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## *Creative Engineers, Inc. – Alkali Metal Experience*

### *Background of Creative Engineers, Inc.*

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Creative Engineers, Inc. (CEI) was formed in 1996 as a chemical process engineering company specializing in alkali metals. The founders of Creative Engineers, Richard VanLieshout and Kevin Berry, have extensive experience with potassium, sodium, NaK (sodium potassium alloy), and potassium superoxide because of their work at Callery Chemical Company (now a division of BASF), where they were responsible for the engineering and operations of all alkali metal processing areas. Callery Chemical Company (now BASF) is the world's largest manufacturer of all of these products (NaK, potassium and potassium superoxide).

Seeing a need for specialized alkali metal engineering, Creative Engineers was formed. CEI's engineers have over 50 years combined experience working with NaK, sodium, potassium, and potassium superoxide as process engineers, project engineers, manufacturing managers and engineering managers.

### *Early Projects*

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#### **Enrico Fermi (EF-1), Breeder Reactor, Primary and Secondary Systems Cleanout 1997-2008**

CEI supported Detroit Edison Company in reacting sodium and NaK residues and other un-drainable pools and accumulations throughout the whole of the Enrico Fermi 1 (EF-1) breeder reactor system. EF-1, a 400 MW demonstration breeder reactor, was shut down in the early 1970's and the bulk of the primary and secondary sodium and NaK was removed in the 1970's and 1980's and taken to other sites for future potential re-use. Components of the primary and secondary systems included the defueled nuclear reactor vessel, primary and secondary reactor pumps, intermediate heat exchangers, steam generators, two large secondary cold traps, six large bulk sodium storage tanks plus a myriad of auxiliary support systems containing sodium and NaK pools and residues.

All equipment and systems have been cleaned and rendered sodium and NaK free. The large reactor vessel cleaning was completed in May 2008.

All sodium reaction/passivation work was completed using the superheated steam process except for one small NaK auxiliary system. The NaK system was processed using a water vapor nitrogen (WVN) process.

This project illustrates CEI's long time experience with sodium and NaK deactivation work in the nuclear industry, and demonstrates the effectiveness of superheated steam for processing a myriad of equipment types. One of the highlights of the extended project was CEI's processing of two large (700 to 900 gallon) cold traps using melt-drain followed by a heat soak then superheated steam processing and flooding of the vessels with water.

### **Oak Ridge Explosion NaK Cleanup      2000**

A violent explosion occurred in the Arc Melt furnace at Oak Ridge's Y-12 facility in Oak Ridge, Tennessee. The explosion resulted when a force was applied to an accumulation of spilled sodium-potassium alloy (NaK), mineral oil and potassium superoxide lying at the bottom of the furnace. Several serious injuries occurred and a DOE Type "A" investigation was completed by DOE. After the Type "A" accident investigation was completed, CEI was contracted to,



- Stabilize the existing situation after the explosion, to assure that no further explosions could occur. This included remediating existing shock-sensitive mixtures. Completion of this activity allowed portions of the area to be re-opened to resume critical production operations which had been suspended for over a year.
- Safely react all remaining NaK liquid (approximately 1,400 pounds) at the Oak Ridge site. The NaK had been used for two different systems in the Y-12 Arc Melt area.
- Safely react all remaining NaK residues in the existing tanks, piping, cold traps, vessels, pumps, heat exchangers, and other equipment from the two systems.
- Chemically decontaminate the Arc Melt area (floors, walls ceiling, overhead cranes, etc.) that were splashed with debris from the explosion. Suspected chemicals in the debris included caustic (sodium and potassium hydroxides), un-reacted NaK, mineral oil, and possibly potassium superoxide.
- Included in the equipment was a small (15 to 20 gallon) cold trap which was also cleaned. The project work was completed safely and thoroughly to the customer's satisfaction. .

CEI was nominated for "Small Business Contractor of the Year", and received the "Administrator's Award of Excellence" for this project.

The project illustrates CEI's unique experience with NaK and potassium superoxide. CEI founders were previously responsible for all NaK, potassium, and potassium superoxide manufacturing and design work while working for Callery Chemical Company (now BASF), the world's largest manufacturer of all of these

products. One of the reasons CEI was selected for this project was because of their extensive experience with NaK and potassium superoxide.

All NaK processing activities were accomplished using superheated steam.

### *Other Nuclear, DOE and NASA Alkali Metal Projects*

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CEI has extensive experience working with nuclear facilities, primarily in the area of remediating alkali metals from breeder reactor systems. In addition to the two projects listed above, Creative Engineers has worked with the following customers in a variety of deactivation and decontamination projects.

- **NASA, Marshall Space Flight Center**

- Design and fabrication of a skid-mounted alkali metal purification system
- Design and construction of a customized small superheated steam system for decontamination and deactivation of alkali metal contaminated systems



- Training of NASA technicians in safe handling of NaK.

- **FFTF Hanford Nuclear Facility**

- Reaction of remaining sodium in their CRCTA vessel, a 55K gallon reactor mock-up
- Processing and cleanup of a fully loaded sodium cold trap and its economizer
- Processing and cleanup of remaining sodium residues in two vapor traps
- Processing and cleanup of remaining NaK from a large auxiliary cooling loop
- Design of two skid mounted systems that the FFTF facility will use for the final sodium cleanup at Hanford when funding is resumed

- Design, fabrication and operation of a unique “alternating pressure/vacuum” pump for removing the last quantities of sodium from the FFTF reactor. No other company provided a viable design.



- **Oak Ridge National Laboratory**

- Full draining and destruction of the contained NaK from a SNAP nuclear reactor that was taken out of service but still loaded with nuclear fuel



- Training of ORNL workers in the safe handling of NaK.

- **Oak Ridge ETTP**                      **2006**
  - Cleanup of sodium spill and associated caustic spill from a protective shield that occurred when a previous contractor performed the work incorrectly.
  - Some sodium was treated on-site and remaining spill materials were packaged into drums for customer disposal at a later date.
- **SEFOR**                                      **2011 and 2017**
  - First contract was for sodium passivation of secondary side sodium storage tanks, equipment, piping, and other components for the experimental fast breeder reactor in West Fork, Arkansas.



- Second contract was for sodium passivation of the reactor itself, along with primary side heat exchangers, sodium storage tank, piping, and other components.
- **Argonne National Laboratory**
  - Cleanup of remaining lithium and NaK from several components.
- **UKAEA, United Kingdom**
  - Conducted demonstration tests for processing bulk and residual quantities of NaK, converting them to sodium and potassium hydroxides.

## *Commercial Alkali Metal Experience*

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CEI has completed a significant amount of work with alkali metals for non-nuclear applications. Listed below is a brief description of other projects that CEI has led or participated in.

- **Australia Magnesium Corporation**
  - Drained a large sodium heat transfer system and reacted residual quantities of sodium from a complex network of sodium contaminated piping, tanks, and heat exchangers using superheated steam processing.
- **ASARCO**
  - CEI cleaned (reacted to sodium hydroxide) the contents of a large storage tank bearing approximately 6,000 pounds of sodium metal using the superheated steam process
- **SARA, Inc.** (Scientific Applications and Research Associates Inc.)
  - Worked with SARA, Inc. to test a system to convert ocean wave energy to electricity, using magneto hydrodynamics (MHD) generators that use NaK as the working fluid.
- **Dow Chemical Company**
  - NaK was used as a catalyst to produce specialty rubbers. When the system was shut down, CEI reacted the remaining NaK and NaK residues to form hydroxides to clean out the system of tanks and pipe lines.
- **ExxonMobil Company**
  - CEI completed the final deactivation of suspected accumulation of sodium catalyst in a very large chemical storage tank.
- **Nanoscale Products (NSP)**
  - CEI has designed built feed systems for feeding sodium as a raw material for production of high value metals on the R&D scale. Recovery work often involved high temperature (1000 C) sodium removal techniques and equipment.
- **Sodium Methylate**
  - CEI has designed complete systems for making sodium methylate. Designs have included sodium handling, raw material storage, reaction system and product handling. Worldwide sodium methylate production has increased recently because of its pre-eminent use as the catalyst to make biodiesel. CEI has designed both batch and continuous processing techniques. Because of customer concerns for confidentiality, customer identities are not listed here.
- **KMR Industries**
  - Installation and operation of a unit for manufacturing sodium dispersion on CEI's plant site in New Freedom, PA.

- Creative Engineers, Inc., as part owner of KMR Industries, has operated the production facility for manufacturing sodium dispersion for over fifteen years. Sodium dispersion is primarily used in the treatment and remediation of PCBs (polychlorinated biphenyls).
- **Sodium Handling Equipment**
  - Design and manufacturing of specialty electromagnetic pumps and flow meters
  - Design and fabrication of a mobile, skid-mounted alkali metal destruction system which CEI takes to customer sites for on-site sodium and NaK treatment with superheated steam.
- **Callery Chemical Company**
  - Designed, installed and implemented a bulk NaK production facility which allowed Callery to increase the commercial supply for NaK, and improved the quality such that all NaK met high purity standards.
  - Designed, installed and implemented a system for safe deactivation of alkali metals (potassium, sodium and NaK) by reaction with steam to produce potassium and sodium hydroxides and hydrogen. The system was used to react alkali metals in vessels, drums and shipping cylinders to effect a thorough reaction of the alkali metal. This system has been safely used for 20+ years for cleanout of alkali metals with excellent reliability.
  - Upgraded an existing facility for production of potassium metal from 2,000 pounds per day to in- excess-of 10,000 pounds per day.
  - Designed installed and implemented an upgraded system to manufacture potassium superoxide using potassium as the primary raw material. The system has been used for over 20 years to produce up to 600 tons per year of potassium superoxide.
  - Redesigning the commercial potassium and NaK production facilities to eliminate > 99% of the impurities. This resulted in commercial grade potassium and NaK that met high purity standards.
  - Redesigning the NaK and potassium shipping container to make it safer, more rugged, and simpler to use. Secured a DOT exemption for use of the containers.
  - Designed, installed and implemented a large automated system for reaction of alkali metals such as potassium, sodium and NaK with alcohols for the production of alkali metal alcoholates.
- **TerraPower, LLC.**
  - CEI designed and built the complete test skid used to conducted R&D gathering data on test components to be used on the TP prototype traveling wave reactor. The system consisted of two 500 gallon sodium storage tanks, one EM pump, two EM flow switches, two mass flow meters, one plugging temperature indicator (PTI), several fine metal filters, and all of the valves

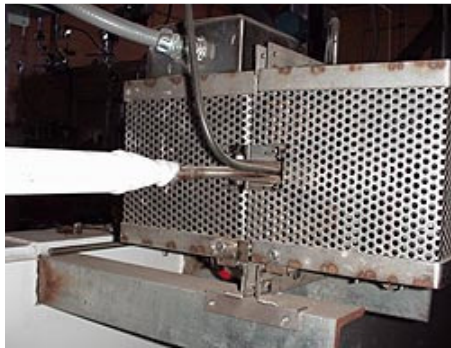
and instruments required to operate the sodium loop at temperatures in excess of 300 degrees C. Initial testing work was completed in early 2016.

### *Other CEI Experience and Capabilities*

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Creative Engineers, Inc. has expanded its core capabilities over the past several years to include other services such as,

- CEI is one of the few manufacturers in the world of electromagnetic (EM) pumps. These pumps are very unique and have no moving parts and no seals. EM pumps are used for pumping alkali metals and other fluids with very high conductivity properties.



- Design and fabrication of skid-mounted chemical handling and processing systems
- Design, fabrication and operation of pilot facilities for customers at our New Freedom PA facility
- Automation of batch and continuous chemical processes using DCS (Distributed Control Systems) and PLC's