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CORE RESTRAINT ENGINEERING

MASTER

FEBRUARY—APRIL 1977

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT EY-76-C-03-0893 TASK 23

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**CORE RESTRAINT ENGINEERING
ELEVENTH QUARTERLY REPORT
FEBRUARY-APRIL 1977**

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ABSTRACT

This report is the eleventh in a series of quarterly progress reports published under Core Restraint Engineering. The objective of the work reported here is to develop, in conjunction with other members of the National Core Restraint Development Program, the design guidelines and the corresponding technology required to design LMFBR core restraint systems and to support applicable licensing processes.*

Progress during February, March, and April 1977 is described for subtasks related to Refueling Force Evaluation and Test, Instrumented Simulated Fuel Assemblies, Core Restraint Transient Analysis, In-Reactor Monitoring, Advanced Core Restraint Studies, and Seismic Evaluation.

**This program was previously contained in GEAP-10028, Core Engineering, Contract AT(04-3)-893, Task 11.*

SUMMARY

CORE RESTRAINT ENGINEERING – 189 No. SG016

The conceptual design development and feasibility assessment study of backup refueling devices has yielded three promising concepts: a refueling grapple with built-in vibration capability, a partial withdrawal holding unit, and an applied moment device.

Initial calculations pertaining to the sequence of refueling and the partial withdrawal technique indicate that most effects are local due to bridging around an altered assembly. It appears possible that a random withdrawal sequence could actually increase refueling loads on a particular assembly.

Due to HEDL delays in responding to the advanced refueling limits test request and an abnormally long turnaround time in processing the corresponding purchase order to ERDA-SAN, it was necessary to delay completion of this effort by three months. The overall funding, however, remains unchanged.

Benchmark CORTAC verification problems for neutron kinetics, reactivity feedback, and thermal hydraulics have been identified, and solutions generated. Comparable CORTAC problems have been programmed and compare favorably with the benchmark problems.

The irradiation of the full-bridge strain gage tension specimens in EBR-II is proceeding without difficulty. These specimens have been included in the HEDL AA-2C experiment which is scheduled for insertion in EBR-II in May 1977.

An investigation has been initiated to determine the feasibility of using the canceled YY08 creep experiment hardware for instrumented strain gage irradiation testing in EBR-II. Incorporation of additional tests such as duct-to-duct contact are also being considered.

Analysis of the apparent temperature dependence of the FTR load transducer has revealed that the problem is attributable to dissimilar thermal expansion characteristics of the sensor element and strain gage mounting flange material. Since the thermal expansion characteristics of these components will be well matched on the production units, it is expected that transducer output will be essentially independent of temperature.

All of the final design drawings for the FTR load transducer have been released for fabrication. Fabrication has begun and is approximately 30% complete.

Initial efforts towards the development of procedures for monitoring bowing/expansion reactivity effects has determined that it may be practical to isolate Doppler and axial reactivity from radial reactivity by conducting transient experiments in which the fuel temperature and duct wall temperatures are separately held constant. Thus, the experimental procedure would require the measurement of some fuel and duct wall temperatures.

The emphasis of the Advanced Core Restraint Studies subtask has been placed on enhancement of core restraint system performance by improvements in core assembly design rather than on advanced overall core restraint system concepts.

The digital master logic for the hybrid seismic model has been completed and the computer program is in the checkout phase.

1. CORE RESTRAINT ENGINEERING — 189 No. SG016

Cognizant Engineer: J. N. Fox

The overall objective of this work is to develop, in conjunction with other members of the National Core Restraint Development Program, the design guidelines and the corresponding technology required to design LMFBR core restraint systems and to support applicable licensing processes. The specific FY-77 objectives are to:

- Participate in planning and coordination of ongoing and future core restraint developments on a national basis.
- Complete the second phase refueling force limits testing and analysis.
- Develop preliminary backup refueling devices and procedures.
- Provide assistance to W-ARD as required, in ISFA checkout, calibration and maintenance.
- Complete verification of the two-dimensional CORTAC computer code and perform an evaluation of three-dimensional effects relative to the current capability of the code.
- Complete the fabrication of the EBR-II irradiation drift test hardware and ship the hardware to HEDL for inclusion in the HEDL AA2 experiment.
- Fabricate the FTR load pad surveillance system and check out its response.
- Develop procedures for monitoring bowing/expansion reactivity effects.
- Assess candidate advanced core restraint systems.
- Complete the preliminary phase of the core restraint seismic response evaluation.

1.1 NATIONAL CORE RESTRAINT DEVELOPMENT ACTIVITIES

The objective of the National Core Restraint Development Program (NCRDP) is to coordinate and plan ongoing and future core restraint development needs on a national basis. GE-FBRD, as a member of the National Program, is actively engaged in periodic coordination meetings and conference calls.

The outstanding comments on the second draft of the NCRDP were resolved by a series of conference calls during the months of February and March 1977. ANL provided additional information and current references for the plan. All participants aided in writing the executive summary requested by RDD. W-ARD issued the final draft of the plan and a May 4, 1977 meeting is scheduled at ANL to resolve any final comments and to finalize the document for publication.

1.2 REFUELING FORCE EVALUATION AND TEST

The objectives of this subtask are to complete the second phase refueling force limits testing and analysis and to develop preliminary backup refueling devices and procedures.

Progress is continuing on the conceptual design development and feasibility assessment study of backup refueling devices. Two promising devices: a refueling grapple with built-in vibration capability and a partial withdrawal holding unit, have been identified. The designs have been refined and are now ready for an internal GE-FBRD review. The design of a third device, an applied moment device, is progressing to the point where it now appears viable. All three devices will be reviewed together after refinement of the moment device.

The applied vibration withdrawal device consists of a grapple with a built-in pneumatic vibration (Figure 1). The only moving part in the vibrator is a steel ball pneumatically driven by argon around a track. Centrifugal force created by the ball is transmitted through the grapple to the assembly handling socket.

The partial withdrawal holding device consists of a jack stand which rests on top of the surrounding six assemblies (Figure 2). The partially withdrawn assembly is supported by the device 4.3 inches (10.9 cm) above its in-core position. This removes the load pads from the load pad plane and increases clearances between other assemblies at the load pad plane. The jack stand includes a spring-activated latch grapple which locks onto the assembly handling socket, an outer hold-down sleeve which rests on the surrounding assemblies, and an inner sleeve which is raised and locked onto the outer sleeve. The inner-to-outer locking is achieved by a spring-activated ball-in-slot locking mechanism. The two springs allow operation by removable push/release actuator shafts. Positioning is achieved by a grapple shaft which also incorporates a ball-in-slot locking device.

The applied moment device consists of a levered assembly grapple (Figure 3). The moment lever arm is positioned circumferentially in the direction of the desired applied moment. This applies a straightening moment to the bowing assembly which reduces the bow magnitude, allowing withdrawal at a reduced withdrawal force. The moment lever arm is actuated by an inner activator shaft. The grapple is attached by a hinge assembly to an outer actuator shaft. The hinge assembly prevents coupling between the grapple and restraint moment forces from the lever arm actuation. The moment lever arm pushes down on the outer periphery of the handling socket and forms a couple with the grapple which provides the straightening moment on the assembly.

Figure 1. Vibrating Fuel Grapple

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NOTE - SEE SHT 2 FOR OPERATIONAL
SEQUENCE

Figure 2. Fuel ASM Jack Stand

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The NUBOW 3-D investigation of sequence of withdrawal and the partial withdrawal technique is continuing. This investigation will determine the benefits from a preferred withdrawal sequence and whether a random withdrawal sequence could result in higher withdrawal loads on some assemblies. Also being investigated are the benefits of partial withdrawal which would utilize the partial withdrawal holding unit as designed by the conceptual design development study. Initial calculations indicate that most effects are local due to bridging around any altered assembly. A random withdrawal sequence could actually increase loads on a particular assembly. Detailed analysis is shown to be necessary to determine the possible few loads which will affect withdrawal loads on a critical assembly in a significant positive manner.

Due to HEDL delays in responding to the advanced refueling limits test request and an abnormally long turnaround time in processing the corresponding purchase order to the ERDA-SAN office, it was necessary to change the A5 Milestone from June 1977 to September 1977 (see Appendix A). As a result, only limited progress has been made on these tests. HEDL and GE have agreed on test procedures and required hardware for both the load pad evaluation testing and the dilated duct withdrawal testing.

1.3 INSTRUMENTED SIMULATED FUEL ASSEMBLY

The objective of this subtask is to provide assistance to W-ARD, as required, in ISFA checkout, calibration and maintenance.

W-ARD did not request GE-FBRD assistance during this reporting period.

1.4 CORE RESTRAINT TRANSIENT ANALYSIS

The objectives of this subtask are to complete verification of the CORTAC two-dimensional effects relative to the current capability of the CORTAC computer code.

Since the verification of CORTAC includes comparisons with the NUBOW 3-D Elastic structural computer code and the TRITON 3-D thermal-hydraulic computer code, the evaluation of the three-dimensional effects will not formally begin until the first phase of verification is complete. The results of this first phase of the verification phase will automatically identify areas in which CORTAC modeling can be improved to better represent three-dimensional effects. The paragraphs to follow address the first phase of the verification effort.

Work is nearing completion on the first phase of CORTAC verification. The CORTAC structural verification portion results have been transmitted to ANL for comparison with results obtained with the core restraint structural codes NUBOW 2-D, NUBOW 3-D, and PARABOW. Results have recently been obtained for the verification of feedback reactivities, kinetics response, and transient heat transfer response. The efforts on each of these three modeling areas are discussed separately.

The feedback reactivities verification problem is a simple unity change in reactor inlet temperature at a zero power reactor condition. All reactivity coefficients (Doppler, radial, axial, fuel density, cladding density, structure density, and coolant density) were set at unity and the power distribution made uniform. For simplicity, the reactor was composed of a total of seven (2 rows) fuel assemblies. A lower axial blanket, inner core, outer core, and an upper axial blanket region were included. Hand calculations of the governing CORTAC analytical equations were compared directly with the CORTAC feedback reactivity results. All of the CORTAC results were found to be identical to the hand calculations.

The neutron kinetics response was divided into two separate problems: one to verify the solution of the point kinetics equations without reactivity feedback, and the second to verify the kinetics response with reactivity feedback. The basic kinetics problem is a step reactivity input including six precursor groups. This problem was chosen since it is one of the few for which an exact analytic solution exists when feedback reactivity is excluded. The kinetics parameters pertaining to the beginning of life of the first CRBRP core were employed in each of the kinetics problems. Step reactivities of ± 0.2 , ± 0.5 , ± 0.9 , ± 1.0 and ± 1.5 were evaluated, neglecting reactivity. The corresponding results are shown in Figures 4 through 7. The CORTAC results were found to be essentially identical to the analytic solution.

The kinetics response problem with feedback was somewhat more difficult to formulate since practical analytic solutions are not available. Because of this situation, it was decided that an analytic solution is not necessary provided a numerical solution (different from CORTAC) can be used against which to "verify" CORTAC. This numerical or analytical solution need only be checked with an exact solution under the conditions of zero reactivity feedback. In this case, the exact solution is provided by results given in the paragraph above. The kinetics response with feedback was chosen to be a 1.5\$ step reactivity input with reactivity feedback proportional to the change in fuel temperature. In formulating the numerical model, it was found convenient to consider only fuel. Thus, the

Figure 4. Kinetics Response to 20, 50 and 90¢ Step Reactivity Input without Feedback

Figure 5. Kinetics Response to 1\$ Step Reactivity Input without Feedback

Figure 6. Kinetics Response to 1.5\$ Step Reactivity Input without Feedback

Figure 7. Kinetics Response to -0.2, -0.5, -0.9, -1.0 and -1.5\$ Step Reactivity Input without Feedback

CORTAC constants were modified appropriately to effectively insulate the cladding and coolant from the fuel. In addition, the heat capacity of the fuel was chosen to minimize the fuel temperature rise during the transient. Finally, the fuel reactivity coefficient was chosen to "turn" the power over at a factor of ten increase in power. The numerical solution of the kinetics equations and fuel temperature was obtained from a standard library computer program that solves a set of first-order differential equations, using the fourth-order Runge-Kutta method. The numerical solution of these equations without feedback is compared in Figure 8 with the exact solution. As indicated, the numerical solution is very close to the exact solution. Hence, the numerical solution is considered sufficiently accurate to be used as the basis of comparison for the kinetics response with feedback. Figure 9 compares the results of CORTAC with the numerical solution with feedback. The two CORTAC options were exercised: the standard "one-time-step behind" reactivity feedback option and the iterative feedback option. As expected, the standard option overpredicts the power as the power increases and underpredicts the power as it decreases. This is a result of the initial underprediction of feedback reactivity and the subsequent overprediction. The accuracy with this option, of course, depends on the true step size and is more accurate with smaller time steps. The iterative option utilized time steps about three times the size of the standard option, but produced results very nearly the same as the

Figure 8. Comparison of Exact and Numerical Solution of Kinetics Response without Feedback

Figure 9. Relative Power as Influenced by Reactivity Feedback

analytical solution. The total calculational time of iterative option was somewhat less than that for the standard option.

Verification of transient heat transfer response is being conducted in two parts. The first part pertains to axial convection and radial conduction between each fuel pin and the associated coolant. The second part addresses the reactor-wide radial conduction modeling in which CORTAC will be compared with results for the three-dimensional thermal-hydraulic code TRITON, recently provided by W-ARD. Since TRITON is a steady-state code, the CORTAC/TRITON comparison can only be made at several representative steady-state conditions—not on a transient basis. However, the verification of the overall transient behavior should be reasonably well assumed if the transient heat transfer response of the first part (axial convection and fuel-to-coolant) and the steady-state comparison of the second part (radial conduction) are separately verified. The second part of the transient heat transfer response has just been initiated, whereas the first part has been completed.

The axial convection portion of the verification problem was completed, comparing the CORTAC results with a simple "exact" benchmark problem. The model consisted of a bare fuel pin (Figure 10) surrounded by a coolant annulus. The exact solution consisted of a timeshare computer program that was developed specifically for the CORTAC verification. The details of the program will be made available following the completion of the verification activity. At this time it is sufficient to note that the node lengths in the exact model were very small, all equal in length, and the time step size was chosen to sweep a node. Two transient benchmark problems were completed. The first consisted of a step power increase of 30 percent where the power is uniform over the entire length of the fuel pin (Case 1) with equal node lengths. Figure 11 shows the temperature response of nodes (average of the section in the case of the exact solution). The CORTAC results were found to be identical to the exact solution. The second problem varied node (section) lengths and the axial power distribution which are both more representative of CORTAC modeling. For this case, the CORTAC calculational time step was increased to three times the sweep time of the shortest node. This three-times sweep has been recommended as a maximum for CORTAC in the past. Figure 11 shows the temperature response of both Nodes 2 and 5. The CORTAC results were found to be essentially identified to the exact solution at Node 2 and within 0.2°F (0.1°C) at Node 5.

The verification problem for the transient radial conduction between the fuel pin and its coolant consisted of a single fuel pin and coolant annulus initially at 0°F (-18°C) and the

CASE 1
SINGLE FUEL PIN SURROUNDED
BY COOLANT – UNIFORM POWER

CASE 2
SINGLE FUEL PIN
UNEQUAL NODE LENGTHS
STEP POWER PROFILE

Figure 10. Single Fuel Pin Models

Figure 11. Temperature Development for a 30% Power Step Increase

power stepped at time zero. The exact solution for this problem was obtained using a radially nodalized model with ten equal volume fuel nodes, a single cladding node and a single coolant node. The resulting 12 equations were solved by the previously mentioned standard library computer program that solves a set of first-order differential equations. Since CORTAC represents the fuel with one radial node, this problem provides a means to assess the validity of the CORTAC representation of the fuel as well as its transient response. Figure 12 displays the response of the fuel and coolant. The fuel temperature for the exact solution is the average of the ten nodes. As this figure illustrates, the CORTAC fuel temperature reaches a value of about 100°F (38°C) higher (out of 2400°F) than the exact solution and the CORTAC coolant temperature is correspondingly less. This discrepancy is considered acceptable since a more realistic case would begin at a fuel temperature of about 2000°F (1093°C) and the fuel would not be subject to such rapid changes in heating rates.

1.5 IN-REACTOR MONITORING

The objectives of this subtask are to complete the fabrication of the EBR-II irradiation drift test hardware and ship the hardware to HEDL for inclusion in the HEDL AA2 experiment; fabricate the FTR load pad surveillance system and check out its response; and develop procedures for monitoring bowing-expansion reactivity effects.

The planned EBR-II irradiation of full-bridge strain gage tension specimens is proceeding without difficulty. The AA-2C experiment with four tension specimens included has been shipped from HEDL to EBR-II. The AA-2A experiment has been reloaded at HEDL with four tension specimens and is expected to be shipped from HEDL to EBR-II in May.

A trip was made to HEDL to determine the feasibility of using the canceled YY08 creep experiment hardware for instrumented strain gage irradiation testing in EBR-II. The YY08 creep hardware consisted of two material experiments. The first was a pure tension specimen loaded by a pressurized bellows system. The second dealt with pressurized fuel cladding specimens. The tension specimen pressurized bellows system with instrumented lead-out capability is ideal for testing the weldable full-bridge six-lead strain gage system planned for the FTR VOTA load pad transducers. Instrumented testing of the strain gage is desirable to determine zero load drift and response of strain characteristics with respect to irradiation-time exposure. The only modification required to do strain gage testing will be the changing of the tension specimen for placement of the weldable strain gage. The laser

Figure 12. Comparison of CORTAC and Exact Solutions for Step Increase in Power

extensometer portion of the YY08 hardware would not be used. The feasibility of incorporating additional tests such as duct-to-duct contact tests is being investigated. It may also be desirable to continue the pressurized fuel cladding experiment portion of the original YY08 experiment.

The strain gage temperature drift tests at GE-FBRD will be completed during the next quarter. Data to date continue to indicate good results with respect to drift and sensitivity stability.

The high temperature tests of the second prototype FTR load transducer have been completed. The data thus obtained showed a major temperature dependence of the output. An investigation of this problem has attributed the temperature dependence to the fact that the gage mounting flange material is Type-321 stainless steel and the second prototype transducer sensing element material is Type-304 stainless steel, providing dissimilar thermal expansions at increasing temperatures. The production transducer will not have the dissimilar materials and it is expected that production transducer output will be essentially independent of temperature.

The tests for axial and transverse frictional force effects on transducer output revealed an additional problem. The second prototype transducer was found to be overly sensitive to axial and transverse frictional loads. To investigate this problem, extensive modeling of the transducer load train was done using the ANSYS computer code. It was determined, as a result, that the axial and transverse frictional effects could be practically eliminated by adjusting some dimensions and modifying the load train/sensor strain element interface.

The third prototype transducer was tested to evaluate the chrome plating on bearing surfaces and its effect on the transducer hysteresis problem. The results of a "before-and-after" chrome test were positive. Hysteresis was effectively nonexistent for the second test case which had chrome-plated bearing surfaces at the sensor strain element pivoting region.

The full model of the transducer to analyze the long-term effects of irradiation on transducer calibration has been completed, but will have to be modified to incorporate recent changes made to the transducer.

All of the final design drawings for the FTR load transducer have been reviewed, issued, and released for fabrication. Fabrication has begun and is approximately 30% complete. Electrolyzing Corporation will be chromeplating the required surfaces of the production transducer, and Union Carbide will chromium-carbide coat the load buttons.

A draft of a test plan for the production transducer has been written. In order to test axial friction effects on the production transducer, a special testing rig has been designed to be used in conjunction with the INSTRON compression tester at the Materials Development Laboratory.

Initial efforts towards the development of procedures for monitoring bowing/expansion reactivity effects were directed toward identifying applicable documents on EBR-II, SEFOR, and Phenix and reviewing their experimental procedures for measuring or implying specific reactivity feedback mechanisms. In conjunction, input for the CORTAC computer code was prepared to conduct transient studies for determining effective experimental methods of monitoring the individual reactivity effects. As a result of this initial work, it has been determined that the Doppler and axial reactivity effects can be isolated (radial effects negligible) by properly maintaining the power-to-flow ratio during a programmed reactor transient. Experimentally, this would mean that the power-to-flow ratio would be held nearly constant so that there would be no negligible change in duct wall temperatures. A system of thermocouples or strain gages would yield the temperatures of the duct wall inner surface. In this way, reactivity changes that could be measured would verify the CORTAC calculation of Doppler and axial reactivity feedbacks.

Further analysis is being done in an attempt to isolate radial feedback. Testing of this mechanism would be done similar to the above-mentioned testing of Doppler and axial, but with temperature monitoring of the fuel to assure that fuel temperature does not change appreciably during the transient.

1.6 ADVANCED CORE RESTRAINT STUDIES

The objective of this subtask is to make an assessment of candidate advanced core restraint systems.

At the outset, efforts on this subtask were concentrated solely on identifying and assessing advanced core restraint system concepts. However, as this subtask progressed, it

became clear that this subtask must also address enhancement of core restraint system performance by improvement in core assembly designs. In fact, now it appears that this subtask should devote more time to the latter than to the former while this subtask will continue to address the modular and thermally activated core restraint systems, the major emphasis will be placed on enhancement of core restraint system performance by improvements in core assembly designs. Such improvements include:

- a. Thinner (reduced bending stiffness) duct wall above the ACLP.
- b. Optimization of ACLP configuration (e.g., spherical surfaces, three- rather than six-face contact).
- c. Pre-bowed assemblies to enhance startup radial reactivity feedback response.
- d. Evaluation of reflector/shield assembly design options relative to core restraint needs.

The thinner duct option has been evaluated using the CORTAC computer code with the CRBRP geometry. Referring to the thermal portion only of Figure 13, the ACLP operating loads decrease as expected; however, the strength of the radial negative feedback also decreases proportionally. This latter trend, in general, is not desirable. It was also found that the duct wall temperature gradients tend to increase (Figure 14) by thinning the duct wall. This effect is simply a result of higher effective interassembly heat transfer.

Figure 13. Effect of Duct Wall Thickness on Radial Feedback Response

Figure 14. Effect of Duct Wall Thickness on Maximum Row 10 - Temperature Gradient

1.7 SEISMIC EVALUATION

The objective of this subtask is to complete the preliminary phase of the core restraint seismic response evaluation.

A report entitled "Core Restraint Seismic Needs" was transmitted to RDD and the other members of the NCRDP. This report identifies core restraint system seismic analysis and testing needs relative to RDT Standard F9-2T, "Seismic Requirements for Design of Nuclear Power Plants and Test Facilities." One of the results of this study was the designation of the core restraint system as Seismic Category I. The Seismic Category I classification requires extensive analysis and testing in support of core restraint system design. Additionally, the inherent nonlinear nature of the core restraint system (e.g., gaps) leads to the conclusion that time-history analytical methods must be developed, if for no other reason but to justify the use of simplified analyses. Finally, the overall complexity of the core restraint system (including all the core assemblies, core barrel and core support structure) requires testing (at least on small-scale mockups) in support of design analysis.

The extremely large number of Individual core assemblies makes it impractical to consider including a full complement of assemblies in time-history analyses. This large number of assemblies also makes prohibitive the full-scale testing that might be used to satisfy design analysis requirements. Also, the model size limitations associated with time-history methods and the obvious long-term advantage of utilizing simplified analyses suggests continued development of applicable static equivalent analysis methods. In the paragraphs to follow, both analytical and testing approaches are recommended to best meet the needs and limitations of core restraint system design.

1.7.1 Analytical

- a. Develop time-history dynamic and static equivalent models in parallel.
- b. Start with a seven-assembly core restraint system model and perform complete analyses that include gaps, fluid inertia, and fluid and structural damping. The seven-assembly core restraint system model is the minimum size array that retains all the important interfaces (pad-to-pad and pad-to-formers).
- c. Vary input parameters to give consideration to the effect of changes in the mathematical model on the computed response. This will aid in defining supporting seismic tests.
- d. Increase the number of assemblies in both the time-history dynamic and static equivalent models to evaluate the size effect. Hopefully, the seismic response of the core restraint system will not depend on the actual number of core assemblies involved, provided their presence is suitably accounted for in those modeled. It is anticipated that a 4- or 5-row model of equivalent core assemblies will be sufficient.
- e. Perform a suitable impact analysis to account for the interaction of the assemblies at the load pad elevations, and evaluate the impact forces.

1.7.2 Testing

- a. Develop testing requirements in conjunction with analytical needs.
- b. Conduct full-sized seismic testing with a total of seven core assemblies (2 rows) with a simulated core barrel and core support structure. These tests would be conducted with and without water in order to maximize experimental results on fluid-related parameters. The clearances should be designed to be adjustable.

- c. Following successful completion of item b above, final verification testing should be conducted in the 1/4-scale Hydraulic Core Mockup (HCM) at HEDL.

The evaluation of the adequacy of current seismic analysis methods is continuing. The overall goal of this activity is to develop a simplistic but conservative seismic design method(s) for core restraint systems. The capabilities of the SAP and MARC structural programs were investigated relative to their static and dynamic capabilities. The results of PLBR core restraint seismic analysis performed at GE-FBRD are being utilized in this activity. A planar model consisting of seven assemblies has been developed to perform both static and dynamic analyses under seismic loadings. The planar model, in conjunction with the two-dimensional models developed under PLBR seismic analysis activity, provides the basic information required to develop a simplified method of analysis of core restraint system for seismic loadings. A parametric analysis of the model, using SAP structural program, is in progress to compare static and dynamic stresses and displacements. An alternate planar model is under development to perform analysis for other possible direction of earthquake.

The hybrid computer seismic modeling and programming are essentially complete. Programming of the analog and digital portions have been completed and checked out separately. The digital master logic has also been completed and the composite program is in the checkout phase.

1.8 QUALITY ASSURANCE

Quality Assurance activities were carried out consistent with the task product classification. The EBR-II irradiation drift test hardware was inspected and released for shipment to HEDL for insertion in the HEDL AA2 experiment.

APPENDIX A **SUBTASK/MILESTONE/COST SCHEDULE FOR FY-77**

E5* Agreement and Commitment No. 2 of the March 24, 1977, VOTA Instrumented Load Pad Meeting at HEDL does not require the FTR load pad surveillance system at HEDL until August 1977.

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