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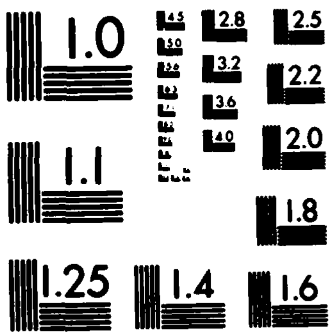
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Gun tubes, rocket and gas turbine nozzles, exit cones, thrust diverters launchers as well as electric, plasma and electromagnetic thrust device solid walls suffer erosion/corrosion and general deterioration from their working environment. This research emphasized identification and understanding of the

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FUNDAMENTAL MECHANISMS OF MULTI-PHASE FLOW EROSION/CORROSION OF SOLID SURFACES

Final Report
(For Period 1 September 1978 - 30 June 1983)

Alfred C. Buckingham   Clifford W. Price

June, 1984

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FORWARD

This report pertains to a research program conducted by the Lawrence Livermore National Laboratory under Contract No. 15812-MS (ARO MIPR 26-78, 27-80, 8-81 and 5-82) for the U.S. Army Research Office, Research Triangle Park, North Carolina, and, in part, for the U.S. Army Large Calibre Weapons Systems Laboratory, Dover, New Jersey and the U.S. Army Ballistics Research Laboratory, Aberdeen, Maryland, during the period (September, 1978 - June 30, 1983).

The technical content and research information for this final report is almost entirely self-contained in the accompanying separate document: Lawrence Livermore National Laboratory Report UCRL-53468, "November 1, 1983." However, this essential document was not printed and distributed until May, 1984, delaying the release of this final report, until this time (June, 1984).

This brief, final report is prepared to provide a summary of some findings from our previous research, a publication list, a list of contributors, a documentation and registry page, and transmsittal information for the accompanying technical report on the last unreported materials science investigations, prepared and conducted by one of us (C. W. Price).

DISCUSSION

Problem Statement

Gun tubes, rocket and gas turbine nozzles, exit cones, thrust diverters launchers as well as electric, plasma and electromagnetic thrust device solid walls suffer erosion/corrosion and general deterioration from their working environment. This research emphasized identification and understanding of the dominant fundamental mechanisms leading to surface deterioration. It was also directed to study the materials, materials properties, materials dynamics and material preparation effective for resisting this deterioration.

Summary of Important Results

Surface chemical reactions in highly transient reactive environments frequently contribute to material degradation and subsequent loss by erosion/corrosion mechanisms. We simulated these reactions with a pulsed laser system in a pressure chamber. Gaseous carburizing and nitriding reactions were studied because of their frequent occurrence in erosion/corrosion environments. Reactions in pure iron and AISI 4340 steel were characterized by secondary ion mass spectroscopy (SIMS), optical metallography, and scanning electron microscopy (SEM). Gases used for laser-pulsing included argon, methane, carbon monoxide, ammonia, and nitrogen. The effect of gas pressure also was investigated. The results demonstrate that significant amounts of the reactive species can be driven into metal surfaces if the energy of the laser pulse exceeds the threshold for surface melting to occur. Specimen response appears to be reproducibly sensitive to the environment even in the relatively short time frame of the 600-μs laser pulse. Tests also were performed on AISI 4340 steel specimens coated with tungsten as a candidate coating material.

We consistently observed strongly coupled surface physical/chemical reactions with the associated possibility of consequent rapid property changes, intergranular stress and dilation, and the onset of significant failure mechanisms in our current laser experiments.

We also examined the integrity and pulsed life-span of refractory material coatings, including interface layers of Ni (used to assist coating/substrate adherence). These interface layers apparently disperse and diffract interface micro stress wave packets which, at full strength, may lead to early coating separation and accelerate wall erosion.

Confirmation was obtained indicating that volatile gas/surface reactions exist in (at least) the $(Cl)_v/(Fe)_s$ group, and, more significantly, that these reactions can take place within time scales equivalent to or shorter than the heat pulse associated with large calibre ordnance firing. We have also initiated chemical analysis to confirm the production and alternation of gas/surface metal chemical composite layers in our long pulse laser deposition experiments. Supplemental flow experiments in our U.C. Berkeley facility generated statistical information on direct strong coupling between turbulent propellant combustion flow and additive particle loading. The combustion process as well as the transport/erosive processes are influenced directly by the additives as suggested by concomitant theoretical studies.

Propellant combustion is inherently unsteady. Rocket nozzle, gun barrel and turbine combustion flows possess either periodic, large scale (relatively low frequency) components or periodic, random small scale components. The former are associated with mean (potential) flow and development and the dimensions of the container, the latter are associated with turbulence. We experimentally and theoretically investigated some related turbulent multiphase combustion flows. We placed our emphasis on the erosive aspects of such flows and the erosion reducing influences of small (micron and below) particle additives.

We addressed the turbulent to particle (and return) interactions in free shear gas combustion. The experiments supporting our theoretical studies were conducted in lean propane flame propagation and mixing geometries. The particles introduced and mixed with the gaseous and reactant products significantly influenced: (1) the growth of the energy dissipative smaller scales and depletion of the energy in the larger production scales;

(2) dissipation at the molecular level and correspondingly enhanced near-wall mixing, kinetics and combustion; (3) reduction of the combustion and flame interaction zone; (4) reduction in solid surface heating and erosion. Mobility (gas-borne dispersal) of particles was found to be a key factor since our results indicated that particle concentrations hundreds of times more dense were needed for the same reduction in heat transfer if the particles were fixed to the wall surface as an immobile coating.

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This report is in two parts. The Technical Discussion of the last phase investigations on Material Science accompany this as a separate document:

Lawrence Livermore National Laboratory Report UCRL-53468
by C. W. Price (November 1, 1983, publication date May, 1984)

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