



COMPTROLLER GENERAL OF THE UNITED STATES  
WASHINGTON, D.C. 20548

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May 25, 1982

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The Honorable John D. Dingell  
Chairman, Subcommittee on Oversight  
and Investigations  
Committee on Energy and Commerce  
House of Representatives

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Dear Mr. Chairman:

Subject: Revising the Clinch River Breeder Reactor  
Steam Generator Testing Program Can Reduce  
Risk (GAO/EMD-82-75)

Your September 2, 1981, letter asked that we review the technical outlook for several components of the Department of Energy's (DOE's) Clinch River Breeder Reactor (CRBR)--the Nation's first liquid metal fast breeder reactor demonstration plant. In February 1982, your office requested that we issue an interim report on DOE's program for testing CRBR's steam generators. This report responds to that request.

Steam generators for liquid metal fast breeder reactors have had a history of serious technical problems. Small breeder reactors in this country and demonstration breeder reactors in foreign countries have experienced steam generator failures. Steam generators for the CRBR have also experienced a number of problems during their development.

Despite that history, DOE does not plan to conduct complete and thorough tests of the steam generator design to be used in the CRBR. Instead, DOE plans to conduct (1) a series of limited tests on a steam generator which differs significantly from those designed for use in the CRBR, (2) a vibration test on a one-third scale model steam generator, and (3) some inplant testing on a CRBR steam generator after all CRBR steam generators have been fabricated. Without conducting more thorough tests of the CRBR steam generator design before building the CRBR units, DOE is assuming that the CRBR units will operate as predicted.

If DOE is correct, the CRBR will be able to proceed on its current schedule, and the cost will be lower than if more complete and thorough testing were done. If DOE is wrong, the costs and delays associated with redesigning and modifying or rebuilding the CRBR steam generators would be substantial.

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DCE's decision to forego more thorough tests is based on (1) a belief that the tests that will be done can be extrapolated to predict steam generator performance in the CRBR and (2) confidence that the steam generator design will be successful. Conversely, the history of problems with steam generators and with development of the CRBR steam generators argues for a more complete and thorough testing program.

The following sections present the objective, scope, and methodology of our review; a background on CRBR steam generators; our findings in more detail; and our conclusions and recommendations.

### OBJECTIVE, SCOPE, AND METHODOLOGY

Our objective was to evaluate DOE's current program for testing the CRBR's steam generators. To accomplish that objective, we reviewed the history of the development of the steam generators, including the results of past tests and DOE's future plans for testing. We also compared the current CRBR steam generator design with the design of the steam generators tested in the past and currently being tested. Documents concerning the testing program were obtained from DOE headquarters in Washington, D.C.; the CRBR Project Office in Oak Ridge, Tennessee; the Energy Technology Engineering Center in Santa Susana, California; Westinghouse Advanced Reactors Division in Waltz Mill, Pennsylvania; and the Atomic International Division of Rockwell International Corporation at Canoga Park, California.

We also discussed DOE's testing program with the major contractors involved in the steam generator program and with DOE officials. Information concerning steam generator development in foreign countries was obtained from DOE subcontractors and technical publications. To assist us in the technical aspects of this assignment, we employed a consultant who has worked in the nuclear industry for over 30 years and who has an intimate knowledge of liquid metal fast breeder reactors and steam generators.

The information contained in this report represents the best information available at the time of our review. It should be recognized, however, that the testing program changed during our review and, even at the time we issued this report, DOE was considering other options.

We performed our work in accordance with GAO's "Standards for Audit of Governmental Organizations, Programs, Activities, and Functions."

BACKGROUND ON THE CRBR AND  
THE CRBR STEAM GENERATORS

In 1970, the Congress authorized the Atomic Energy Commission (AEC) <sup>1/</sup> to enter into cooperative arrangements with industry to build and operate the CRBR. During the early and mid-1970s, great urgency was attached to the CRBR program because predictions showed that current generation nuclear reactors would be running out of uranium fuel by the year 2000. The CRBR was initially scheduled to be completed by 1980 to permit a decision in the mid-1980s on commercial deployment of breeder reactors. We are currently completing work on a report which addresses the options available for the timing of the CRBR. That report includes information on a number of factors which have changed since the CRBR was originally authorized. Specifically:

--Current DOE data show sufficient natural uranium to fuel the light water nuclear industry well past the year 2020.

--Latest DOE data show breeders may not be economical until after the year 2025.

In commenting on a draft of that report, DOE argued that it is imperative to proceed with the CRBR schedule--current plans are to have the CRBR operating by 1990--and that any slowing of the program could lead to industrial disruption, constrained economic growth, and increased reliance on foreign energy supplies. While recognizing DOE's comments and concerns over possible delays in its current program, we concluded that the changes in the factors affecting the timing of when breeder reactors may be needed show that slowing the program has become a viable option.

Developing and demonstrating reliable steam generators have been and still are one of the most significant technical problems facing the CRBR project. Steam generators provide the transfer of heat from the reactor coolant to water, which is heated to steam to drive the plant's turbines. According to a Nuclear Regulatory Commission report, 33 of 45 operating nuclear plants with steam generators have experienced some form of steam generator problems. During the 1970s, these problems caused about 21 percent of forced outages at those plants. Many of these problems are operational problems and are not related to design deficiencies or inadequate testing. It is obvious, however, that steam generators are the source of considerable problems in existing nuclear plants. In

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<sup>1/</sup>The Atomic Energy Commission and the Energy Research and Development Administration (ERDA) were predecessor agencies to DCE. AEC was abolished on Jan. 19, 1975, and many of its functions were transferred to ERDA. ERDA's functions were transferred to DCE on Oct. 1, 1977.

comparison to commercial reactors, the steam generators needed for the CRBR represent a more difficult challenge because sodium is used as the reactor coolant. Sodium steam generators impose severe mechanical stresses on the metal barrier between sodium and water within the steam generator. Even a small failure allowing contact between the two fluids raises the possibility of a fire or explosion resulting from a sodium-water interaction.

#### Breeder reactor steam generator history

According to Atomics International, the fabricator of the prototype steam generator for the CRBR, many designs have been used for breeder reactor steam generators around the world. Atomics International maintains that problems have been experienced in all cases where the steam generator design has not been thoroughly tested.

Smaller breeder reactors in the United States have experienced steam generator problems. For example, a steam generator in the Enrico Fermi reactor (near Detroit, Michigan) failed in 1962 when vibrations and other problems created holes in the metal tubing, allowing contact between the sodium and the water. Other countries have also experienced steam generator problems in breeder reactor plants. Structural integrity problems in a demonstration breeder plant in Russia caused leaks in four of six steam generators. Similar problems delayed full power operations at the British demonstration breeder plant when four of nine steam generators leaked. As recently as April 1982, the French demonstration breeder reactor was shutdown because two sodium leaks in a steam generator caused a fire.

#### CRBR steam generator program

In 1974, AEC chose a steam generator design for use in the CRBR that was quite different from any previous domestic steam generator, and it was also different from the steam generators used in foreign breeder reactors. During 1974 and 1975, Atomics International was selected to design and fabricate (1) two model steam generators, (2) a prototype steam generator, (3) nine steam generators for use in the CRBR, and (4) one backup unit. Until 1982, DOE's steam generator development program consisted of three major elements.

1. Testing the Model Steam Generators. The model steam generators, tested in 1978, were full-length steam generators but contained only 7 water-carrying tubes instead of the 757 tubes in a plant unit. The purpose of testing the model steam generators was to obtain data on full power steam generator performance and endurance.
2. Testing a Prototype Steam Generator. The prototype steam generator, to be tested in 1982 and 1983, was

originally to have been a full-size, 757 tube prototype of the CRBR steam generators. However, changes to the CRBR design resulting from the testing of the model steam generators and subsequent design reviews could not be fully incorporated in the prototype steam generator and, as a result, the prototype differs significantly from the CRBR steam generator design. The original purpose of building the prototype was to verify the steam generator manufacturing process and to test the structural integrity of the prototype under simulated operating conditions. Prototype steam generator testing is proceeding on schedule.

3. Fabricating and Installing the CRBR Steam Generators. The CRBR steam generators are the units which will ultimately be installed in the CRBR. As previously noted, the design of the CRBR steam generators has changed significantly over the past several years, and DOE does not plan to conduct complete and thorough testing of the current CRBR steam generator design prior to installation of the steam generators in the CRBR.

CRBR officials are currently adding another element to the CRBR steam generator testing program--fabrication of a one-third scale model of the CRBR steam generator--to test the design's ability to withstand flow-induced vibration.

DOE terminated the steam generator contract with Atomic International in 1981 and is currently resoliciting proposals to fabricate the nine redesigned CRBR steam generators and one backup unit. DOE expects to announce award of a contract in the near future.

#### DOE IS NOT MINIMIZING RISKS IN ITS STEAM GENERATOR TESTING PROGRAM

DOE's program for testing CRBR's steam generators is deficient in that

- model steam generator testing and prototype fabrication were conducted concurrently, thus deficiencies found in the models were not corrected in the prototype;
- prototype testing involves testing a design which is significantly different from the design for the CRBR steam generators;
- prototype testing will not include simulating important operating conditions; and
- the steam generator design to be used in the CRBR will not be completely and thoroughly tested prior to fabrication and installation of all CRBR steam generators.

Problems noted during model  
steam generator testing were  
not corrected on the prototype

Because of the perceived urgency of building the CRBR, program officials began fabrication of the prototype steam generator before completing testing of two model steam generators. Under normal conditions, the models should have been tested before fabrication of the prototype began. Initial tests on the model steam generators began in May 1978, but they were prematurely concluded in December 1978 because of deficient performance. Subsequent examination showed that the model steam generators could not withstand fluctuations in temperature because of fabrication errors and inadequate tube spacing and tube support.

The contract for the design and fabrication of the prototype was awarded in September 1975, thus fabrication of the prototype steam generator was well underway when the test results from the model steam generators became available in 1979. As a consequence, the design and fabrication problems noted in the model steam generators were not corrected in the prototype. Instead, major changes were made to the CRBR steam generator design. Therefore, the prototype steam generator scheduled for testing from May 1982 through March or April 1983 is not prototypic of the current CRBR design, and it contains many of the same deficiencies as the model steam generators. Thus, testing the prototype will not identify all the problems that could occur in the CRBR steam generators. In total, the cost of the prototype steam generator tests is about \$8.2 million.

Prototype testing inadequate

DOE officials have concluded that the prototype might fail if tested to the limits originally specified to simulate anticipated CRBR operating conditions. As a result, the test program for the prototype was changed to delete or reduce the severity of the tests that were originally planned. The revised test plan approved in July 1981 does not include requirements to demonstrate the

- structural integrity of the steam generator, a major cause of failure in foreign breeder reactors,  
or
- ability of the steam generator to withstand large temperature changes occurring over a short period of time, the major cause of the model steam generator failure.

In addition, the prototype test never was planned to include the ability of the steam generator to withstand flow induced vibration, the major cause of the Fermi steam generator problems. These tests are critical to predicting performance because they involve the areas most likely to cause failure.

DOE will not fully test the  
CRBR steam generator design

As currently planned, DOE will not conduct complete and thorough tests of the steam generator design before they are installed in the CRBR. The nine CRBR steam generators and one backup unit are scheduled for delivery between January 1985 and May 1986. DOE plans to test a one-third scale model for flow-induced vibration and at a later date, install various performance-measuring instruments in two CRBR steam generator units and, after all units are installed, conduct pre-operational testing in the CRBR.

The one-third scale model tests will not provide all needed data on the structural integrity of the steam generator design or its ability to withstand large temperature changes over short periods of time. As mentioned previously, problems in these areas have plagued other breeder reactor steam generators. The inplant tests would provide some information related to these issues, but it would be conducted only after the CRBR steam generators have been completed, resulting in the same situation as the concurrent model steam generator tests and prototype fabrication. That is, by the time the inplant tests could occur, it would be too late to modify the CRBR steam generators to correct any major problems that may be discovered without incurring substantial costs and delays.

DOE previously considered complete and extensive testing of a full-scale CRBR steam generator at its Santa Susana, California test facility, in addition to the tests for flow induced vibrations. DOE currently, however, does not plan any additional tests of a full-size steam generator. DOE's Chief of the CRBR plant component branch said that the current steam generator test program is adequate to confirm the design, and that DOE does not wish to unnecessarily delay the CRBR project. According to DOE officials, testing a full-scale CRBR-design steam generator could delay the program by as much as 45 months if fabrication of the CRBR steam generators is halted. If fabrication of these units is not halted, eight CRBR steam generator units would be delivered by the time the test results are available in April 1986. The remaining CRBR steam generators and the backup unit would be substantially complete by that time and would be too far completed for major modifications without incurring large cost and schedule slippages.

Clinch River project officials contend that despite the problems that have been experienced with steam generators, more extensive CRBR steam generator tests are not required, and the tests being conducted are adequate and can be extrapolated to provide the information necessary to predict inplant performance. A Clinch River project official believes additional testing prior to fabrication of the remaining CRBR steam generators would unnecessarily delay the project. Our consultant recognizes the potential problems in the areas of structural integrity and ability of the CRBR steam generators to withstand temperature changes. He also acknowledges that the planned tests will not provide adequate data in these

areas. However, he agrees with DOE that any steam generator tests that would result in a delay in the construction of the CRBR are not appropriate.

DOE's prime contractor for the CRBR--Westinghouse Electric--stated that the information gained from the prototype tests will be inadequate for resolving concerns about vibrations and recommended the one-third scale model tests. Westinghouse, however, also recognized that neither test would provide data concerning structural integrity or the CRBR steam generator's ability to withstand temperature changes.

In a February 26, 1982, letter to us, officials of Atomics International--the original designer and fabricator of the prototype steam generator--expressed disagreement with DOE's CRBR steam generator testing program. Atomics International officials recognized that it is highly desirable to minimize development cost, but that it is also highly desirable to minimize the risk of (1) forced outages from failure of untested features and (2) delays in licensing due to a lack of data from component testing under simulated reactor conditions. They noted that the CRBR steam generator design incorporates features which substantially differ from the prototype and are unsupported by tests. According to Atomics International officials, even after completing the prototype test, CRBR steam generator design and performance uncertainties will remain. Atomics International officials concluded that extensive testing of a full-scale CRBR steam generator and a scale model steam generator would eliminate the uncertainties.

In addition to delaying the program for up to 45 months, DOE officials estimate that installation and testing of a full-scale CRBR steam generator would cost about \$7 million. This would however, eliminate the need for testing the prototype steam generator. Cancellation of the prototype test would save about \$3.2 million, which would reduce the additional cost of testing a full-scale CRBR steam generator to less than \$4 million. The resulting program delay and any accompanying inflationary increases would also, of course, impact on the overall CRBR cost and schedule.

We note that DOE's position on testing steam generators is inconsistent with its programs to develop other, perhaps less critical CRBR components. For example, DOE is testing the sodium pumps extensively. These tests have already proved worthwhile because a deficiency, which may result in a change in the plant unit design, has been discovered. It is exactly this type of situation which causes our concern over not testing the CRBR steam generators.

In lieu of tests to provide assurance that CRBR's steam generators will operate as required, DOE could obtain operability guarantees from the steam generator designer or fabricator. However, the contractor, which is selected to fabricate the CRBR steam generator, will have to guarantee only that the steam generators will be built in accordance with the design provided by Westinghouse. DOE officials stated that they will not request an operability guarantee for the fabricator because no company

would provide such without first reviewing in detail the steam generator design. DOE officials stated that such a review would delay the program and increase program costs.

If the steam generators were to be built in accordance with the stated technical requirements, but failed because of design deficiencies, the Government would have to assume the additional costs of amending the design and reworking the steam generators because the design has not been guaranteed by Westinghouse--the lead reactor manufacturer. DOE officials explained that Westinghouse officials would not likely guarantee the steam generator design because it is developmental and a guarantee of that nature would be too risky.

### CONCLUSIONS

In essence, DOE's steam generator testing program is based on the urgency of proceeding with the CRBR. This has been pointed out most recently in a DOE letter containing comments on a draft GAO report on options for the timing of the liquid metal fast breeder reactor program. (See p. 3.) While recognizing DOE's concerns and its desire to move forward as expeditiously as possible, our work shows that changes in the factors affecting the timing of when breeder reactors may be needed make slowing the breeder program and the CRBR a viable option.

The highly critical nature of the steam generator to overall CRBR success makes a strong argument for taking a cautious, conservative, and prudent approach to developing, fabricating and testing the CRBR steam generators. DOE--as well as our consultant--disagree and are confident that the steam generator, as currently designed, will operate as predicted. They base this position on their confidence in the technical design and testing program, and because they do not believe the CRBR program should be delayed by steam generator testing. This position, however, is not supported by (1) the history of steam generator development, (2) the test results to date, (3) DOE's program to test other CRBR components, and (4) the DOE contractor who designed and fabricated the prototype steam generator.

We recognize that all steam generator problems are not related to design deficiencies and that testing cannot eliminate all elements of risk. The ultimate test must come when the steam generators are operated in the CRBR. A good testing program can, however, minimize the risk involved. In this regard, DOE's current test program does not minimize the risk involved as it will not provide complete and thorough information in two critical areas where problems have been experienced in other breeder reactor steam generators, both in this country and abroad--the structural integrity of the steam generators and their ability to withstand large temperature changes over short periods of time. Without testing the CRBR steam generator design to obtain data in these two areas prior to fabricating the CRBR steam generators, DOE is assuming that the steam generators will work. If DOE is

right, CRBR will be completed sooner at a lower overall cost. If wrong, it will prove a more costly and time-consuming risk to take.

In our view, DOE has several fundamental options to obtain the required data. More complete and thorough tests of the one-third scale model would provide much of the required data, but would be limited in that it would not provide full-scale data. Testing a full size CRBR steam generator could theoretically provide more complete data, but may not provide full vibration data. A third option would involve a combination of the scale model and full-scale tests and would provide data in all critical areas. Although conducting any additional testing would increase program costs and delay the program, we believe that minimizing the risks through a more complete and thorough testing program is far more attractive than the risk associated with purchasing steam generators which may not operate as required. Should the steam generators prove inadequate for optimal operation in CRBR, DOE would have to finance modification of the 10 completed steam generators or scrap the completed units and build 10 new steam generators.

We recognize that because of the complexity of the CRBR and because it is a research and development effort, some element of risk will always be involved. However, we believe a cautious, conservative, and prudent approach to developing, fabricating and testing this highly critical component should be taken to minimize that risk. For this reason, the information developed in our review is most supportive of the following courses of action.

- Stopping the CRBR prototype steam generator test program because of the limited value of testing a steam generator which differs significantly from the current CRBR design.
- Canceling the current solicitation for the fabrication of 10 CRER steam generators.
- Developing a program for more complete and thorough testing of the CRBR steam generator design in as expeditious a timeframe as possible.
- Withholding a decision on procuring the CRBR steam generators until test results are received and evaluated and any necessary design modifications made.

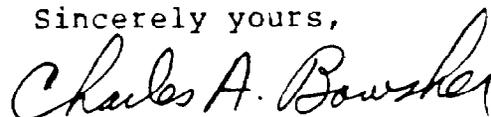
#### RECOMMENDATION

We recommend that the Secretary of Energy evaluate the information presented in this report, as well as the risk assumed in not conducting more complete and thorough tests of the steam generator design, in deciding on how to proceed with the procurement of the CRBR steam generators.

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As arranged with your office, unless you release or publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of the report. At that time, we will send copies of this report to the Director, Office of Management and Budget; the Secretary of Energy; and to other interested parties and make copies available to others upon request. At your request, in order to provide this report in time for use during the appropriation process, we did not solicit DOE's comments on this report. The information presented in this report was, however, discussed with responsible DOE officials to ensure accuracy.

Sincerely yours,



Comptroller General  
of the United States