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ATOMIC PRODUCTS
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ATOMIC POWER EQUIPMENT DEPARTMENT

March 1, 1963

Mr. Saul Levine, Chief
Test & Power Reactor Safety Branch
Division of Licensing and Regulation
U. S. Atomic Energy Commission
Washington 25, D.C.

Dear Mr. Levine:

Enclosed herewith are five (5) copies of a Supplementary Report concerning redesign of the GETR control rods.

This information is being forwarded to you in the hope that it may assist in your review of Proposed Change No. 1 sent to Mr. Lowenstein's office today.

Very truly yours,

B. D. W[illegible]
Administrator-Licensing
Building N - Room 114

ems

Enclosures

DOCKET NO 50-70 (Suppl)
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SUPPLEMENTARY REPORT

ON

GETR CONTROL ROD REDESIGN

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U.S. Atomic Energy Commission
Division of Licensing & Regulation

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USAEC
Division of Licensing & Regulation
MAR 4 1963
Docket Officer

General Electric Company
Atomic Power Equipment Department
2151 South First Street
San Jose, California

1625

SUPPLEMENTARY REPORT ON GETR CONTROL ROD REDESIGN

I. INTRODUCTION

The General Electric Test Reactor (GETR) has operated for approximately four years using the original control rod design (Mark I). Some minor changes, such as clearance and tolerance revisions have been made, but in general the basic rod design has not been altered. Some deficiencies in the original rod design have been evidenced by failure of certain parts or materials. The GETR was designed with a substantial safety margin so that the rod failures noted to date have not created an unsafe condition. Failures of a control rod are, of course, undesirable in any form and have in many cases created considerable inconvenience.

The failures experienced in the control rod assemblies to date can be categorized as follows:

A. Component: Rollers have become inoperative. The latches have been damaged by handling and extended usage. In some cases repairs have been made by replacing damaged parts. Screws have been lost from the fuel sections.

B. Materials: The boron-stainless steel has become embrittled and cracked. In some cases pieces of the poison material have chipped off. Some of the welds in the poison material have cracked. The graphite bushings in the rollers failed.

C. Operation: Damaged latches caused operational inconveniences and foreign material (loose screw) has caused rods to seat improperly.

These three areas have been evaluated and based on this information selected components have been redesigned and some material changes have been made. Similar operational failures have been experienced at the Engineering Test Reactor (ETR). The ETR and GETR have control rods which are quite similar in design and operation.

The ETR control rods have been redesigned and in order to conserve time and still have a proven design many of their features have been incorporated into the redesigned GETR rods (Mark II). In particular, the latches and rollers have been patterned after the ETR design. The method of attachment of the poison material is not the ETR design. The following sections present a complete description of the design changes proposed for the Mark II GETR control rods.

II MECHANICAL DESIGN

Experience with the Mark I GETR control rods (as described in the Introduction) has given valuable information in determining the design criteria for Mark II features. Improvements were desired in the control rod latch mechanism, roller assemblies, and structural integrity of the poison element.

The present latch design has presented many operational problems due to excessive friction in the actuating cam and insufficient strength of the latch dog supporting shafts. These two items have caused much difficulty during insertion and removal operations.

Roller assemblies on both the poison and shock sections originally had graphitar bushings which failed frequently. Elimination of the graphitar bushings on manufactured spare poison elements and subsequent operation showed that such bushings were not necessary. The fixed roller shafts were not mounted with sufficient support and several were found loose during routine inspection.

The poison element construction has presented the major problem with the GETR control rods. The boron-stainless steel has performed well as a poison material, however, this material has presented serious problems when performing as a structural member of the element. Radiation damage of this material makes it undesirable as a load bearing member of the control rod. Material failures have occured where the boron-stainless steel supports the latching mechanism and in areas weakened by roller holes. Fusion welding problems present in the eight original elements have been eliminated in successive elements by developing improved welding techniques.

From the above information, analysis of failures, operational difficulties, and hot laboratory repair experience, the following features are included in the Mark II design.

1. Poison Element: The boron-stainless steel material performs no structural function; i.e., rollers, latches, etc. do not depend upon the poison material for support.

2. Latch Mechanism: The latch mechanism has no moving parts except for two spring fingers on both the poison and shock sections. The fuel element "latch mechanism" consists only of engagement holes for the poison and shock spring fingers.

3. Roller Assemblies: Roller assemblies, both spring mounted and fixed, have been improved by redesigning to more compact assemblies, better pin attachment and stronger roller cages.

4. Repair Features: All latch and roller assemblies are mounted in such a manner to facilitate replacement.

The Engineering Test Reactor originally used control rods similar to the Mark I GETR rods. Their operational experience was essentially the same as that at GETR. Redesigned control rods have been in use at ETR since early 1961. The design has been entirely successful and has been reviewed with GE personnel on several occasions. The GETR Mark II design utilizes the ETR latch and roller design. The ETR test programs and operating experience has been extensive and is completely applicable to the GETR Mark II rods.

Design Details of the Mark II Control Rods are as follows:

1. Poison Element (Dwg. 212E916): The poison element is built around a welded stainless steel box section with a 0.125" wall thickness. The poison material, four 0.100" thick type 304 stainless steel plates with 1% boron enriched to 92% B^{10}, are mounted on the outer sides of the box structure and this assembly is enclosed with a stainless steel sheet, 0.015" thick. Each of the four boron-stainless steel plates is fastened to the outside of the structural box assembly by four screws which also hold the skin to the poison material. Roller and latch assemblies are fastened directly to the box structure and transmit no loads to the poison material.

   The stainless steel skin completely covers the element and retains the boron-stainless steel. Structural failures of the boron-stainless steel material (cracks) do not affect the element's operation, since the poison material cannot escape. The stainless steel cover is held against the assembly by the four screws holding the poison material. The cover and poison material are also retained by the latch and roller mounting screws without transmitting loading to the poison.

   The .015" thick stainless steel cover is spot welded to the poison material at various locations along the assembly length.

The gap between the cover and poison material is limited to a maximum of .003 inches. Vent holes in both the cover and box structure are provided.

Two latch assemblies are provided on each poison assembly. Each consists of a hook finger mounted in a latch guard. Assembly of the poison and fuel element is performed in the guide tube by inserting the poison latch into the fuel element. The fuel element has square holes into which the spring fingers move and provide a positive latch. Unlatching is performed by pulling the complete poison element and several inches of the fuel section out of the guide tube and rotating the poison element 45°. A cam surface machined in the fuel element depresses the latch fingers as the poison is rotated and frees the poison element.

The latch guard performs two functions: 1) protecting the latch spring fingers from inadvertent loads and deflections, and 2) provides alignment in one direction between the poison and fuel elements. Alignment in the other direction is provided by two ears on the poison element which insert into a machined recess on the fuel element.

Mounting holes for latch assemblies are provided on both ends of the poison element. Latches are installed only on one end but may be removed and installed on the opposite end. This allows the element to be reversed if desired.

2. Fuel Elements

a. 14-Plate Element (Dwg. 144F666) - Existing fourteen plate Mark I fuel elements (unirradiated) will be modified to allow use with the new poison and shock elements. The modification consists of machining off both ends of the element, removing the existing latching mechanism, and welding new end boxes on both ends of the element. The ends are then machined to provide the latch spring receiver holes, cam surfaces, and alignment surfaces for the poison and shock latches.

The latch actuating plate existing in the original element will be removed and replaced with two dummy (non-fueled) plates.

Installation and removal of the fuel element is identical to the handling of the poison element as described above.

b. 16-Plate Element (Dwg. 144F606) - Future elements will be of the 16-plate design. This element is identical to the modified 14- plate element except the additional available center space is utilized to include two additional fuel plates. Total fuel loading for the assembly will not be increased. This element is reversible to obtain maximum fuel utilization.

End identification is obtained by having one spacer comb on the bottom end and two combs on the top end.

3. Shock Section (Dwg. 612D177) - The shock section design is basically unchanged. The new latches have been added to the upper end and the new style roller assemblies are used. The piston has been modified slightly to simplify manufacturing operations.

4. General Items

   a. All screws used in the control rod assembly are staked by spot welding. This method has been used successfully on other GETR components.

   b. The spring roller design used on both the poison and shock section, plus the removal of the original poison element latch mechanism reduces the inside flow restrictions considerably.

   c. Outside dimensions and over-all lengths of all control rod components remain unchanged with respect to the original control rod dimensions.

5. Materials - An extensive materials review was made during the design phase of the control rod project. Adequate experience with all materials used has been collected by APED on various projects and development test programs.

All stainless steel components are Type 304 Stainless Steel. Roller springs and shafts, latch springs and guards are AMS 5667F (Inconel X). The shock section piston material is Armco 17-4 PH stainless steel.

III HYDRAULIC DESIGN

Since there is great physical similarity between the present ETR control rod and the Mark II GETR control rod, the hydraulic performance of each should also be similar. An extensive hydraulic test program was conducted by the ETR on this design and reported in detail in IDO 16671. Based on these data the GETR Mark II control rod will have about 10% more coolant flow than the Mark I rod has. This increase in flow is due to the more streamlined design of the latches and rollers in the Mark II rod. The fuel loading has not been increased in the Mark II rod as compared to the Mark I loading. It is, therefore, evident that cooling of the Mark II rod, (primarily the fuel section) is assured since the power is essentially unchanged and the flow will be increased over Mark I conditions. The experience and test data of the ETR was relied on for the redesign effort and adds to the confidence in these new rods.

IV NUCLEAR DESIGN

The Mark I GETR control rods were considerably over-designed from a physics standpoint. Since the basic box-design is a flux trapping device (neutrons are moderated by the inside water and then captured by the poison), the wall thickness of the poison material could be reduced without significantly changing the reactivity worth of the rods. The principal reason behind changing the control rod design is to allow the mechanical life of the rod to more nearly approach the nuclear life. The new design utilizes a thinner poison section sandwiched by stainless steel on the inner and outer surfaces. Physics design calculations and experimental tests used to substantiate these calculations have been made. It is planned that a complete rod calibration will be performed when the Mark II control rods are installed in the reactor.

1. Design Calculations

The Mark II control rod design, from a nuclear standpoint, was based upon physics calculations comparing the total number of neutron captures within a new poison section to that for the present control rod design. These comparisons were made using a one dimensional P-3, monoenergetic, transport theory calculation. On the basis of these calculations, the following design was chosen: Type 304 SS poison section with 1 w/o enriched boron - a 2.275" sq. poison section x 0.090" wall, 1/8" thick SS on inner surface of poison with 0.015" thick SS on outer surface. The reactivity worth of the rod bank was calculated to be 16.8% $\Delta k/k$, compared with 17.5% $\Delta k/k$ worth for the present control rods. The 16.8% $\Delta k/k$ rod bank worth is satisfactory from a control standpoint.

2. Experimental Verification

In order to confirm the results of the physics calculations, a special poison section was fabricated and tested such that reactivity measurements could be made comparing the effect of the Mark I and II rods. The test poison piece, which contained 0.87 w/o enriched boron in 304 SS, was 2.320" sq. x .105" wall, 1/8" thick SS on inner surface of poison with 0.030" thick SS on outer surface.

Prior to Cycle 41 startup measurements were made comparing the reactivity worth of the new and old poison sections in the E-5 core position. Results indicate that, for this position, the Mark II rod was worth approximately 0.4% $\Delta k/k$ less than the Mark I design poison section. Taking this result and correcting for the position in which the measurement was made to the positions at which the control rods operate, the reactivity worth of the new control rods is expected to be 16.8 $\pm$ 0.4% $\Delta k/k$. This value is acceptable from a control standpoint for GETR operation, since it provides adequate shutdown for the maximum reactor excess reactivity of 11.5% $\Delta k/k$.

V TESTS AND INSTALLATION SCHEDULE

A. Test Program

The following tests will be performed prior to GETR power operation with the Mark II control rods.

1. Design Verification Tests - These tests consists of measurements of latch and roller spring constant, latch joint tensile strength, and measurement of latch insertion force and unlatching torque. These tests will verify design calculations. Parts will be examined for wear after usage in the reactor.

2. Physics Tests - Extensive physics experiments are scheduled during the installation of the control rods. The tests consist of a complete calibration of the control rods at various bank positions.

3. Rod, Scram Time Tests - Control rod drop time tests will be performed at both flow and no-flow reactor conditions. Test results will be compared with previous rod drop data and the GETR Operating Standards.

4. Operational Tests - Tests will be performed to evaluate control rod installation, handling methods and latchability of the new design. These tests will also serve as an evaluation of the control rod handling standard operating procedures and as GETR operator familiarization and training sessions.

5. Hydraulic Tests - No hydraulic tests are required prior to installation since the new design permits an increased coolant flow of 5 - 10%. It is planned, however, at some later date to perform flow tests to obtain a more accurate percentage increase value.

6. Manufacturing Control - Close control during manufacture of the new components will be maintained by both the APED Quality Control Group and the design engineers. APED is well qualified and experienced in fabricating equipment for nuclear applications.

B. Conversion Schedule

Following the above testing program, power operation of the reactor will commence with two Mark II control rods in corner rod positions. At the completion of one cycle of operation, these rods will be inspected in the GETR canal and reinstalled. Two additional Mark II control rods will then be installed. Following the second cycle of operation, inspection will again be performed and complete conversion made. The GETR control rods presently in operation use poison elements which were fabricated in November 1962. Prior to fabrication, the design was modified to strengthen areas which previously had been subject to failure. These poison elements will be in use during the conversion period, but operating time will be limited to an amount shown by previous experience to minimize the likelihood of damage. This limit is based on an extensive review of previous operating history and recent data available on boron-stainless steel material properties.

Following the total conversion to the new design, normal routine inspection procedures will be effected. These procedures require control rod component inspection whenever a control fuel section is replaced. This inspection frequency may be altered following the accumulation of operating and inspection experience with the new rods.