LA-AC-10, 116

MASTER

CONF-690601-1

MEETING ABSTRACT
OF PROPOSED PAPER FOR
AIAA FIFTH PROPULSION JOINT SPECIALIST CONFERENCE
NUCLEAR PROPULSION SESSION

"ROVER FUEL ELEMENT THERMAL STRESS
EXPERIMENTS AND ANALYSES"*

NOTICE
This report contains information of a preliminary nature and was prepared, submitted, and released under the authority of the AEC. It is not to be distributed outside the AEC and therefore does not constitute a final report. It is to be used for information only and should not be abstracted or further disclosed without the approval of the originating installation or D-14 Extension, Oak Ridge.

AUTHORS: John C. Rowley,
Group Leader
Robert G. Lawton and
William R. Prince,
Staff Members,
Group N-7
Los Alamos Scientific
Laboratory,
P. O. Box 1663
Los Alamos, New Mexico 87544

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission
A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights, or
B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.
As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

* Work Performed Under Auspices of U. S. Atomic Energy Commission

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISTRIBUTION OF THIS DOCUMENT IS LIMITED
TO AEC Offices and AEC Contractors

RECEIVED BY DTIC DEC 10 1968

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

"ROVER FUEL-ELEMENT THERMAL STRESS EXPERIMENTS AND ANALYSES"

INTRODUCTION

The fission energy (heat) by the fuel in the core element of Rover nuclear propulsion reactor is transmitted through the fuel-element matrix to the hydrogen propellant flowing through channels in the elements and is removed through convection. This heat creates temperature gradients and, consequently, induces thermal stresses in the fuel-element matrix which, if high enough, may lead to cracks or fractures (complete separation of pieces). Because even minor surface defects would expose the matrix material to the very corrosive temperature hydrogen, it is necessary that fuel elements retain their structural integrity throughout reactor operation.

This paper summarizes the progress made in a continuing program to study the power-density and thermal-stress limitations of Rover reactor fuel elements. While the initial work (discussed at the 2nd AIAA Propulsion Joint Spec. Conf. in 1965) was centered primarily on graphite fuel elements loaded with dispersed UO_2 (oxide-loaded), present work (discussed in this paper) is centered primarily on graphite elements loaded with pyrocarbon-coated UC_2 beads (bead-loaded). Work at LASL, however, was also extended to thermal-stress experiments and analyses of graphite fuel elements having increased thermal expansion and to metal carbide-carbon composite fuel elements.

EXPERIMENTAL APPROACH

The heating by fission in a reactor is simulated experimentally in the fuel-element samples by dc electrical-resistance heating. The current is passed longitudinally through ~ 14-in. long pieces cut from full-length fuel elements, and the major portion of the generated heat is removed by flowing hydrogen through the coolant channels. Thermal gradients are created primarily by this convective heat removal, but also, to some extent, by the loss of heat from the outer surface of the specimen to the cooled walls of the experimental apparatus.

Because one major objective of the fuel-element thermal stress program has been the determination of power-generation and thermal-stress limitations of fuel elements over a range of temperatures, each specimen was subjected to progressive thermal-stress loading until it fractured or cracked.

BEAD-LOADED GRAPHITE FUEL ELEMENTS

For experiments with bead-loaded specimens, the experimental procedures were changed to minimize corrosion. In earlier experiments with oxide-loaded samples, the heat, generated by a dc current, had been increased to some predetermined value and had been held at this temperature for a certain length of time or until fracture occurred. In these tests, the current was increased in short, 15- to 30-second, ramps.

Two basic types of thermal-stress perturbations were introduced. First, for specimens with two different coolant-hole diameters, the center hole was plugged, and for those having only one hole diameter, several inner holes were also plugged. The purpose was to perturb the

temperature distributions so as to create fracture-producing thermal stresses at lower heat-generation rates. Second, specimens were made with the holes purposely moved from their usual locations. Since thermal stresses are significantly affected by coolant-hole location, moving the holes was expected to cause fracture stresses at different heat-generation values.

A correlation has been established between experimental thermal-stress fracture results and thermoelastic calculations. Consequently, predictions of thermal-stress and maximum power-density limits for graphite fuel elements now have a firm experimental and theoretical basis.

INCREASED-CTE AND METAL-CARBIDE COMPOSITE FUEL ELEMENTS

Continuing efforts have been made to obtain valid thermal-stress evaluations of improved fuel elements for Rover reactor cores. One of the desired improvements was a graphite-element matrix with an increased coefficient of thermal expansion (CTE) to provide a closer match between matrix and NbC coating. (This coating protects the matrix against hydrogen corrosion.) The second attempted improvement is in the area of advancing the overall temperature capabilities of the fuel. The approach is to fabricate uranium carbide in combination with various metal carbide-graphite composites. Both the higher temperature potential and the higher corrosion resistance of such materials appear to be quite promising.

The increased CTE of the graphite, as well as the increased CTE and elastic modulus of the composites, can be expected to lower the thermal-stress resistance of these materials as compared to current fuel elements. The experimental and analytical thermal-stress evaluation program has therefore been extended to provide guidance in establishing the power-density limits of these new materials.

Parametric Isostress Curves, Experimental Conditions,
Graphite Fuel Elements

Nominal Graphite Fuel Element Property
Dependence on Temperature

Experimental Results, Graphite Fuel Elements

Thermal Stress Perturbation Experiments,
Graphite Fuel Elements

Correlation of Calculated Thermal Stress Data Vs
Temperature, Graphite Fuel Elements

Comparison of Thermal Stress Correlation With
Reactor Conditions, Graphite Fuel Elements

High-CTE Graphite Flour Thermal
Stress Results, Loaded Extrusions

High-CTE Graphite Flour Thermal
Stress Results, Unloaded Extrusions

Thermal Stress Results For NbC-C Composites
Extruded in Fuel Element Shape