WRPS-70260-VA
Revision 0

NUCON Thermal Oxidation System (Destruction of Tank Waste Vapors)

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-08RV14800

P.O. Box 850
Richland, Washington 99352

WRPS-70260-VA
Revision 0

NUCON Thermal Oxidation System (Destruction of Tank Waste Vapors)

E. Morrey
Washington River Protection Solutions

Date Published
April 2024

To be Presented at
ALARA Symposium

Washington River Protection Solutions
Richland, Wa.

04/25/2024

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-08RV14800

P.O. Box 850
Richland, Washington 99352

APPROVED
By Sarah Harrison at 3:04 pm, Apr 22, 2024

Release Approval Date

NUCON Thermal Oxidation System (Destruction of Tank Waste Vapors)

Eugene Morrey**, Erik Zepeda*, Travis Barnes*, Ted Wooley*, Carolyn Burns**

*Washington River Protection *Solutions*, Richland, WA 99354, **Pacific Northwest National Laboratory, Richland, WA 99354

BACKGROUND

In 2016, Savannah River National Laboratory (SRNL), under contract to Washington River Protection Solutions (WRPS), performed an assessment of candidate vapor abatement technologies relevant to the Hanford tank farms. SRNL reviewed published literature and solicited commercial vendors for candidate technologies. A workshop was convened, and potential vendors were interviewed. Evaluation criteria of the identified technologies were as follows: technical feasibility (and maturity), design features, operational considerations, secondary waste generation, safety/regulatory, and cost/schedule. Over a dozen candidate technologies were evaluated and ranked. Two technologies were identified as leading candidates, including Strobic Air and NUCON Thermal Oxidation System (TOS). The U.S. Department of Energy (DOE) and Washington River Protection Solutions agreed to demonstrate the two technologies at the Hanford Site as part of the Vapors Settlement Agreement[2].

1. Burns, H.H., M.E. Farrar, S.D. Fink, SRNL-STI-2016-00484, *2016*, Savannah River National Laboratory, Aiken, SC
2. Vapors Settlement Agreement (Hanford Challenge v. Moniz, DOE & WRPS (Vapors): EDWA 4:15-CV-05086)

NUCON THERMAL OXIDATION SYSTEM CONCEPT

The concept proposed by NUCON International was to create a mini-exhauster that removes vapor-laden air from a single-shell tank and passes it through an activated carbon bed for mercury removal and a combustion engine and exhaust catalyst for vapor destruction. A process flow diagram for the original concept is shown in Figure 1. Several of the components have changed as the design has evolved (e.g., heat exchanger was replaced with a heater and guard and polishing beds were removed), but the basic concept remains the same. The target performance of the system is to reduce vapor concentrations to less than 10% of occupational exposure limits (OELs) before being exhausted in a 20’ stack.

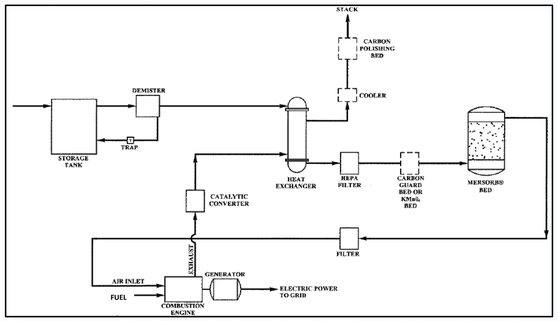

Figure 1: Process Flow Diagram for Original NUCON Thermal Oxidation System Concept

By actively ventilating the tank, a slight negative pressure should be created in the headspace, which will reduce or eliminate passive emissions from the tank (i.e., passive breather filter, fugitive emission sources). Similar to actively ventilated double-shell tanks, vapor concentrations are reduced as headspace air is removed and replaced with fresh air through the passive breather filters. The headspace concentrations eventually reach equilibrium with the underlying liquid or interstitial liquid (see Figure 2).

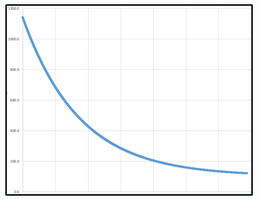

Figure 2: Predicted Vapor Concentration Decrease Over Time Upon Startup of the NUCON Thermal Oxidation System

PROOF OF CONCEPT TESTING

NUCON International continued to develop the idea and in 2017 designed, built and tested a prototype at their expense to demonstrate the technology to the DOE. The prototype unit was outfitted with a propane generator as the main vapor destruction source (see Figure 3). During the test, intake air was spiked with several chemical vapors typically found in Hanford tanks. Vapor concentrations were measured at the system inlet and outlet to determine destruction and removal efficiencies (DREs). The chemical vapors tested and their resulting DREs were as follows :

- Mercury: > 99% removal
- Ammonia: > 98% destruction
- Formaldehyde: > 96% destruction
- Furans and Hexane Mixture (furan, 2,3-dihydrofuran, 2-furan carboxyaldehyde, hexane): > 81% destruction
- Hydrocarbon Mixture (pyridine, toluene): > 99% destruction

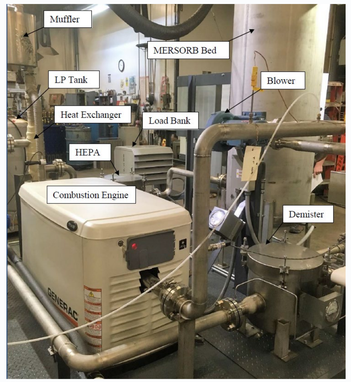

Figure 3: Proof-of-Concept Test Prototype with Propane Generator

Results from the proof-of-concept test were encouraging enough to warrant further development and testing, although some of the test conditions (concentration levels) were well in excess of Hanford tank vapors.

ENGINEERING SCALE TESTING

Upon evaluation of the technology, WRPS determined that a propane generator would not be feasible in the tank farms due to nuclear safety issues. The NUCON TOS prototype was retrofitted with a diesel generator as the vapor destruction unit. The modified prototype was then put through rigorous engineering scale testing at Pacific Northwest National Laboratory (PNNL) using vapors and concentrations that bounded conditions in the tank headspaces (see Figure 4). The chemical vapors tested and their resulting DREs were as follows:

- Acetaldehyde: > 99% destruction
- Acetonitrile: > 99% destruction
- Ammonia: > 98% destruction
- Benzene: ≈ 97% destruction
- 1,3-Butadiene: > 99% destruction
- 2,4-Dimethylpyradine: 99% destr.
- Formaldehyde: ≈ 46% destruction[3]
- Furan: > 99% destruction
- NDMA: ≈ 56% destruction
- Nitrous Oxide: ≈ 73% destruction[3]
- Propanenitrile: > 99% destruction

Figure 4: Engineering Scale Test Prototype with Diesel Generator

[3] Formaldehyde and Nitrous Oxide failed to meet 95% destruction target since they are normal constituents in diesel exhaust.

IN-FARM DEMONSTRATION TEST

A site selection study and site survey were performed to select a suitable site for demonstration of the TOS technology on a single-shell tank. Tank 241-BY-108 was selected based on the following criteria.

- 241-BY-108 is one of the more challenging tanks regarding number and concentration of chemicals of potential concern (COPCs)
- Necessary services are readably available (e.g., electric power)
- The NUCON TOS demonstration will not interfere with other work in the tank farm

Installation of the NUCON TOS technology on 241-BY-108 is intended to be temporary, sufficient to support a 6 to 8-week test. Following completion of the test and test report, the technology will be removed from the farm. Based on the temporary nature of the installation, a modular design was developed that minimizes in-farm installation activities. The NUCON TOS system includes two skids (filter skid and TOS skid) connected to existing tank farm power using above ground cable and yellow-jacket cable protection. The layout of the two skids and power cable runs near 241-BY-108 are shown in Figure 5.

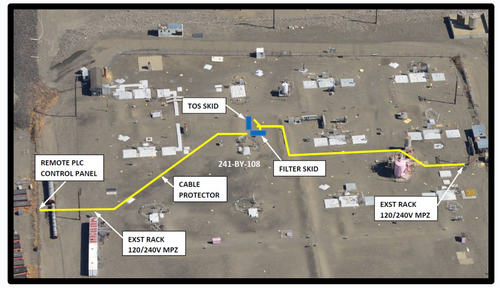

Figure 5: NUCON Thermal Oxidation System Layout in BY-Farm (skids are roughly 20’ x 8’ x 10’ each)

One of the main objectives of the on-site demonstration is to determine the DRE performance of the TOS technology on actual tank waste vapors. To perform this analysis, special sampling cabinets will be fabricated and installed on the filter skid (see Figure 6). Sorption tube samples will be collected during operation for 21 COPCs before and after the TOS system. Samples will be submitted to accredited labs for analysis using EPA approved methods.

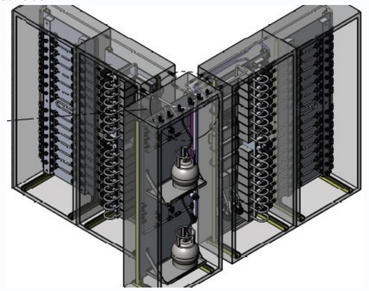

Figure 6: Sampling Cabinets for Determining Destruction and Removal Efficiencies

NUCON THERMAL OXIDATION SYSTEM DESIGN FOR 241-BY-108

A detailed design was completed for the NUCON TOS system to be connected to 241-BY-108 (see Figure 7 for 3-D rendering). The equipment is distributed between the filter and TOS skids. The filter skid will be attached to a 241-BY-108 riser and will include a demister, heater, pre-filter two HEPA filters, a radioactive particulate monitoring system and DRE sampling cabinets. The TOS skid will include a booster blower, MERSORB® carbon bed, inert gas purge system, fresh air bypass for startup, cooler, diesel generator, engine load bank, oxidation catalyst, diesel particulate filter and 20’ tall exhaust stack.

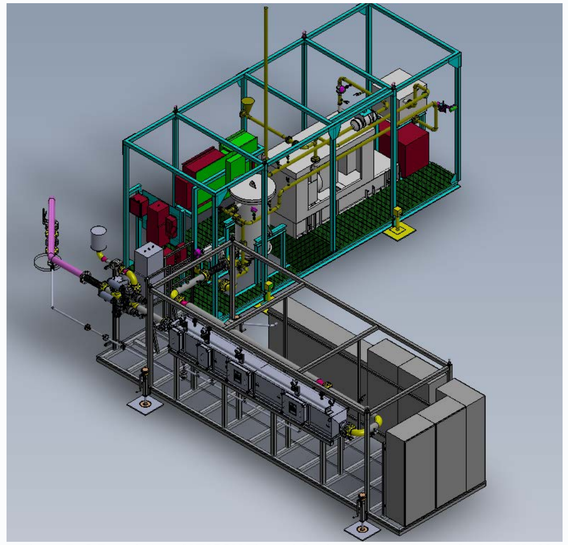

Figure 7: 3-D rendering of NUCON Thermal Oxidation System Design for 241-BY-108

NUCON THERMAL OXIDATION SYSTEM TEST ON 241-BY-108

The NUCON TOS test on 241-BY-108 is planned for summer of 2026. The primary objective of the test is to evaluate the efficacy of the TOS vapor treatment on an actual Hanford single-shell tank involving a complex vapor mixture in an operational tank farm environment. The test will also satisfy commitments contained in the Vapors Settlement Agreement[2]. Performance targets for the NUCON TOS technology include:

- 95% destruction or removal of each COPC
- ≤ 10% of occupational exposure limit for each COPC at point of emission
- < 500 ppm total volatile organic compounds at point of emission
- operates reliably and achieves a nominal steady-state while interacting with 241-BY-108 headspace vapors

CONTACT

For more information contact Eugene Morrey, NUCON TOS Project Manager, Chief Technology Office, Washington River Protection Solutions (WRPS), 509-376-0986, eugene_v_morrey@rl.gov