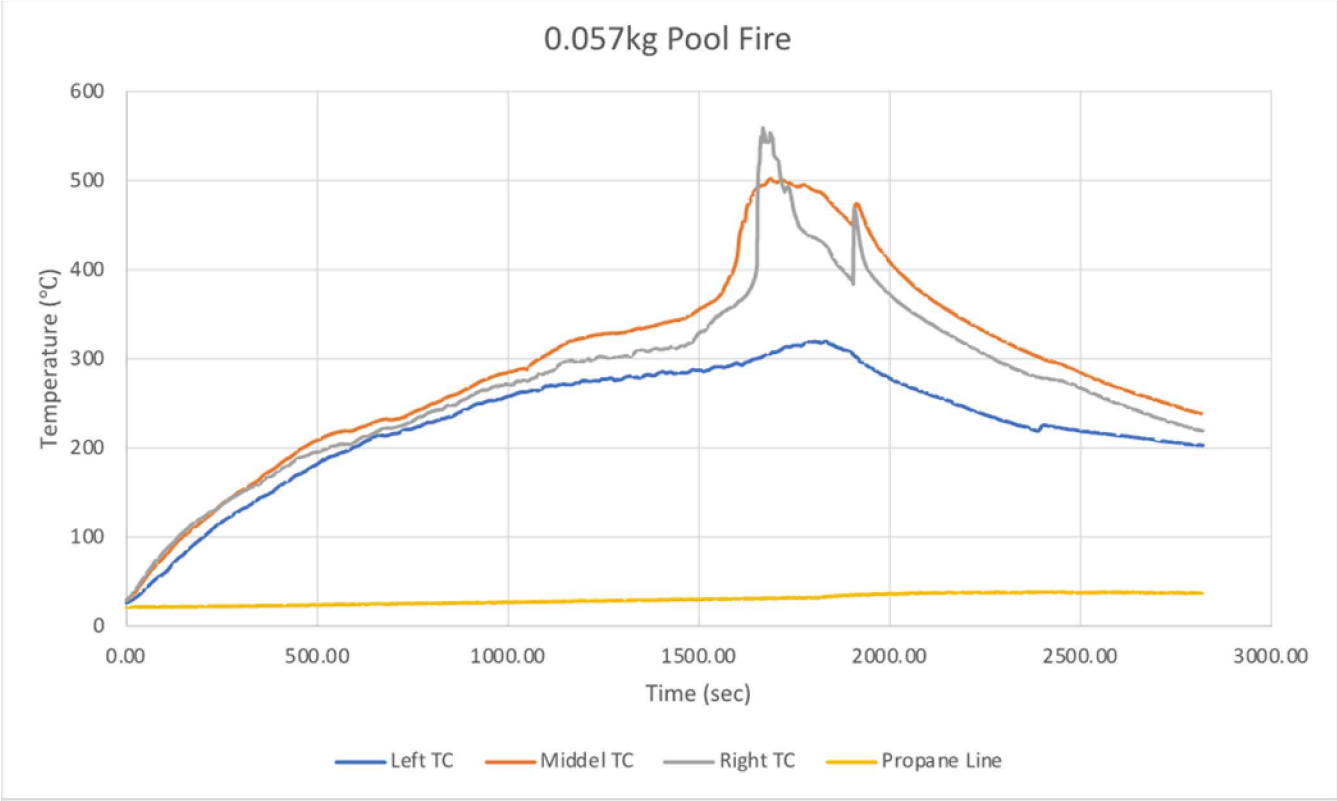


2.0kg Pool Fire with Concrete

0.057kg Pool Fire Data

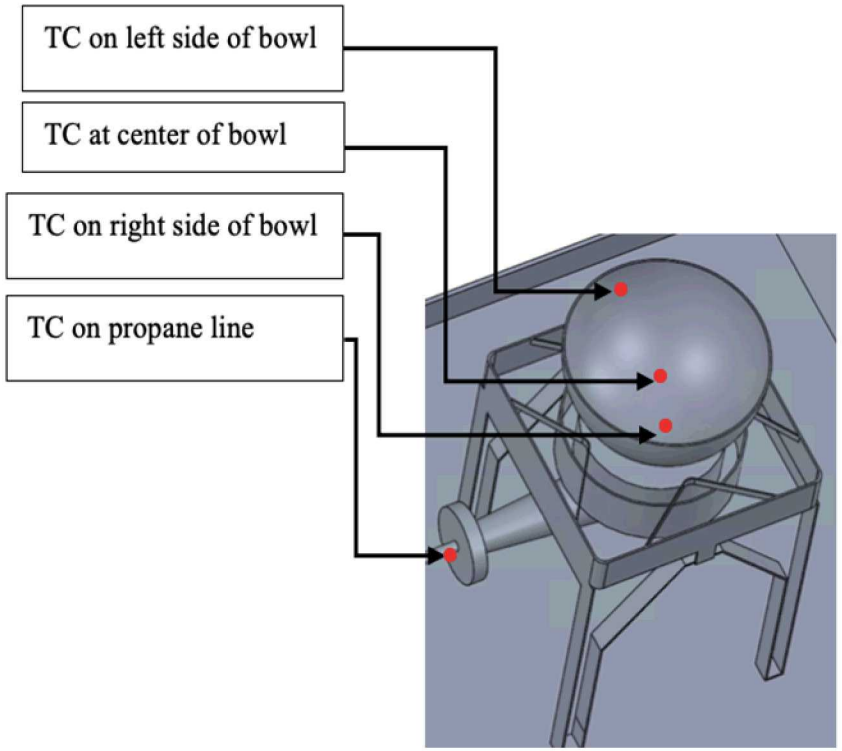
- Three TC's placed at bottom of bowl where sodium was placed as blocks and melted non-uniformly.
- Relatively smooth temperature increase with a large excursion during ignition.

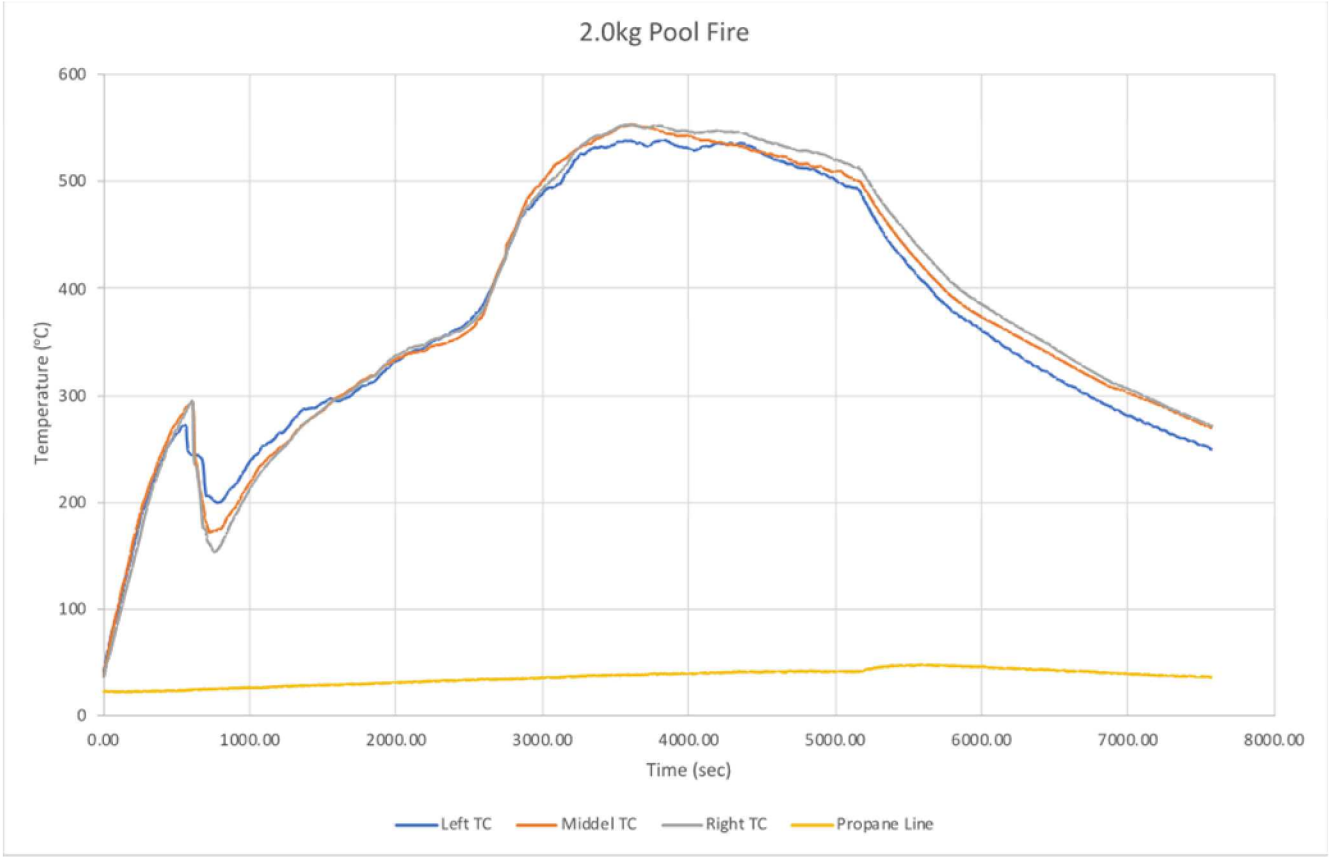




2.0kg Pool Fire Data

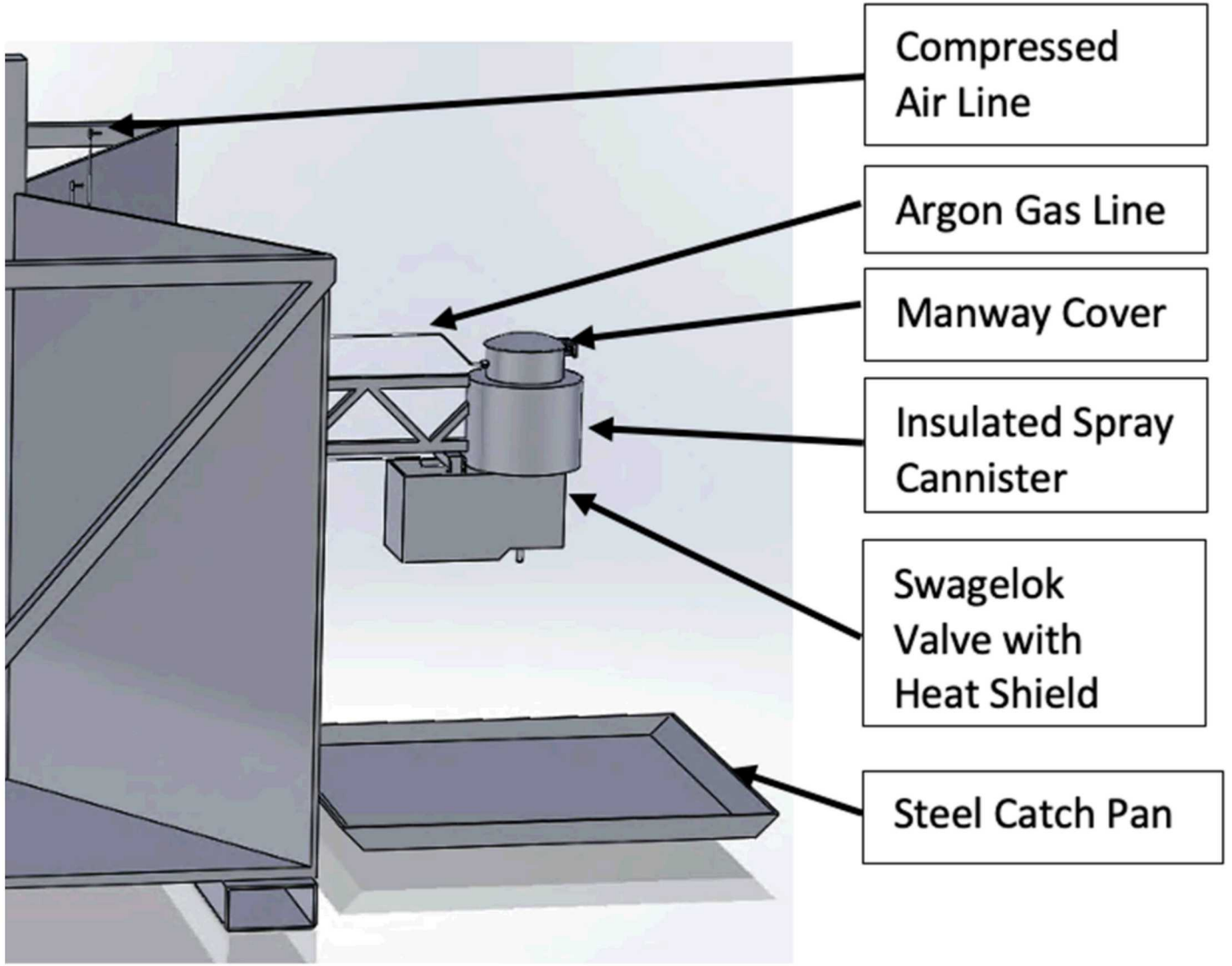
- Larger sodium blocks facilitated non-uniform heating and caused an initial spike in Temps.
- Ignition was observed to be more gradual than with the smaller volume.





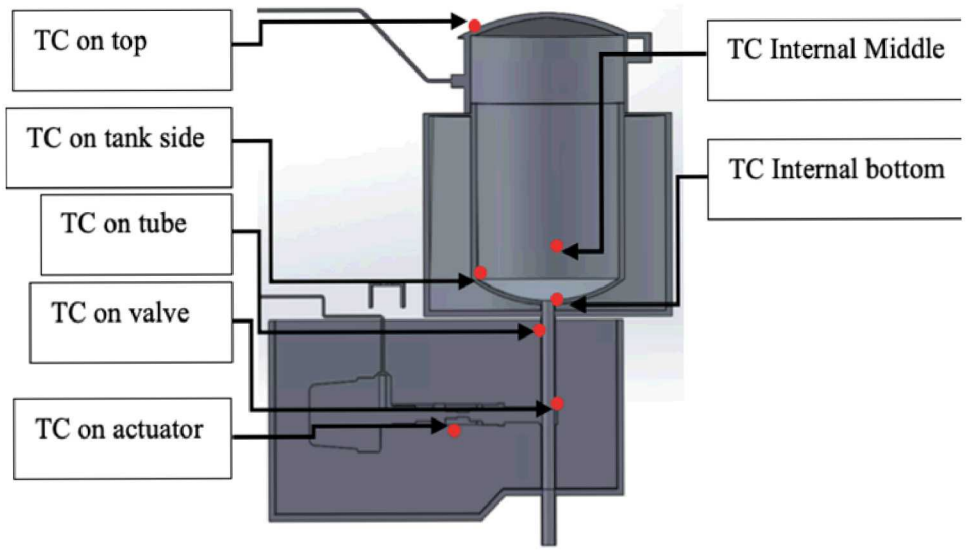
Spray Fire Test Rig

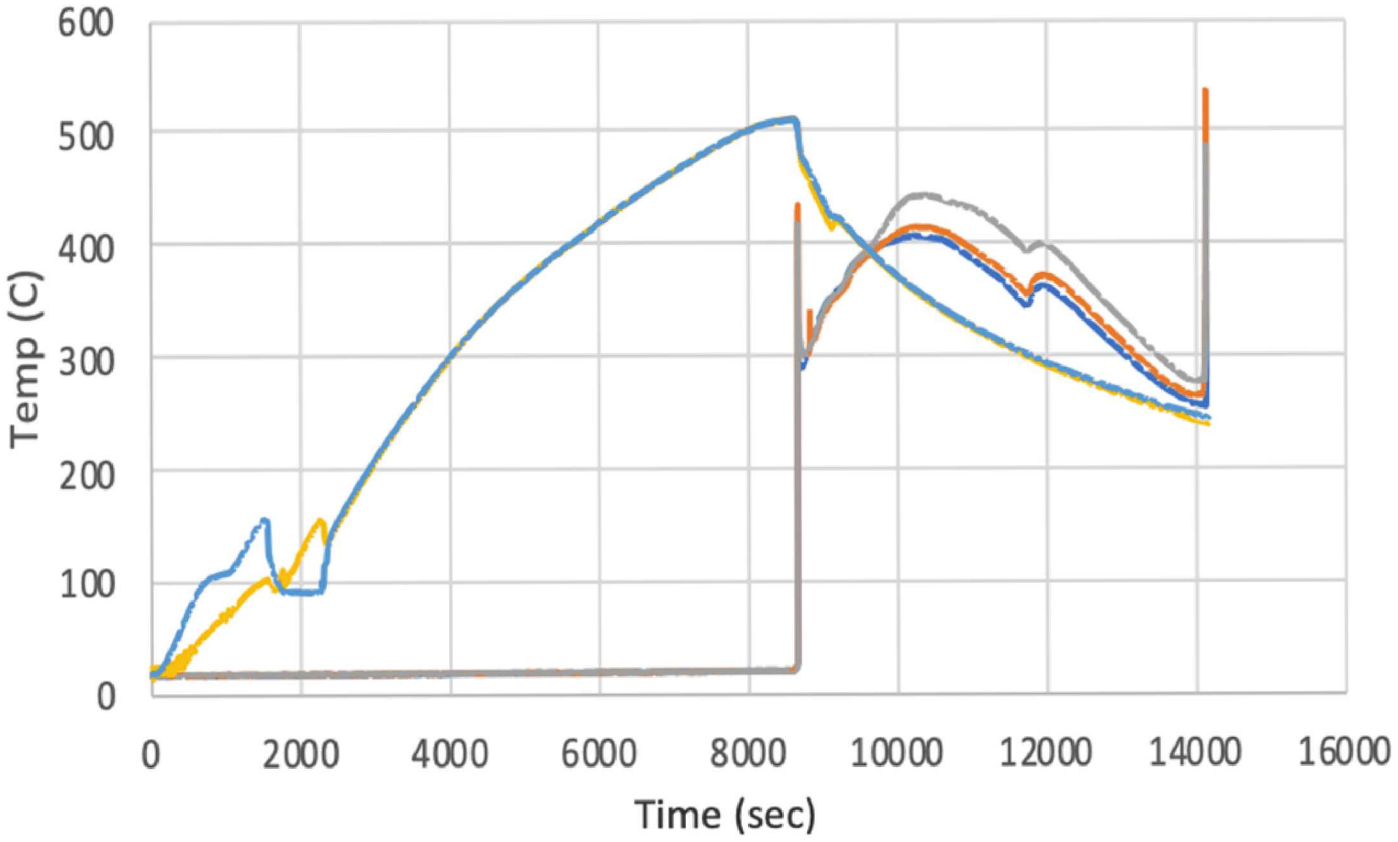
- Spray fires were simulated using a custom-built spray cannister wrapped in heat trace.
- The cannister was constructed of 304 SS pipe with a welded end plate on the bottom and a manway cover with graphite gaskets on top.
- Argon cover gas was supplied through the side wall.
- A Swagelok pneumatically-actuated bellows valve was welded to the bottom.
- Sodium samples were placed inside and heated to the desired temperature before remote triggering of the Swagelok valve to dump the sodium



2.0kg Spray Fire

Spray Fire Data





Firefighting Observations

- KAFB Fire Department personnel extinguished sodium fires by cycling the addition of soda ash & stirring it. This was repeated multiple times in 10-15minute increments.
- Fire personnel noted a crust of sodium/soda ash residue. Unreacted sodium remained within the residue, able to reignite and burn with visible popping and flames after priary testing was complete.
- The bowls of sodium and soda ash residue were dumped in a large metal container where they were completely reacted out.
- Within the container, the sodium was stirred with a metal rod and gradually sprayed with water to break up the lumps and react out remaining sodium.

Conclusions

- NEPA Flow-down requirements needed prior to construction.
  - Air Quality Requirements
  - Waste stream & stormwater requirements
  - Biological Requirements
- SNL Health & Safety (Primary Hazard Screening - PHS) – Ongoing.
- Sodium fire ignition occurred on average at approximately 317 ℃, higher than literature suggested for our conditions.
- The time for sodium fires react out increased with the initial sodium mass.
  - 2.0 kg tests required over 1.5 hours to ignite.
- The addition of concrete to the pool fires resulted in spalling and higher sodium fire temperatures (>900 ℃).
- Spray fires did not result in auto-ignition upon exposure to air unless the sodium particle size was significantly small

Acknowledgements

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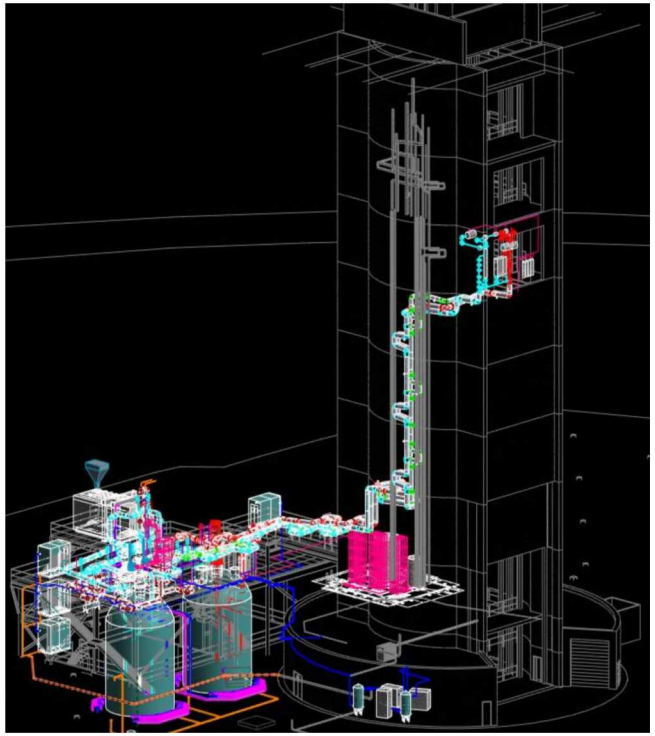
Thank you.



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