ORNL TM-4898

An Operational Method for Demonstrating Fuel Loading Integrity in a Reactor Having Accessible ^{235}U Fuel

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OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION · FOR THE DEPARTMENT OF ENERGY

ORNL/TM-4399

Contract No. W-7405-eng-26

OPERATIONS DIVISION

and

HEALTH AND SAFETY RESEARCH DIVISION

AN OPERATIONAL METHOD FOR DEMONSTRATING FUEL LOADING INTEGRITY IN A REACTOR HAVING ACCESSIBLE [illegible] FUEL

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Date Published - July 1979

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Department of Energy

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ABSTRACT

The Health Physics Research Reactor is a small pulse reactor at the Oak Ridge National Laboratory. It is desirable for the operator to be able to demonstrate on a routine basis that all the fuel pieces are present in the reactor core. Accordingly, a technique has been devised wherein the control rod readings are recorded with the reactor at delayed critical and corrections are made to compensate for the effects of variations in reactor height above the floor, reactor power, core temperature, and the presence of any massive neutron reflectors. The operator then compares these readings with the values expected based on previous operating experience. If this routine operational check suggests that the core fuel loading might be deficient, a more rigorous follow-up may be made.

INTRODUCTION

It is important that fissionable reactor materials not be diverted for uses other than those for which they were intended. At the Health Physics Research Reactor (HPRR), a procedure has been developed whereby the operator can demonstrate, on a routine basis, that the full complement of reactor fuel is indeed still present in the core.

This procedure has been designed so that it can be used with a minimum of disruption to the normal reactor operating routine. A much more tedious "standard-conditions" test may be performed by the operator whenever a more detailed check of the core fuel inventory is required.

METHOD OF TESTING

A nuclear reactor should repeatedly achieve criticality at the same control rod settings if all parameters remain unchanged. Thus, by demonstrating, under rigorously controlled conditions, that the reactor goes critical with the control rods positioned within the acknowledged accuracy of their prescribed settings, one confirms that the amount of fuel present in the core is correct. The basic test is straightforward, and the only complications concern the treatment of the various influencing parameters and the degree of precision required.

PARAMETERS AFFECTING TESTS

The following parameters were considered during the development of this procedure:

1. Neutron poisons in the core. Neutron poisons are not a problem at the HPRR, because there is no significant buildup of xenon or other core poisons, and the HPRR employs no movable or burnable poisons in its design.

2. Neutron moderators or reflectors at the core. Neutron moderators or reflectors are not designed to be part of the HPRR core.

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3. Large neutron reflectors near the core. Large neutron reflectors may be present in the form of the concrete floor (reactor height determines this effect) or as large shields of metal or hydrogenous materials that are used to alter the radiation spectrum during certain reactor experiments.

4. Control rod positions. Control rod positions are under the direct control of the reactor operator and are subject only to the precision of the control rod limit switches and control rod position indicators.

5. Core temperature. Core temperature is a factor because the HPRR becomes demonstrably less reactive as its core temperature rises. This parameter is difficult to control because the core temperature varies (a) day by day; (b) minute by minute during startup toward high power; (c) location by location within the geometry of the core. Thus, the simple application of the core's known average negative temperature coefficient of reactivity will not automatically satisfy all desired test conditions.

TEST REQUIREMENTS

An effective test should reveal the absence of the smallest piece of fuel that could be removed from the core without major disassembly. It has been demonstrated that the only pieces of core fuel removable with simple tools are the sample-irradiation hole U-Mo plug (105 grams of ^{235}U) and the nine U-Mo bolt inserts (112 grams of ^{235}U each). (See Figure 1.)

A test run was made with one of the U-Mo bolt inserts missing, and a comparison of control rod positions at critical revealed that the missing U-Mo insert is worth 13 cents of reactivity. The sample-irradiation-hole plug is worth slightly more than 13 cents, because it is located closer to the center of the core.

It was decided that a routine test should be developed which will formally demonstrate that the fuel loading is complete within 10 cents of reactivity (86 grams of ^{235}U at the bolt insert location). In practice, such a test should be capable of detecting a deficiency representing as little as 5 cents in reactivity.

ROUTINE OPERATIONAL TESTS

During a normal reactor startup from room temperature the safety block is inserted, the regulating rod is established at 7.0 inches from its fully inserted position, and the reactor is made critical by means of the mass adjustment rod. The mass adjustment rod reading is recorded after a delay of several minutes while successive rod adjustments are made to correct for the contributions from delayed neutrons but before any rod adjustments are made in the opposite direction to correct for the effects of core heating.

As noted earlier, various parameters influence this rod reading and arithmetical compensations are made according to the empirically derived information shown in Figure 2. Compensatory additions are made to the mass adjustment rod readings if: (a) the reactor core height is above 1.5 meters; (b) the reactor power is above 100 watts; (c) the core temperature at startup is above 70^{O}F; or (d) the reactor is in Pulse-Preparation mode (pulse rod latched OUT) rather than in Steady-State mode (pulse rod latched IN). Compensatory values are subtracted from the observed mass adjustment rod readings if: (a) the reactor core height is below 1.5 meters; (b) the core temperature at startup is below 70^{O}F; or (c) if massive shields are close enough to scatter an appreciable fraction of neutrons back into the core.

A rubber stamp has been prepared to facilitate recording on the operating log sheet the rod positons at critical and also the compensatory corrections to be applied. The recorded information (see Figure 3) documents the fact that the core fuel loading was shown to be normal for that particular operation and also preserves the computations leading to that determination.

Figure 4 is a histogram of the distribution of mass adjustmend rod readings at delayed critical for the reactor runs during one quarter of a year; a new histogram is developed each quarter. Also shown on the figure is a portion of the mass adjustment rod calibration curve. The last two digits of the current reactor operation number are first plotted below the base line at the horizontal location corresponding to the uncorrected mass adjustment rod reading determined for that particular operation. Then the various compensations as determined from data in Figure 2 are applied, and the same final two operation-number digits are again plotted, this time above the baseline and at the horizontal location corresponding to the corrected mass adjustment rod reading. If a corrected point falls below the "check point" value (currently 5.50) representing the limiting acceptable reading, it suggests that the core fuel loading may be deficient by as much as 10 cents of reactivity. In practice, any corrected point falling outside the normal grouping will be investigated.

SPECIAL STANDARD-CONDITIONS TEST

A special standard-conditions test can be performed whenever the regular operational test indicates that a more detailed follow-up check should be made. For this more accurate check, the reactor is raised to its highest elevation (5.08 meters) and mass adjustment rod readings are taken at critical with the pulse rod and the regulating rod at their respective limits, thus:

Pulse rod OUT, regulating rod OUT,
Pulse rod OUT, regulating rod IN,
Pulse rod IN, regulating rod OUT,
Pulse rod IN, regulating rod IN.

These mass adjustment rod readings are then corrected to give the readings expected at 70°F (by applying the 0.17¢ per °F negative temperature coefficient of reactivity already established for this reactor), and the results are plotted on the mass adjustment rod calibration curve as shown in Figure 5. It has been observed that these four check points are repeatable within rather narrow respective ranges, and limits of acceptability have been established (currently 0.1 inch above or below the respective check points) which will assure the operator that the core fuel loading has not been altered.

CONCLUSIONS

The routine operational check can be used to detect variations in fuel inventory that are smaller than the smallest piece of fuel used in the core. The special standard-conditions test is available when more precise observations are believed to be necessary. These checks combined with routine visual observation of the core provide assurance to the operator that the fuel loading remains unchanged.

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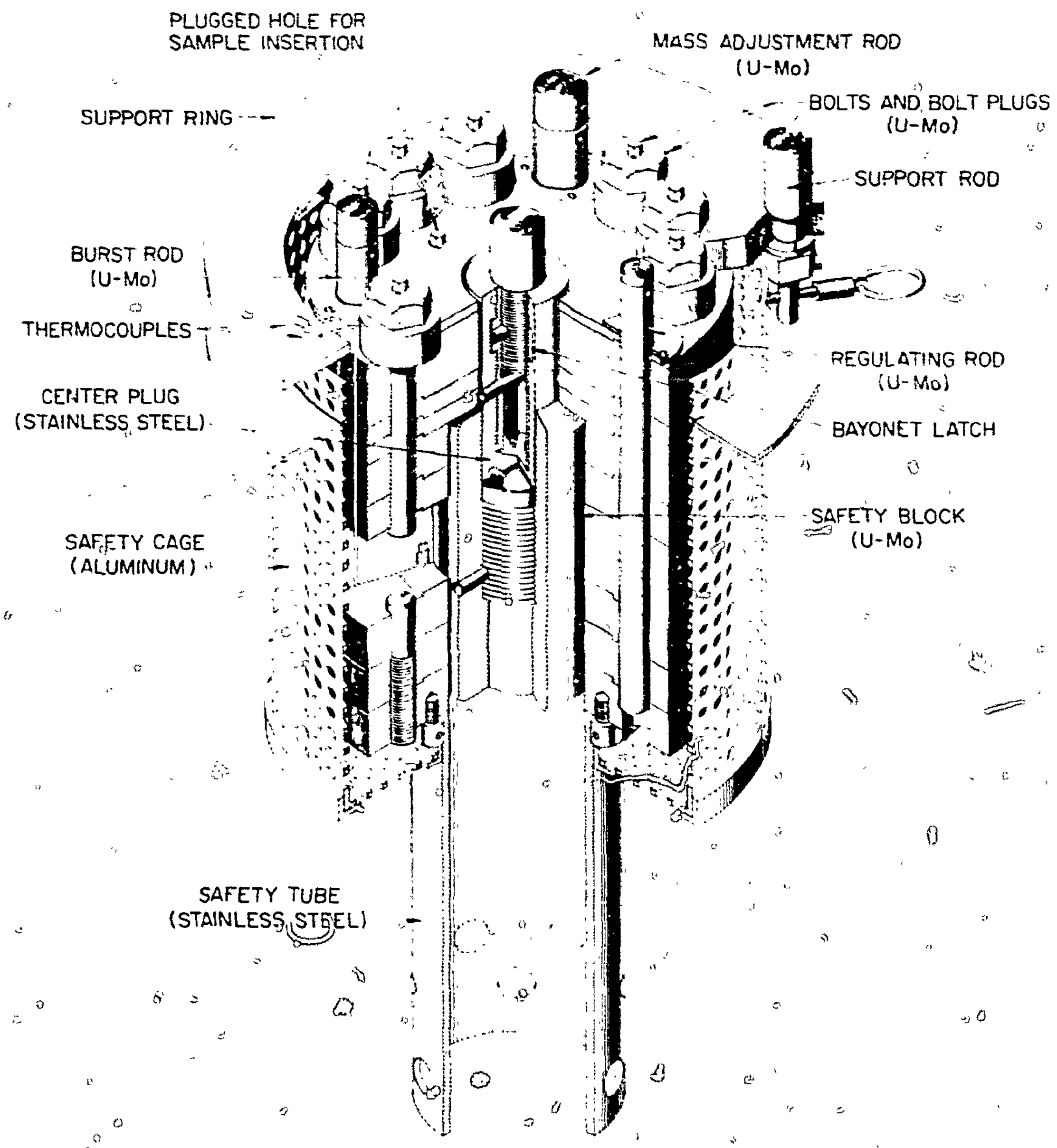

Fig. 1. HPRR Core

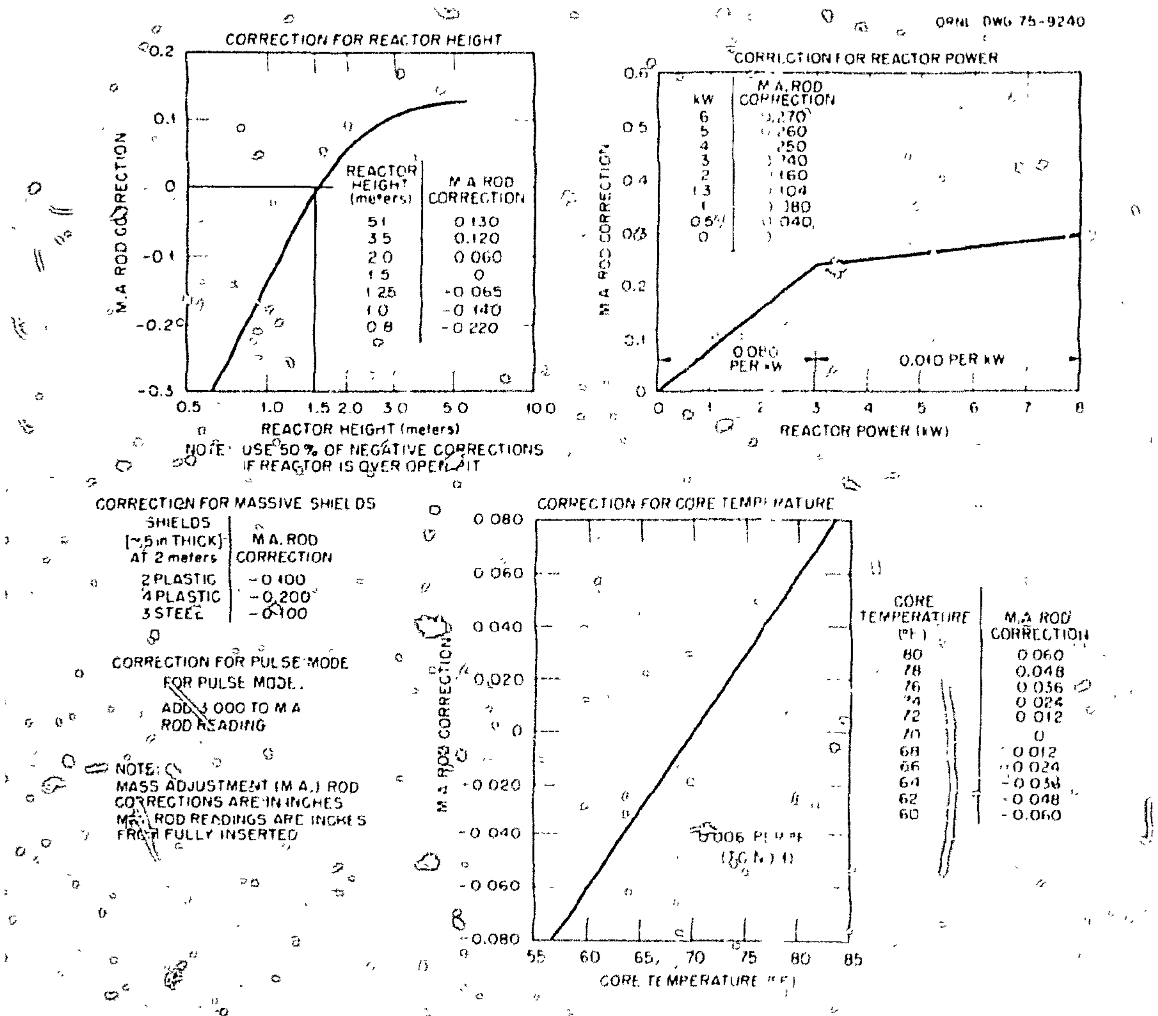

Fig. 2. Empirically Derived Corrections to be Applied to HPRR Mass Adjustment Rod Readings.

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OPERATIONAL CHECK OF HPRR CORE FUEL LOADING

POSITIONS: Reg. Rod	________	M.A. Rod	________
CORRECTIONS:		Total Corrections	________
Reactor Power	________	As Corrected	________
Reactor Height	________	Must Exceed	________
Reactor Temp.	________	Fuel Loading	
Shields	________	Certified OK	________

Fig. 3. Form Used to Record Arithmetical Corrections to Mass Adjustment Rod Readings.

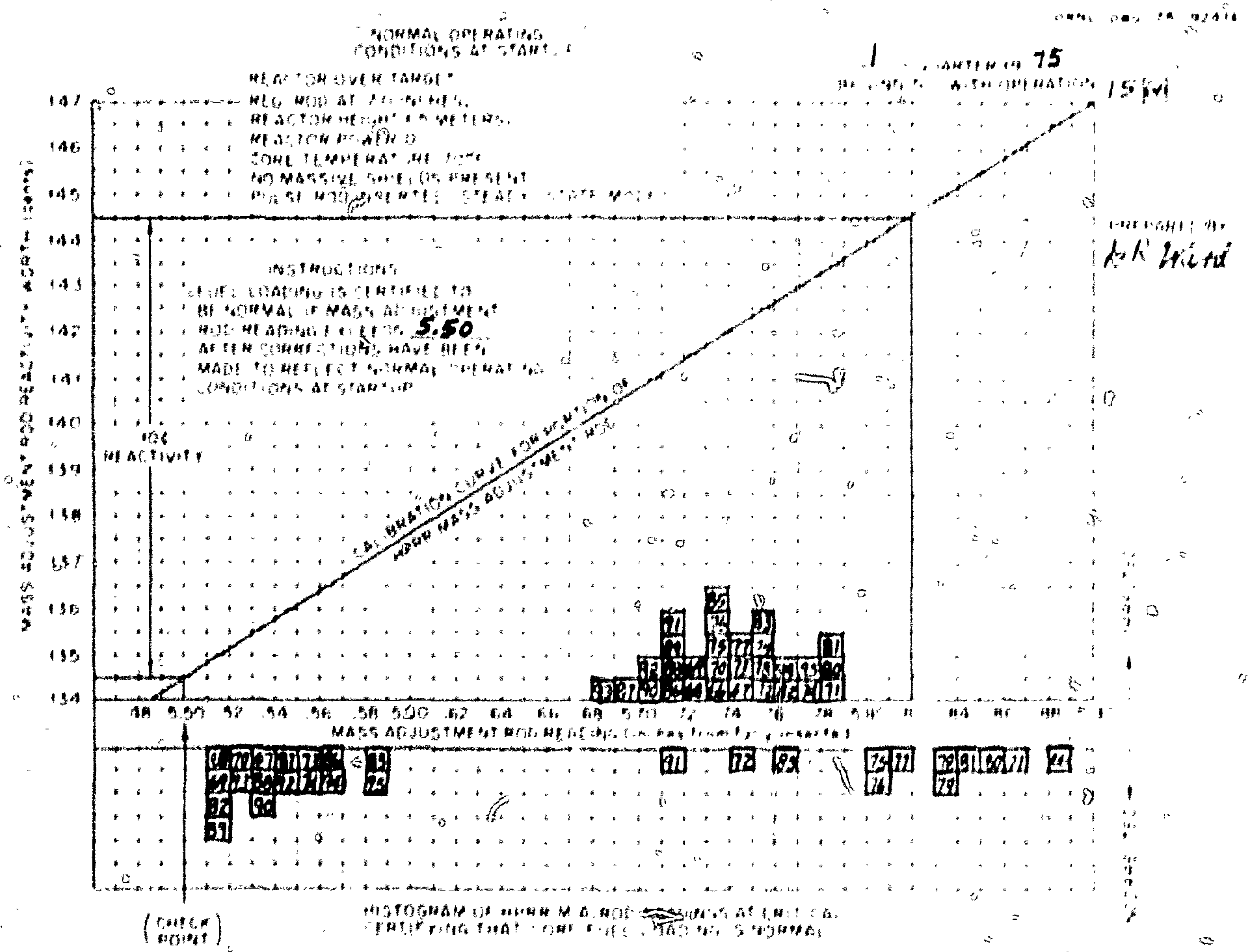

Fig. 4. Typical Histogram of HPRR Mass Adjustment Rod Readings at Critical, Certifying that Core Fuel Loading is Normal.

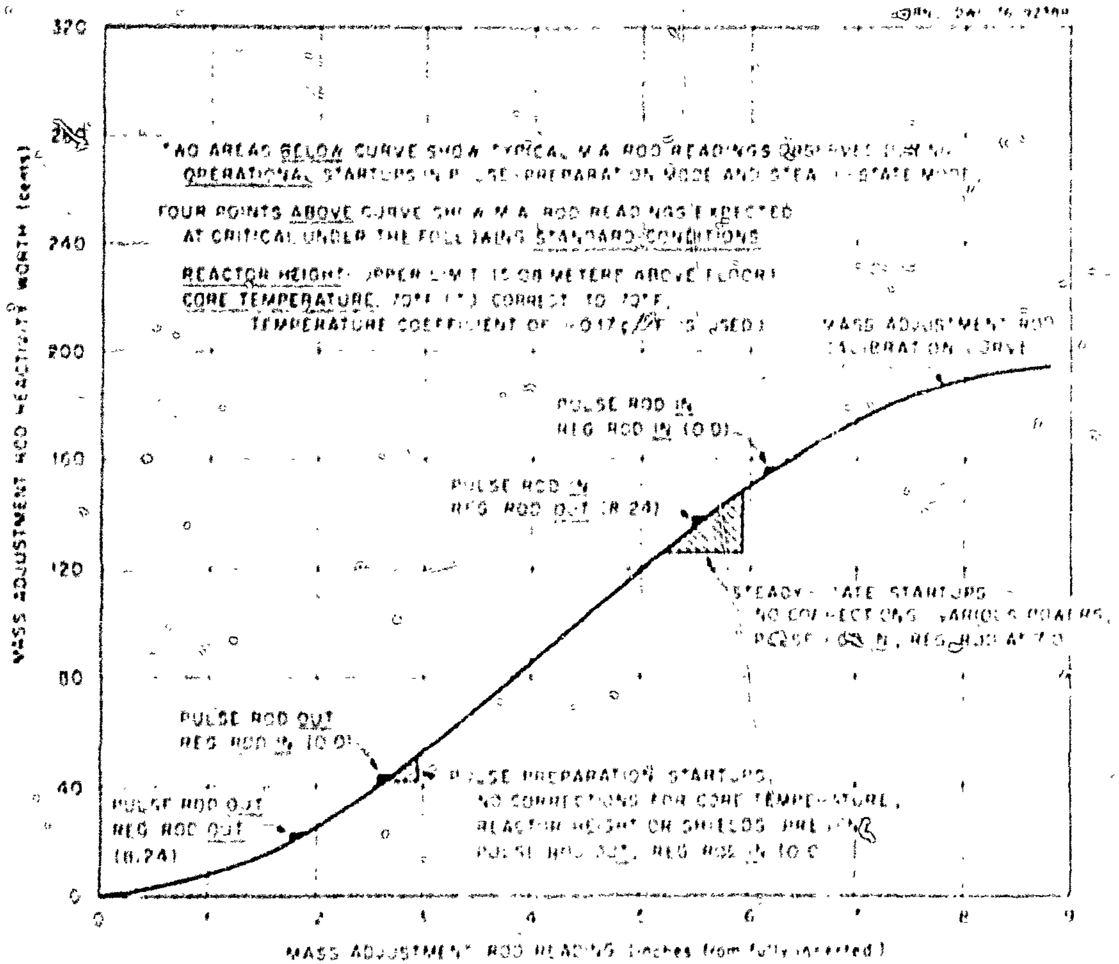

Fig. 5. HPRR mass adjustment rod calibration curve showing readings to be expected at critical under various conditions.

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