Project ID number: DEFG0797ER 14831

Project Title: **Isolation of Metals from Liquid Wastes: Reactive Scavenging by Sorbents in Turbulent Reactors**

Publication Date: Wednesday, October 24, 2001

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Number of graduate students actively involved in project: 4

Research Objective:
The objective of this work is to develop the fundamental knowledge base for the design of a broad class of high-temperature reactive capture processes to treat metals-bearing liquid waste in the DOE inventory. The major thrust is devoted to understanding phenomena that govern process performance and are critical to achieving emission specifications.

Research Progress and Implications:
In the incineration of liquid hazardous wastes, there exist "rogue" droplets (>100 μm radius) which penetrate past the flame zone and burn as isolated droplets in the postflame gasses. Mulholland et al. [1] demonstrated that these droplets can limit the overall incineration efficiency. Hence detailed knowledge of the droplet lifetimes are essential to keeping the destruction removal efficiency in excess of the 99.99% required for these wastes. The spread in trajectory endpoints of individual evaporating droplet streams of a fuel mixture injected into a hot swirling gas turbulent diffusion flame was investigated numerically. Preliminary results indicate good agreement with the measurements reported by Mulholland et al. Correlations between endpoints and initial droplet size, initial droplet velocity, inter-droplet spacing, and droplet injection angle were investigated. The model utilizes the novel One Dimensional Turbulence (ODT) model developed by Kerstein [2] for the time developing fluid velocity and temperature fields.

The One Dimensional Turbulence Model is able to sufficiently predict the mean velocity and temperature profiles of the Mulholland et al. combustor in one dimension. The ODT model can accurately predict the spread of droplet burnout points due to the random variation of the velocity/temperature field due to the high turbulence in hazardous waste incineration without the cost of doing a 3-dimensional (DNS) calculation. Improvements in the simulation over the last year have included better agreement in burnout due to initial diameter variations and initial injection angle. Also, modest improvements in the agreements of burn out due to initial velocity have been achieved. The model was still unable to reproduce the spacing/diameter variations which are recorded in Mulholland et. al. (Incorrect initial conditions are suspected to be the cause of the failure.) Simulations were also done to take note of the effects of adding a pressure drop. The effects of adding a pressure drop on the measured spread was found to be negligible.

To extend and verify the ODT model, experiments are planned to measure the movement and destruction of droplets in turbulent flows. Measurement of droplet trajectories in reactive flows requires novel optical apparatus, which has taken considerable ingenuity to design, fabricate, assemble, and test. The apparatus, designed at the University of Illinois, has now been assembled at the University of Arizona. Several key tasks have been completed in the optical diagnostics component of this project. The first task completed was the construction of vibrating orifice drop generators capable of generating monodisperse drops in the range of 300 – 700 micrometers along the axis of the thermal reactor. Another task involved the assembly of an imaging system capable of producing aberration compensated images. Drop trajectories were investigated for different drop sizes and drop spacing, as well as different flow conditions. It was found that coagulation within the drop streams increased as flow conditions became increasingly turbulent. Spatial vapor concentration maps of evaporating diesel drops within a flame sheet have been recorded in order to refine vaporization models. Concentration maps of soot have also been recorded.

1. Mulholland, J.A., Srivasta, R.K., Wendt, J.O.L., Agrawal, S.R., and Lanier, W.S., *Trajectory and Incineration of Rogue Droplets in a Turbulent Diffusion Flame*, Combust. Flame, 86: 297-310 (1991).

2. Kerstein, Alan R., *One-dimensional turbulence: Model formulation and application to homogeneous turbulence, shear flows, and buoyant stratified flows*, J. Fluid Mech. (1999)

Planned Activities:
Under the current project, experiments will continue at the University of Arizona to validate the droplet model(s) against laminar flow reactor experiments.

Information Access:
Schmidt J.R., Kerstein, A.R., and J.O.L. Wendt, *"Capturing the Spatial Variation of Burning Droplets in a Turbulent Combustor Using the One Dimensional Turbulence Model"* presented at the American Flame Research Committee 2000 AFRC International Symposium, Newport Beach, CA. September 18-21, 2000.

Schmidt J.R., Kerstein, A.R., and J.O.L. Wendt, *"Capturing the Spatial Variation of Burning Droplets in a Turbulent Combustor Using the One Dimensional Turbulence Model"* presented at the Second Joint Meeting of the US Sections of the Combustion Institute, Oakland, California, March 25-28, 2001

J. Cabalo, A. Pearlstein, J.O.L. Wendt, and A. Scheeline, "Optical Diagnostics of Reactive Metal Scavenging in Thermal Reactors" presented at the Gordon Research Conference on Laser Diagnostics in Combustion, Mount Holyoke College, South Hadley, Massachusetts, July 5, 2001.