hue PRNC 57 PUERTO RICO NUCLEAR CENTER DESCRIPTION OF REACTOR AND EXPERIMENTAL FACILITIES AND INFORMATION FOR EXPERIMENTERS. OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT (40-11-1829 FOR U. S. ATOMIC ENERGY COMMISSION ---Page Break--- * DESCRIPTION OF REACTOR AND EXPERIMENTAL FACILITIES AND INFORMATION FOR EXPERIMENTERS Prepared by the Reactor Division of the Puerto Rico Nuclear Center, Mayagüez, P. R. Operated by University of Puerto Rico under Contract No. AT (40-1)-1833 for U. S. Atomic Energy Commission February 1965 ---Page Break--- TABLE OF CONTENTS Introduction Reactor Description Experimental Facilities Reactor Design Data Core 11 A Parameters Reactor Service Requests Radiation Safety Rules Specific Activity After Intermittent Irradiation Sample Forms References ---Page Break--- LIST OF ILLUSTRATIONS Puerto Rico Reactor - Front and Side Elevations Reactor Pool - Plan View Typical Thermal Column Reactor Room Basement Floor Layout Standard Fuel Element Identification Coding for Storage Rack and Irradiation Facilities Gamma Room Flux Mapping Flux Distribution at Core 11 A Flux Distribution along Center Line of Beam Tube Flux Distribution Curves for Core 11 A Final Configuration of Graphite in the Thermal Column Neutron Physics Parameters Location of Gold Foils Used with Final Graphite Configuration Final Flux Distribution at the Surface of the Vertical Access Position, Fold in Graphite ---Page Break--- INTRODUCTION This manual has been prepared to provide experimenters and other scientific personnel with information regarding the reactor and its facilities. Practical information regarding facility size and shape, gamma or neutron flux, etc. has been compiled in ready reference form for those who use, or who wish to use, the reactor facilities. The information regarding neutron fluxes and gamma dose rates is representative and is intended to serve only as a guide in planning an experiment. A section containing regulations and procedures for obtaining irradiation services and for

performing gross activity determinations has been included. ---Page Break--- DESCRIPTION OF REACTOR AND EXPERIMENTAL FACILITIES 1. REACTOR DESCRIPTION, (1) The 1 megawatt pool-type research reactor is a light-water moderated, heterogeneous, solid fuel reactor in which water is used for cooling and shielding. The reactor core is immersed in either section of a two-section concrete pool filled with water. One of the sections of the pool contains an experimental stall in which beam tubes and other experimental facilities converge. The other section is an open area permitting bulk irradiation. The reactor can be operated in either section. The pool is spanned by a manually-operated bridge from which an aluminum tower supporting the reactor core is suspended. Control over the reactor core is exerted by inserting or withdrawing neutron absorbing control rods suspended from control drives mounted on the reactor core bridge. Additional control is provided by the temperature coefficient of reactivity. The aluminum tower and movable bridge are shown in Figure 1. Heat created by the nuclear reaction is dissipated by a forced circulation cooling system. Externally located pumps, a water-to-water heat exchanger, a cooling tower, a demineralizer plant, and a filter complete the water handling system for the reactor pool. REACTOR SPECIFICATIONS Fuel 20% enriched U-235 in U_3O_8 and Al dispersion MTR type, Al clad fuel assemblies (18 plates) Power One megawatt (heat) Lattice 54 holes on 6 x 9 rectangular pattern Moderator H_2O Reflector Beryllium and graphite Shielding H_2O, Lead, barytes concrete, and regular concrete Cooling Primary loop - heat exchanger Secondary loop - cooling tower ---Page Break--- FIGURE 1 PUERTO RICO REACTOR - FRONT AND SIDE ELEVATIONS ---Page Break--- Water Purification control Irradiation Facilities Operating Conditions: Maximum fuel plate sheath temperature Primary water flow rate Coolant inlet temperature Coolant outlet temperature core pressure drop Secondary water flow rate Secondary coolant inlet temperature

Secondary coolant outlet temperature demineralizer flow rate. EXPERIMENTAL FACILITIES. The experimental facilities are designed for the irradiation of materials while affording protection to personnel. Continuous demineralization of a portion of the primary flow. Boron-carbide shine rods, 1 stainless steel regulating rod, 6" beam tubes, 8" beam tubes, pneumatic rabbits. Thermal column design facility. 10°F, 900 °P, 00°F, 107.6°F, 1 ps, 700 cm, 95.0°F. The facilities described below furnish means for embedded in the concrete walls of the stall area at core level are the beam cube locations shown in Figure 2. Doors and plugs afford access to the external pneumatic rabbit loops. Two 5-inch diameter and four 6-inch diameter beam tubes and a 4 by 9 foot thermal column. At the outer pool surface, shielding for experimental units. In addition, access is provided 4m horizontal planes outward from the reactor core. The basic tube. ---Page Break--- with WMG ~ ToOd ae MBIA NVId 2.8: ---Page Break--- Assembly consists of an embedded stainless steel sleeve, retractable aluminum liner, and a set of interior shielding plugs of canned barytes concrete and lead. Provisions are made for loading the beam tubes with device state (be) pneumatic rabbits. This facility is a constant-exhaust system of concentric aluminum air lines which carry a sample carrier or rabbit into the high neutron flux areas at the core. Automatic timing controls the period of irradiation and retrieval of the air valving. The exhaust air is filtered and monitored before discharge to the atmosphere through a stack. Thermal Column: The Thermal Column (Figure 3) is a stacked lead assembly for irradiation experiments with highly thermalized materials. A steel and aluminum chamber is cast integrally with the stall wall and the barytes shield at core level. This chamber is square and extends horizontally from the inside wall of the stall to the outer surface of the barytes shield. Forming a part of the embedment is a circular vertical access chamber extending from the top of the shield.

downward to the horizontal chamber. The inner surfaces of the chamber are lined with boral sheet which reduces activation of the embedment and the adjacent concrete. Stacked within the boral liner for the length of the horizontal chamber is a closely packed arrangement of graphite blocks. Fastened over the outer face of the graphite stacking is a boral plate backed up by a lead block shield. A square opening in the shield is provided for the insertion of lead plugs. A 1½-inch thick, 5' x 6" square barytes concrete door covers the entire exposed area of the horizontal column at the face of the barytes shield. Access to the thermal column vertical face is provided by means of the overhead crane system, which opens the barytes concrete door. The door is pinned against the vertical face by a safety lock bar at the top of the door. A central square opening allows for the introduction of a shielding plug. The smaller plug in the door and in the inner lead shield permits the insertion of small specimens for irradiation experiments while the door is kept shut. The vertical portion of the thermal column is an air chamber with the opening at the top of the barytes shield closed by a lead plug and a concrete access cover. Both the cover and plug have lifting lugs to permit removal by the overhead service crane. ---Page Break--- "NWNM109 WWBHL- £ 3uNdId Nwn09 WHMSHL MUHL NOLLORS TWOILYBA ---Page Break--- A lead and graphite assembly forms the portion of the thermal column between the rear face of the reactor core and the outer wall of the stall. This assembly consists of an aluminum support frame bolted to the stall floor mounting pads. A lead shield is bolted to the front of the frame immediately adjacent to the reactor core, and a graphite and lead can assembly is fastened directly behind the lead shield. (1) Gamma Room. (2) The Gamma Irradiation Room is an integral part of the reactor pool structure and is adjacent to it at the first level on the east side of the building. The room is a cube approximately six feet square.

It has 2 tapering sides that terminate in a four-foot-square aluminum window (Figure 4). This window is the only partition between the room and the reactor pool, and it is located at a depth of approximately twenty-seven feet. Access to the irradiation facility is through a five-foot-thick high-density concrete door mounted on a railroad-type dolly, which can be rolled back. Operations are performed by placing highly enriched elements in a rack adjacent to the aluminum window. Any number of fuel elements, up to eight, are placed in this rack, which can be moved by means of an overhead crane. Removing the fuel elements to a distance of approximately eighteen feet from the window will bring radiation exposure inside the gamma facility below the permissible operational level of 7.3 mR/h. A factory-calibrated ionization chamber type detector connected to a microammeter and recorder is being used at present. Since flux intensity varies according to the distance and because the chamber volume is fairly large (diameter 3", height 12"), it is impossible to obtain an accurate measurement of the irradiation dose at a given point. For greater accuracy on simultaneously irradiated samples, individual monitors must be used. Gamma ray dose rates from six fuel elements after a one-day decay period are of the order of 15 kilo-roentgens per hour at zero distance.

3. REACTOR DESIGN DATA

(2) Introductions

The core described in this report is a 30-element unit in a 6 x 5 array, which contains 20 standard (18-plate) fuel elements, 5 partial (18-plate) fuel elements, and 5 control (9-plate) fuel elements. This assortment permits adjustment of core excess reactivity by rearrangement of the standard and partial fuel elements to compensate for U-235 burnup and for low cross-section fission.

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(seyoul) TIWM WONS 3ONVISIC « * oe ” (pazyowsouy 30a —oo — 1, | _ _ _ p——- a _ - PS | —- —T T i —T | _ | + —- — —_}—_-|— yoold WOYd 21 ONY JNIT ¥aLN39 iv (@sop pezijpwiou) ONiddVW XMM14 WOOu VWAVS t ---Page Break--- product poisoning. The core has been designated as core number LL, with core ILA representing the stall end configuration and core II B the open pool configuration. The fuel elements for the PRNC reactor consist of 20% enriched UO2 compound dispersed in powdered aluminum. The U-235 mass per standard fuel element is 192 grams, the partial and control fuel elements contain 96 grams. (b) Summary of Reactor Parameters. TABLE 1 Core Characteristics Type Power Level (initial) Power Density Moderator Coolant Reflector Open Pool Position Stall Position Coolant Flow Avg. At Across Element Cold Clean Critical Mass (Core II A) Operating U-235 Mass Effective Prompt Neutron Lifetime (avg.) Temperature Coefficient (avg) Mass Coefficient (avg) Avg Thermal Neutron Flux in Fuel 4h the Power Heterogeneous thermal 1,000 kilowatts 208 kW/kg U-235 40 20 40 W,0, Lead and Graphite 900 cP™ 7.6 4223.5 g 4799.5 g 6.0 x 10^7 sec 5.5 x 10^7 Brrr 5:25 10^ BE) gram U-235 12 5.2 x 10^10 n/cm^2 sec In the excursion calculations of the hazards analysis, the neutron lifetime is quoted as 6.1 x 10^8 sec, applicable for the U-shaped core under a value which is lying in the hazards analysis. ---Page Break--- Fuel Elements Number of Fuel Places Standard Element Partial Element Control Element Mass U-235 per Element Standard Element Partial Element Control Element Number of Fuel Elements in Core Standard Elements 20 Partial Elements 5 Control Elements 3 Control Rod Number 4 shim safety rods plus type worth leads playfully fall Absorbing

Material Shim-Safety Rod 240+ ca. Liner Regulating Rod stainless steel Reactivity Worth Core IA 751 OK & 4 Shim-Safety Rods + 88 Oe + 098 A Total Worth set at worth Worth 74 Core Kage (all rods fully inserted cold clean condition) Core II 4 0.91 Core II B 0.95 ---Page Break--- Experimental Facilities

Reactivity Effect (Beam Tubes, air-filled vs water) ‘4 six-inch diameter beam tubes ~0.58% AK 1 graphite thermal column 10.856% AK Reactivity Allowance for 1 MW Operation are Equilibrium Xenon-135 1.40 Equilibrium Samarium-149 190 Temperature Effect 104 Experiments (other than Beam Tubes) 100 Control 130 U-235 Burn-up and Low Cross Section Fission Product Accumulation for 75 MWD +30 Total on gK * This value (4.16%) is less than 50% of Shim Rod value for core 11 A, ---Page Break--- TABLE 11 + CORE TTA PARAMETERS. (a) RATIO OF Og / Je (AVERAGE NEUTRON FLUX TO ELEMENT TO AVERAGE NEUTRON FLUX IN CORE) FOR DIFFERENT CORE POSITIONS. Position 1 Hip, Position 2, 652, 77 - 785 2 1.687 3 318 3 1.310 4 +390 “4 at ~ 460 “ 002 873, et +390 2 1.000 2 1.063 3 1.496 4 1.523 “ 922 4 902 +856 - to 996 Pa 140 ~ 1584 2 902 “3 1.805 ~ +830 “ Low “ 834 = +808 352 ---Page Break--- TABLE 12 (>) THERMAL NEUTRON FLUX AT VARIOUS DISTANCES FROM CORE THERMAL NEUTRON FLUX AT VARIOUS DISTANCES FROM CORE. MID PLANE EXTENDING OUTWARD IN A NORTH DIRECTION ‘MID PLANE EXTENDING OUTWARD IN A NORTH DIRECTION » (ea) 4 (open? see ° 5.016 x 10^7 1 6.057 3 6.440 ‘ 5.810 10 1.966 15 7.058 x 10^7 20 2.m2 25 Lun 30 4.257 x 10^7 35 Lrse 38 Luis ---Page Break--- DISTANCE FROM CORE (cm) “CORE MID FLUX AT: E 28 Bfewnece a a" sesgwaru @ ---Page Break--- for AOR FUT ACTIVATION on BARE FILLS {4 jr Pry a ~| 410 — ACTIVATION ON BARE FILLS [frre fuse Fie9- BEAM TUBE No.2 Fuk pisthie Center Line of the ‘ano baery mons.(2) 01 F A jow On a Fu 01, a —L 1 ° . co 18 24 30 DISTANCES IN INCHES FROM FACE OF BEAM TUBE, ---Page Break--- Figure 10 FLUX DISTRIBUTION CURVES FOR CORE 1A, ae Ana Ana — +785 —-a18 —* 590 VERTICAL SCALE, 1 UNIT= 2 IN., HORIZONTAL UNITS; ARBITRARY. 1) 3 ---Page Break--- FLUX DISTRIBUTION CURVES FOR CORE 1A, 12 ae Y if f ---Page Break--- Fig FLUX DISTRIBUTION CURVES FOR CORE 114. ---Page Break--- FLUX Fea 934 Fos 352 VERTICAL SCALE, 1 UNIT=2IN, HORIZONTAL UNITS; ARBITRARY, ---Page Break--- (o)

"NNETICD TWHUBHL BL NI BLIHAVEO 4O NOLIMUNDLINOD TWNLd-It “O14 ---Page Break--- s34020 2Ns-AANOd NRIMCD NI GOA 20M IMNGZIMON ‘SEBLMANG.SOISANS NOMAMGN ~21 94 1324 ‘ssapov ‘WiNGZIbON Wow 29180 ‘e 8 4 s 6 * . z t ° = [reine yam enue ou) ¢ ee fie ms nouunan awmeant ---Page Break--- e 8 a 8 7 2 ° ° TeeerTrrcetercrterstisteticeetenrete cee Cc ---Page Break--- THERMAL NEUTRON FLUX x 108 10 is DISTANCE FROM CENTER, INCHES Fig.l4-FINAL FLUX DISTRIBUTION AT THE SURFACE OF THE VERTICAL ACCESS POSITION, VOID IN GRAPHITE. (4) ---Page Break--- 5. REACTOR SERVICE REQUESTS. Persons requesting neutron irradiation service from the factor Division must. (a) FALL out one Radioisotope Production card for each set of samples to be irradiated. (A set {3 understood te be a group of identical samples irradiated simulea~ Beously.) A "Questionnaire for Reactor Experiment” must be filled out and submitted to Wealth Physics Division (5) for each new ‘radiation. Use brief form for short, irradiations. (0) Deliver card and sample to Reactor Supervisor's office. Note special instructions on reverse side of catde Please use the following instructions when filling out the card. (1) Sample number - Identification mmber or code of your sample, (2) Date ~ bate when sample is submieee (3) Flux of irradiations - neutron flux desired. (4) Time in and time out - to be £illed in by Reactor Division. (5) Total time = desired irradiation time. (6) Material and weight ~ specify composition and Weight of cach sample to be irradiated: (7) Activation cross section - cross section of material to produce desired radioisotope, (8) Hale 1ife - half 160 of desired radiotsocope. (9)

Gatcutaced activity - activity of desired radio= isotope. Tn cases of activation analysis or when impossible to make calculations please specify so make a reasonable estimate, (00) Expected activity - activity to be expected from all materials irradiated. (This includes sample conteiners carrier mterials or undesirable materials which suse be irradiated with sample.) WD) Originator +"

signature of Division Head or Program Director requesting irradiation, or his designated representative, ---Page Break--- (02) Delivered to - signature of person to whom Sample is delivered. This signature will be requested by a reactor supervisor at the time sample is delivered. Except in cases in which the neutron irradiation is a repetition of the previous one, the "Questionnaire for Reactor Experiment" must be filled out and submitted to the Health Physics Division at the same time the Radioisotope Production card is submitted. (@) When the service desired is other than a neutron irradiation, the "Questionnaire for Use of Irradiation Facilities (other than Reactor)" must be filled out and submitted to the Health Physics Division- ---Page Break--- RADIATION SAFETY RULES. The Reactor Division has adopted six radiation safety rules concerning monitoring and shielding. These rules should be taken into consideration when planning an experiment. (a) Monitoring: (1) ALL experiments installed around the reactor facilities in the basement at the present time should be reviewed to determine the need for constant or intermittent neutron monitoring. All future experiments are to be reviewed for the possible need of constant neutron monitoring. (2) Gamma monitors suitable for use at or near the bands shall be used when handling unshielded radioactive substances of the near-curie order. (3) Audible signal gamma monitors shall be used near operating areas where samples are loaded or unloaded during an irradiation service. These monitors should produce a signal which is easily related to radiation intensity (e.g., increase in signal rate or signal intensity). (b) Shielding: (1) ALL samples whose activity is 5 r/hr or more shall be transferred to a lead container under at least two feet of water. Enough shielding shall be provided for use during the transportation operation so that radiation intensity does not exceed 200 µr/hr at contact. (2) Samples whose radiation intensity is of the order of 1-5 r/be shall be handled with a remote.

handling tool Ceonge (3 feet long) during transfer operation. (3) Samples whose radiation intensity is below 1 r/hr shall be handled with tongs at least 18" long. A health physicist will monitor the transportation operation at any time the radiation intensity outside the lead shield (at contact) is greater than 50 mr/hr. Written permission shall be obtained from H.P.D. when it is desired to remove a sample from the reactor building whose expected radiation is 200 mr/hr outside the lead shield. The unloading, transfer, and transportation operation shall be performed under the direct supervision of a health physicist. ---Page Break--- Specific Activity after Intermittent Irradiation by MAN FLEGENHEIMER, Comision Nacional de Energia Atomica, Buenos Aires Argentina and VIEHAK MARCUS, Israel Atomic Energy Commission, Rehan, Tel Aviv. The activity of the salt and irradiation for a pad implies a requirement for activity when some before sample that has become reactivated by intermittent cycles. A national entity must ensure that all irradiation periods (and constant Rate 1 @ activity factor 4/1 is equivalent to a Seat count). The monitoring must be done at several flux levels, one must consider an equivalent amount of 1. Several pages contain activity that must be summed to get the total activity over a factor. The factors are sorted according to the equivalent activity. The (4) **60) is displaced on the D curve. Theory 1 thin quantity replaces the second 4¢ unit to the left or to the right, depending on whether the sorghum activity for current term is based on whether 4/4 is given by the formula. The conversion factor of 0.63640 is to be added (or subtracted) to the decay factor and the expression for the activation cross-section in accumulated activity terms. The neutron yield is 110% B/emtac, and I will be able to see the accumulated activity. The equivalent of the factor rain for the production is required.

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gfe hr eating yon the ne aaah tse he GP On x orth aor catia of the cave fry ask 3.0 «gm aul Aw O20Ae Oey ony (OS™ Br 8) ag ay bal OPE OSL ge Net eal te le 4. Move the trampasentahet vets" With several fox voles (rote tHe otinate (0.2) Sealy or oraontaly nit ark 2, Uma that al up the malic] FF the sane preede with ‘since with Drrare sori vty tu the equation mut 4a radiate, 5 Mark the solinate af the Beurve be aimed separates ant then Ce St the toms (0280, te oar) ined. Uscthefolmingprmesane HL Compute seve activity from 8 Adiunt the origins of the tw» A Coopute the fax tartar. in (Al normal! wives. Por the fects to rigee, then tute the Prsiem i thee ox = 1 ‘eral problen tie 0280 x 297 transparent sheet horizontals, avi I. Deter the Boson the fax) 2B/EM Wath to coincien with rut ‘This that ie tguvalet tothe After telus thecrration rn nt 4) om the gues wale. Un te Dies agrees wad Aden end he abe coro tie the length Invlved i fom ta 13 fl, mio Tae saa {11 co 5 25 Normolted Tine 8 NORMALIZED GROWIN AND DECAY CURVES oer © gick need fo efeing dice ocvny m pooner ne Moy, 1962 - NUCLEONICS ---Page Break--- zigée be Pxey Rs ob Sz B2E €283 85 68 ---Page Break--- QUESTIONNAIRE FOR REACTOR EXPERLIENTS What 18 the purpose of the experiment? 2. What division and 4: reaent is sponsoring the experiment? 3, What neutron flux and/or ganaa flux 1s desired? 4, What will be the duration of the experiment prograa? 3s What will be the desired operating time for each irradiation? ©. What are the anounts and kinds of materials which vill be wtthin the reactor? List both the physical materials and their elemental breakdown, What {9 the expected gross activity of the sample? 8 What are the recognized hazards associated with the experinent? 9. What will be the final disposition of the radioactive portions of the experiment? To “Signature of Person Completing Questionnaire (Please use additional pages for answering the above questions, but sign ehis ‘and £111 tn the date, Return to Héctor Barcelé, Head, Reactor Diviston) ---Page Break---

(QUESTIONNAIRE FOR USE OF IRRADIATION FACILITIES (Other than Reactors)

1. Facility requested (underline those needed): hot cells, gamma pool, fuel element gas exhaust, gamma field, gamma irradiation, special setup.

2. Material to be irradiated

3. Radiation dose(s) to be used

4. Approximate total exposure time

5. To be used from %, SESE

Signature Supervisor Date

6. Person in charge of the experiment:* Name, Division: Phone:

If the experiment is to be used here, to avoid the insertion of any kind of material whatsoever.

IMPORTANT Notice

1. ALL experiments inserted and removed from an irradiation facility shall be monitored by a Radiation Monitor, or other person authorized by the TBD.

2. Submit the proposal to the appropriate committee for its approval. The division will return one copy with its approval or comments to the originator and one copy to the person in charge of the facility.

For Use of the P.S. D. only

Approved: Yes No

Date Signature, Form PRIC-EPD (Ri) 663

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9. REFERENCES

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