LA-3952-MS

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LOS ALAMOS SCIENTIFIC LABORATORY
of the
University of California
LOS ALAMOS • NEW MEXICO

Quarterly Status Report on
Ultra High Temperature Reactor Experiment (UHTREX)
for Period Ending January 31, 1968

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

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Printed in the United States of America. Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151

Price: Printed Copy \$3.00; Microfiche \$0.65

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Report written: February 1968

Report distributed: June 1968

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Compiled by K Division

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ULTRA HIGH TEMPERATURE REACTOR EXPERIMENT (UHTREX)

During this reporting period, data from the final UHTREX critical experiments (UCX-II) were evaluated and compared with those obtained in UCX-I and with results predicted by calculations.

Leak tests of the secondary containment were again conducted, and the results indicate that the reactor containment is ready for full power operation of the UHTREX.

Numerous improvements were made to instrumentation and mechanical systems in the reactor complex to improve reliability of certain components. Final seal welding, followed by leak testing with a mass spectrometer, was completed on items such as control rod drive housings and fuel loading equipment.

REACTOR PHYSICS

Progress has been made in improving the agreement between physics calculations and experiments in UHTREX. The basic experimental data available for comparison with calculations are the critical masses and power profiles observed in the two critical assemblies UCX-I and UCX-II. UCX-I was the experiment conducted separately in the preassembled core and reflector components of UHTREX.⁽¹⁾ The UCX-II experiments were carried out in mid-1967 after final assembly of the reactor in the pressure vessel.

The essential difference between the two assemblies was inclusion of low-density carbon insulation in the reactor vessel; it surrounded the graphite reflector and acted as additional neutron reflector in UCX-II. It had not been present in UCX-I. A comparison of the observed critical masses, which

were 7.0 kg (93.3% ^{235}U) in UCX-I and 6.3 kg in UCX-II, shows that the additional reflector present during UCX-II had an appreciable effect.

Power Profiles

The power profiles measured in the two assemblies are illustrated in Figs. 1 and 2. The individual profiles represent the variation in relative fissions per gram of ^{235}U in fuel elements from the bottom to the top of the core for a given radial position, I , in a vertical column of fuel channels. The index $I = 1, \dots, 4$ denotes the innermost to outermost radial positions, and the index $J = 1, \dots, 13$ identifies vertical channel positions.

Calculated power in the fuel elements is also given in Figs. 1 and 2. These powers were obtained from two-dimensional S_4 calculations using six energy groups, including five fast and one thermal group. Although the radial slope in the calculated power remains consistently less than that observed, a significant improvement over previous results has been achieved. The improvement stems from a more careful treatment of the distribution of voids across the core and reflector regions.

Preliminary calculations indicate that the remaining discrepancy may be resolved by improving the treatment of the radial thermal neutron spectrum shift. In general, a soft thermal spectrum is expected in the reflector regions far from the core, and a relatively hard spectrum in the interior of the core. Hardening of the spectrum in the core is due to the preferential absorption of lower energy thermal neutrons by the core uranium. In previous

Fig. 1 Comparison of 2-D, 6-group calculation of fuel element powers with experimental results for UCX-I.

Fig. 2 Comparison of 2-D, 6-group calculation of fuel element powers with experimental results for UCX-II.

calculations, separate infinite medium thermal spectrum calculations were performed for each of the four radial fuel element positions. It is found that this approach gives too fine a subdivision of the core, since the regions are too small for an equilibrium spectrum to be established. The consequence is that the effective thermal fission cross section estimated for the innermost fuel elements is too small and for the outermost elements is too large. Better results are obtained using a medium derived by homogenizing the entire core for thermal spectrum calculations. Calculations to investigate the effects of this new procedure on the power profiles in Figs. 1 and 2 are in progress.

It is somewhat paradoxical that multigroup thermal calculations give results that are not in as good agreement with experiment as one-group calculations. This is illustrated in Fig. 3 where 6-group (1 thermal), 25-group (13 thermal), and 7-group (3 thermal) calculations are

compared with a detailed fuel element scan taken in UCX-I. There is generally more negative curvature in the multigroup plots than is observed experimentally. This curvature is due to the spectral shift effects discussed earlier which are taken into account in multigroup calculations but not in one-group calculations. It is thought there are moderator radial streaming effects, in addition, which are really not treated adequately in any of the calculations to date. The spectral and streaming phenomena would have opposite effects on the shape of the radial power profile which would tend to cancel fortuitously in one-group calculations.

Information on the radial streaming effects should be forthcoming from the three-dimensional cell code discussed in the last Quarterly Report.⁽²⁾ In addition, detailed radial profile experiments in UCX-II to support the UCX-I data are planned.

PLANT ENGINEERING AND OPERATIONS

During the operating period associated with UCX-II and in later operational and engineering tests of all of the reactor and auxiliary systems, deficiencies were found in some systems and the performance of others was less than ideal. Therefore, the entire report period was spent in a systematic effort to improve the safety, dependability, and ease of operation of all systems.

Instrumentation and Controls

A detailed systems analysis demonstrated that there is no necessity for a primary blower shutdown when a high flux trip of the nuclear safety system occurs or when an automatic rundown is initiated. Therefore, the circuitry for shutting down the blower was eliminated from both the scram and automatic run-down systems.

During cold flow tests, the primary loop flow monitor, the secondary loop flow monitor, and the secondary loop pressure control safety system performed erratically. The differential pressure input signal to each of the systems was unstable. Some drift was present in the zero and span of the ΔP transducers, but the major source of signal error was found to be defective switches in test circuits. The test circuits were rebuilt, and performance of the three systems is now stable and reproducible.

Variability was detected in the operation of the safety systems that monitor the temperatures of the main heat exchanger tubes and of the reactor inlet coolant pipe. In both systems, the trouble was traced to stray currents flowing through ground loops. After isolated power supplies were installed, both systems operate well.

After the emergency power supply for the safety systems had been on line for about four months, routine tests revealed that the wet-cell batteries in the supply were not maintaining their charge. As originally designed, the batteries floated on line, supplying power to the safety systems and receiving power from a recharging circuit. If a line power failure occurred, the batteries alone continued to supply power. In the new configuration, the batteries are on stand-by, receiving a trickle charge, while line power feeds the safety systems through duplicate on-line power supplies. If

Fig. 3 UCX-I radial fission profile.

Eigenvalues

Eigenvalue or k_{eff} calculations have been much improved by the more detailed treatment of voids, and by a recent re-evaluation of the thermal cross sections used in UHTREX calculations. Recently calculated k_{eff} 's for the critical loadings in UCX-I and UCX-II are:

Critical Assembly	k_{eff}
UCX-I	0.995
UCX-II	1.017

Further improvement may be forthcoming from the studies in progress.

a component in either on-line supply fails, a backup on-line supply switches in without interruption of output to the safety systems. Should a second component failure occur, or if line power is lost, the batteries are switched in to feed the safety systems. The new power supply arrangement showed no battery degradation in the first month of operation.

Reliability of the secondary loop isolation valve operating system was improved by the installation of monitors on the four power supplies in the squib valve firing circuits and on the compressed nitrogen supply to the isolation valve pneumatic operators. If one of the power supplies should fail, its monitoring circuit substitutes power from a standby wet-cell battery, which normally receives a trickle charge. The nitrogen pressure is monitored by the computer, which initiates an alarm on low pressure.

More-sensitive detectors in an improved geometry and better wiring improved the performance of the secondary loop contamination monitoring system. A circuit was added to produce an analog signal output to the computer.

Deficiencies in the neutron counting channels were corrected and improvements were made in the instrumentation. During UCX-II, two coaxial cables routed in underground conduits failed due to insulation breakdown when water entered the conduits. To eliminate the possibility of recurrence of these failures, new cables were installed in above-ground outdoor conduit and indoor conduits protected from water entry. The display of count rate on operations console meters was made more reliable by an improved signal conditioning circuit.

Capability for monitoring gamma level in the reactor room was improved by substituting a commercial unit for the original log gamma chassis.

Linear power signals are now transmitted directly to the computer for use in monitoring and computing operations. Heretofore, the computer could not detect the switching of the chassis range switch as power rises and descents were made. Other new computer inputs are analog signals from the secondary loop isolation and bypass valves and motor current signals from the coolant loop and gas clean-up system blowers.

Continued malfunctions in the annunciator system led to a general overhaul that put the system

into satisfactory condition.

Reactor

In preparation for final seal welding of their housings, each of the rod drives was reconditioned. On each drive, the decelerator was removed, disassembled, tested in place, and the housing seal weld was made. After that, the rod position indication systems were calibrated, and the proximity switches on all of the rods were realigned to indicate inner and outer limits of rod position.

Coolant Loops

In early cold flow tests of the coolant loops, defects were found in some of the loop pressure and differential pressure transducers, and the performance of others left doubts about their reliability. To provide standards against which future transducer performance can be judged, precision Bourdon-tube gauges were installed in parallel with the primary and secondary loop pressure transducers, and five mechanical differential pressure gauges were installed in parallel with critical ΔP transducers. All of the gauges, mounted inside the secondary containment, are visible through shielding windows in the operating corridor, where the gauges can be read while the reactor is operating. Remotely operated block valves can close the tubing that connects the gauges to the loop pressure taps in the event that a gauge should develop a leak.

After the standard gauges were installed and all defective transducers were repaired, a series of blower operational tests were run, over a period of 14 h. During these tests, reactor operations were simulated in the control room, from where operation of the coolant loops were controlled over the ranges of flow expected under operating conditions.

When the seal welds on the rod drive and fuel handling system components were finished, a helium leak test of the coolant loops was made at 500 psi, and a few minor leaks were found and repaired. Then the loops were repressurized and cold flow tests were made, primarily to collect data for correlation of recuperator bypass valve position to fraction of flow bypassed. The results of the test agreed with the original design analysis made with computer programs. Concurrently with the flow tests, the fuel loading system was operated under full coolant system pressure.

During the final phase of the cold flow tests, the primary loop blower shut down unexpectedly and could not be restarted. Failures were found in the conductors between the inner and outer seals of the power feedthrough. Apparently the current flowing while the blower was operated at relatively high flow rates had overheated a connector inside the feedthrough, damaged the insulating material in the connector, and created a short circuit path. The outer seal was damaged enough that it leaked helium, at an intolerable rate, the inner seal less severely. As originally designed, the conductors in the outer seal could not be increased in size to reduce electrical resistance, and thereby decrease heating, nor could those in the inner seal. A new outer seal design was prepared, and a prototype built, that incorporates individual ceramic-metal seals on each of the three conductors, instead of the three pins in a single ceramic disk used in the original design. Modifications have been made on the blower case cover to receive the new seal, which will be subjected to operational tests.

Improvements were made in sensors for the safety system that monitors air flow at the heat dump. The original system used an indirect indication of air flow: a tachometer on the heat dump fan drive shaft. Now, impact tubes in the air flow stream feed a differential pressure signal to a sensitive meter relay with high and low limit switches that trigger annunciator drops and the safety system.

Fuel System

Minor changes in the configuration of the fuel element conveyor boats and in the guides that align the boats at their end positions were made to correct occasional malfunctions found during the UCX-II operations. The conveyor systems were then closed, seal welded, and tested successfully under operating pressures.

The position readout system for the fuel loader rams was calibrated by moving the rams inward to contact the core and noting the ram position. This operation was repeated at several core positions to verify the accuracy of ram position indication. Then the ram drive, elevator, and preloader drive motor housings were seal welded and leak tested.

Operational tests of the fuel loading system while the primary loop was pressurized proved the adequacy of the gas lock purge system for the first time. The tests also revealed a leak in the outermost ball valve of the outlet primary gas lock. After loop depressurization, the entire three-valve set was exchanged with the spare set, which passed a later test under pressure. The leaking valve, which had passed about 3000 fuel elements, was disassembled and a damaged main seal was found. No damage was detected on the surface of the ball that mates with the seal, however.

Gas Cleanup System

All previously untested components of the gas cleanup system performed well in operational tests. The regeneration of the molecular sieve beds was performed and the entire system was operated in conjunction with the pressurized primary loop.

Initial operational tests were made of the gas sampling systems for the chemical analysis instruments, and of the instruments themselves. The infrared analyzers and the electrolytic hygrometer are ready to operate. Systematic tests of the gas chromatograph are being made to prepare it for operation.

An operational test of the sidestream adsorption beds confirmed previous indications of a flow imbalance between the jackets of the beds, which are heated with parallel streams of hot air during regeneration. The cause of the imbalance was an improperly installed discharge nozzle, which is being repaired.

A differential pressure transducer, across the main Gentile tube flowmeter, had been damaged by an inadvertent reversal of flow when the primary loop was filled. The transducer was replaced with one of another type, not subject to reverse flow damage.

Facility

On 29 December 1967, the UHTREX secondary containment was pressurized to 2.25 psig for a measurement of the containment leakage rate by the absolute pressure drop method. Data were collected hourly for 24 h and somewhat less regularly for a span of over 96 h. The resulting leakage rate for both periods was less than 1.8 per cent per day at 2 psig.

To ensure the integrity of the secondary containment, the two parallel bleed fans were removed from the ventilation system and replaced with two motor-operated valves connected in series. For monitoring the tightness of these two valves, the dual valves installed in the fresh air and stack vent lines, the seals on the personnel doors, and the dual valves in the contaminated liquid waste drain line, a system of duplicate pressure switches was connected to each intervalve or seal zone. In the case of the valves, the zone is pressurized to 5 psi and the air supply closed off. If the system leaks, either of the pressure switches can detect the pressure decrease and sound an alarm. For the door seals, which operate under vacuum, the pressure switches sense a rise if leakage occurs.

All of the combination absolute and charcoal filter banks in the facility ventilation systems passed performance tests made with dioctyl phthalate and ^{131}I .

A reserve water tank was installed to supply spray water to the evaporative coolers which remove heat from the cooling water systems. The reserve tank will allow continued operation of the reactor for a full day (under the most severe weather conditions) and provide the necessary back-up for the normal mains-supplied cooling water.

Operator Qualifications

The entire operating crew, five supervisors and 10 reactor operators, completed the qualification program, which consisted of lectures and study sessions on operating rules and on each of the reactor and auxiliary systems, followed by oral examinations and walk-through demonstrations of the operation of each system. Under the supervisors, each crew performed simulated reactor startup and operation.

Process Computer

Digital control systems such as the primary blower control, that used computer analog outputs to drive a servo system which sets a potentiometer, have not performed well. It has been decided to eliminate the analog outputs in the control circuits and instead use sets of single shot circuits to drive the console potentiometer. The new circuits

were designed and have been installed. The control circuit changes require a complete overhaul of existing control programs. The primary blower control (PBC) program has been rewritten and is partially checked. The new PBC program has a variety of improvements including a self-check on stability. It can also be run every 10 seconds rather than 30 seconds and will give better response without any sacrifice in gain margin.

Programs that use interrupts have had routines added to protect the program from false interrupts. The relay output program, which could potentially make an erroneous output in the event of a false interrupt, has had both a parity routine and an independent time delay check added to prevent erroneous output in the event of false interrupt or other error.

A system of diagnostic lights (to indicate which programs are running) has been installed to aid in debugging and as a visual check that all programs are running properly. The fuel loading program has been revised as a result of changes in the hardware and control systems, and the operator's console program has been revised to provide better communication between the console operator and the fuel loading cell area. Subroutines have been programmed for the Laboratory's CDC 6600 to read paper tape output from the UHTREX process computer, and to produce source tape from IBM cards. Other routines can produce binary tape so that tables can be revised without using the process computer off-line to assemble these tables.

MISCELLANEOUS

Digital Simulation

The UHTREX digital simulation code UXSIM6 now has the capability to simulate operation of controllers. The neutronics and heat transfer systems models provides the system feedback to the control loops. Transfer functions may be obtained from UXSIM6 to aid in evaluating the controller parameters. Arbitrary perturbations can be made which, when coupled to operation of the controllers, permit a check of the effectiveness of the controllers, i.e., a step change in primary flow demand might be used to check the effectiveness of the primary blower control loop.

Analog Computer

One of the TR-48 analog computers will be assigned for on-line calculations during reactor operation. The necessary wiring on this computer for a reactivity calculator has been completed. An almost identical calculator, solving the neutron kinetics equation with six groups of delayed neutrons for reactivity with linear power as an input signal, was successfully used during part of the UCX-II series.

Fluid Circuit

In the previous quarterly report (LA-3835-MS), it was reported that one fluid circuit assembly had been fabricated from reject components and that a second assembly was in process. This assembly, made from acceptable components, was completed during this report period. The fluid circuit assemblies were formed by diffusion bonding chemically-milled Nb foils using Ti as a diffusion-promoting material. The foils were first bonded together to form two end sections and a center section. These subassemblies were then bonded to each other and Ta tubes brazed to the channel inlet and outlet. A V-35 Nb braze alloy was used in this operation. The two diffusion bonding steps were required to obtain good, uniform bonding of the foils over the channels. The base of the assembly shown in Fig. 4 is approximately 0.25 x 0.25 in. square.

Fuel Migration

A second UHTREX fuel element has been tested for fuel migration in the temperature range of 3150° to 3300°F to confirm earlier observations that migration occurs at these temperatures. The element was at temperature for two weeks. Periodically during the test the element was removed, cooled, and the surface was surveyed for alpha count to determine how the temperature history influenced the amount of uranium that migrates to the surface. The temperature and alpha count results are presented in Fig. 5.

The evidence for migration in previous experiments was from the observation of dense areas on microradiographs. To confirm that this was uranium, and not extraneous metal smears from machining operations, autoradiographs were made. The autoradiographs also indicate uranium concentration at

Fig. 4 The fusion bonded and brazed fluid circuit assembly.

the surface, confirming the previous tests and the alpha count observation.

References

1. Quarterly Status Report on Advanced Reactor Technology (ART) for Period Ending July 31, 1965, LA-3370-MS, August 31, 1965, p. 52.
2. Quarterly Status Report on Ultra High Temperature Reactor Experiment (UHTREX) for Period Ending October 31, 1967, LA-3835-MS, December 22, 1967.

Fig. 5 UHTREX fuel migration test temperature and surface alpha count record.