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P.T. - IP-272-A-FP, PILOT TEST OF SELF-SUPPORTED
FUEL ELEMENTS IN RIBBLESS ZIRCONIUM PROCESS TUBES

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P.T. - IP-272-A-FP, PILOT TEST OF SELF-SUPPORTED FUEL ELEMENTS IN RIBLESS ZIRCONIUM PROCESS TUBES

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P.T. - IP-272-A-FP, PILOT TEST OF SELF-SUPPORTED
FUEL ELEMENTS IN RIBLESS ZIRCONIUM PROCESS TUBES

OBJECTIVE

The objective of this test is to authorize irradiation of pilot scale quantities of self-supported fuel elements in ribless zirconium process tubes to confirm fuel geometry, to test on a pilot scale the self-supported fuel element and the zirconium process tube concepts, and to permit development of reactor equipment capable of handling self-supported fuel elements.

SUMMARY OF TEST

Up to one hundred ribless zirconium process tubes are to be installed in C Reactor, and necessary reactor equipment modifications made to permit routine charging of these tubes with self-supported natural uranium fuel elements. This test authorizes continued loading in these tubes until authorized by process standards or until it is deemed impractical to convert C Reactor to this geometry.

DISCUSSION

Previous testing in support of this test has been accomplished under two programs; a) Projection Fuel Testing, and b) Zirconium Tube Development. These are summarized below: Economic aspects are discussed in references⁽⁴⁾.

- a) Projection Fuel Testing: (1,2) Development of projections for self-supported fuel elements has indicated that it is feasible to attach a collapsible support of the bridge rail type either by electrically spot welding or by ultrasonically bonding the support to the fuel element after fabrication. Irradiation Testing⁽¹⁾ of solid fuel elements in the B Reactor Ribless Tube Facility at annular specific powers up to approximately 60 Kw/ft (equivalent to approximately 85 Kw/ft for I & E elements having an annular heat flux of 60 Kw/ft) has indicated that within the test limitations, a reduction in hot-spot incidence did occur, even though the incidence on the control material was lower than predicted also (1 observed). No hot-spot flow patterns were observed on the self-supported elements.

During the first quarter of CY-1959 irradiations in the test facility were converted to I & E fuel elements to be compatible with the remainder of the reactor and testing has continued. To date, thirteen columns of self-supported I & E material have been discharged from the ribless tubes at exposures up to 870 MWD/T. Visual examination of these elements has revealed no hot-spot flow patterns or areas of excessive corrosion.

To establish the incidence of hot-spots on the fuel elements irradiated in production columns, three buckets, ~750 elements, were chosen at random for visual examination. They exhibited a hot-spot incidence of about 7.5%. A comparison of these data with the self-supported fuel data has indicated that for both the solid and I & E fuel element testing hot-spot incidence is reduced by a factor of about 4 with a 99% confidence. At the 95% confidence level this factor of reduction is 13 for the I & E fuel and 7 for the solid fuel. (The differences being in sample size). Based on these data it is concluded that further testing is justified on a pilot scale to observe these differences in actual fuel performance.

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b) Zirconium Tube Testing

Justification for the use of the more expensive zirconium process tube lies in the high strength and corrosion resistance of the metal itself. To all practical purposes, the zirconium or zircaloy tube has an infinite life expectancy. Thus once installed, the tube need not be replaced for the remaining life of the reactor except to replace tubes damaged by ruptured fuel elements or mechanical damage to end fittings.

To date, only a limited number of zircaloy tubes have been installed in HAP0 reactors. Production Test IP-143-A Supplement A (5) authorized limited installations of ribbed zircaloy tubes in C reactor. Under this test 3 tubes were installed. One tube was removed after a short service due to a cracked Vanstone flange. Subsequent investigation (6) indicated that the Vanstone had not been adequately formed upon installation although all testing had indicated a sound flange. The two remaining tubes performed satisfactorily until one was removed recently after a fuel failure. The initial study by Lang (7) discussed the economic incentives for conversion to zircaloy process tubes. The prime incentives are 1) elimination of tube replacement and associated lost production, and 2) an increase in either conversion ratio (by using larger slugs) or power level (by increase in coolant flow) which would be possible with the larger ID zircaloy tube. The original study postulated gradual replacement on a normal replacement schedule. Subsequent studies by Lang have indicated a greater desirability of replacement on "single-shot" basis. In either case, the payback period is of the order of 1.5 to 2.5 years on a 50-3* analysis basis.

However, because the zircaloy tube has essentially an infinite life, a number of possible methods of increased production must be integrated into one expansion program. As part of the overall program, this test is to be conducted to provide information as to the feasibility and advisability of the smooth bore tube - self supported fuel element concept.

TEST DETAILS

1. Fuel Elements: a) all fuel elements utilized in this test shall have the following nominal dimensions:

	<u>Canned</u>	<u>Core</u>
Outside Diameter	1.500"	1.410"
Inside Diameter	0.380"	0.485"
Length	8.965"	8.325"
Effective Rib Diameter	1.670"	

Prior to rib attachment, all elements shall have passed all normal quality control standards. Each fuel element shall have four supports attached to each end of the fuel elements, approximately one inch from the end, on 90° centers. The supports are to be attached either by electrical spot welds or by ultrasonically formed bonds and shall be in accordance with H-2-7950 (blue-print). b) Downstream dummies may be either expendable perforated dummies

* 50-3 indicates an economic basis which assumes a \$50 per gram Pu worth and a payback period of 3 years.

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with attached supports similar to the fuel elements or those fabricated by extrusion shown in SK-1-3688. The latter will be used if they are available in time.

2. Process Tubing: The process tubing which shall be required for this test will be zircaloy-2, uniform wall thickness, ribless tubes having an inside diameter of $1.681" \pm 0.005"$. Outside diameter shall be $(1.764 \pm .004)$ identical to those aluminum tubes currently in use at C Reactor. These tubes will be installed into channels having aluminum tubes which are scheduled for initial replacement in the central flow zone of C Reactor (exclusive of the ball valve region), and will be chosen by the assigned process engineer with the concurrence of the Manager, C Processing Operation.
3. Charge Machine: Since current charge machines are inadequate for projection fuel charging, a modified machine is being developed to eliminate the need for hand charging. This machine will be capable of charging projection elements at a slightly reduced rate into the larger inside diameter nozzles attached to the ribless tubes, and will be capable of handling both projection and normal elements.
4. Nozzles
 - a) Inlet nozzles shall be overbored to an inside diameter of $1.680" \pm 0.003"$ to permit charging of the self-supported fuel elements. These nozzles will be pressure tested to 150% of maximum expected front face pressures, i.e., 900 psig, to assure that overboring has not weakened the nozzle sufficiently to cause failure.
 - b) Outlet nozzles shall be overbored to an inside diameter of $1.700 \pm 0.010"$ to permit discharge of the self-supported fuel elements. These nozzles shall be pressure tested at 600 psig prior to reactor installation.
 - c) It is understood that neither of these nozzle modifications would be a final choice for reactor use since the reaming job is fairly delicate; however, for preliminary testing it is expedient to use existing reactor equipment. Further it is also obvious that this reaming will in all probability eliminate any potential use of these nozzles with the continuous Charge-Discharge equipment. To avoid confusion all nozzles reamed in conjunction with this program will be painted yellow after machining.
5. Schedule

For planning and scheduling purpose, the below outlined tentative schedule is provided; however, it is understood that other factors such as associated equipment schedules, reactor outage dates, and fuel element availability may modify the program appreciably.

<u>Approximate Date</u>	<u>Test</u>	<u>Remarks</u>
Nov. 1, 1959	Charge two short charges into two ribless zirconium process tubes to check hydraulics. Columns to be equipped with thermo-couple trains.	Columns to be hand charged since charge machine will not be ready

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- Jan. 1, 1959⁶⁰ Install and charge eight additional ribless zirconium tubes with full length charge of CIVN elements with thermocouple probe trains to obtain basis for operating limits for demonstration loading. Columns will require hand charging.
- Feb. 1, 1959⁶⁰ Install and Charge thirty ribless zirconium process tubes as first portion of demonstration test. Use prototype charge machine
- Mar. 1, 1960 Install and charge the remaining ribless zirconium tubes as the final portion of the ribless tube demonstration.
- Apr. 1, 1960 and thereafter - Provide for replacement charging of the facility at a rate approximating 30 columns per month as long as the zirconium tubes are in use or until the test is terminated.

6. Duration

This test shall continue until full-scale reactor use of this material is initiated or until the test results indicate that insufficient justification for this program exists, and thereafter until the ribless tubes have been removed from the reactor. Status reports reflecting the progress of the program will be prepared when necessary.

7. Monitor Columns

- a) The preliminary loading of 10 columns shall be specially weighed and measured so as to permit evaluation of corrosion and dimensional stability of the CIV geometry elements. These columns shall be thirty-two pieces in length and shall each have two additional pieces for use as spares. Each piece shall be numbered by piece and column in the normal manner. Two of these columns shall be used as shortened columns for the initial testing and will be fabricated from old KI size cans and KII size spires. The remainder will be fabricated from components obtained for this test.
- b) Five monitor columns per month shall be charged for corrosion rate determinations and at the discretion of the test author and with the concurrence of the Manager-C Processing Sub-Section, may be equipped with thermocouple probes for refinement of operating limits and investigations into currently unforeseen problem areas.

8. Charging

Initial charging under this program will of necessity be done by hand since charging equipment will not be available until about October 15, 1959. After that date, the demonstration scale loadings will be charged by the adapted equipment. All columns which are numbered must be charged in order with piece number one downstream, and the series number (charge number) and the associated tube number is to be relayed to the author. The remainder of the charges may be charged as normal, mixing fuel-element lots only where absolutely necessary. Normal metal accounting methods shall be used for all columns except the monitor columns prior to and during irradiation.

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9. Irradiation

- a) During irradiation daily temperature and panellit data shall be obtained on data sheets provided for all monitor columns under irradiation. In addition, thermocouple probe data will be required where appropriate.
- b) The Goal Exposure Plan for all columns of this test with the exception of the monitor columns shall have the same slope as the normal goal plan but the intercept will be increased 200 MWD/T with a maximum of 1000 MWD/T; however, should experience indicate goal changes appropriate, they may be modified by mutual approval of the authors and the managers of C Processing and Process Technology.
- c) Sufficient fuel elements will be processed in time to provide an inventory of 5 tons should early discharging be required of a portion of the load.

10. Discharging

- a) All monitor columns charged as part of this test shall be discharged and picked up separately and held for examination in the C Metal Examination Facility.
- b) The remainder of the columns may be discharged with the normal discharge and handled as regular metal, or separately as dictated by experience.
- c) After irradiation all monitor charges shall be visually examined, weighed and measured to observe irradiation changes. Hot-spot flow patterns and areas around the supports shall be examined in detail. If necessary destructive examination of several pieces in the radio-metallurgical laboratory is authorized.
- d) Should a failure occur in any of the test columns, it will be extremely desirable to obtain the failed piece for examination, its location in the reactor and the remainder of the column.

11. Physics Aspects

Reactivity and conversion ratio calculations as well as a discussion of the physics aspects of this program are discussed⁽⁸⁾ by Richey.

TEST HAZARDS

Hazards peculiar to this test fall into two categories, i.e., fuel element failure costs, and failure of the concept. Since this is a fairly new concept which has only been tried in B reactor with roughly 25-50 charges of metal, and since the geometry of the elements was chosen as a result of calculations which were extrapolations of empirical data, there is a definite probability of encountering fuel failure difficulties. Every attempt is to be made to avoid these however, through laboratory checks of the hydraulics, and through a cautious loading schedule. Since this element will be slightly larger (0.040") than any previously used, it is possible, but not likely that a threshold has been crossed and failures will be encountered.

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The other possibility is that the entire concept may be deemed not feasible. This could arise from a cancellation of the zirconium tube program due to lack of sufficient economic justification and subsequent decisions to use ribbed aluminum tubes of the current type. Metal handling procedures could also become sufficiently complex as to make self-supported elements unattractive. Previous economic studies indicate sufficiently short payout periods to make the zirconium tube program attractive and use of the cheaper tube (ribless) makes the payout period even shorter. As in any such study, the choice of assumptions could affect the result; however, it is unlikely that other reasonable assumptions will change the result in this study. If it should be decided to use ribless aluminum tubes rather than zirconium, preliminary tube wear and corrosion data are being obtained at B Reactor where the columns are charged into 62-S aluminum tubes.

It would therefore appear that no extreme risk is involved in this testing program with regards to safety; and no production losses other than those normally involved in any fuel development program are expected.

RESPONSIBILITIES

FUEL PREPARATION DEPARTMENT

Manufacturing Section shall be responsible for canning all pieces by the "F" process, for normal quality control, for attachment of the supports and for pre-irradiation measurements and marking.

Engineering Section shall be responsible for liaison in the 300 Area portion of this test, for development of the means of attaching the supports and choice of process, for technical assistance where required; and if necessary for initial production.

IRRADIATION PROCESSING DEPARTMENT

RESEARCH AND ENGINEERING SECTION

Process and Reactor Development Sub-section shall be responsible for coordination of the test, data analysis and for reporting of irradiation performance. Specifically Reactor Engineering Unit shall be responsible for provision of the necessary zirconium tubing, installation techniques and equipment and technical assistance with regards to the zirconium tubing as well as provision of basis for operating limits. Reactor Fuels Unit shall be responsible for liaison contact with the affected Processing Sub-section, for scheduling of fuel elements, for coordination of the various equipment modifications regarding nozzles and charge machines, and for provision of technical assistance with regards to fuel elements. Both groups shall be responsible for reporting their phases of the program when necessary.

Process Technology Sub-section shall be responsible for assistance to both the Processing Sub-section and the Process and Reactor Development Sub-section, regarding choice of test channels, specification of operating limits, scheduling, and charging of the test; and shall be responsible for forwarding of operating data from the control material to the test authors.

Testing Sub-section shall be responsible for obtaining and reporting post-irradiation fuel examination data.

Operational Physics Sub-section shall be responsible for assistance in choice of test channels and physics aspects of scheduling.

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B-C REACTOR SECTION

C Processing Sub-section shall be responsible for scheduling , for the operational safety and production continuity of the reactor, for collection of operating data and for charging all columns of the test under the direction of the Research and Engineering Representative. In addition they shall furnish nozzles for reaming to the test author.

B-C Maintenance Sub-section shall be responsible for all maintenance required by this test to include tube installation and removal, special charge machine installation and maintenance, thermocouple probe train installation and maintenance and pressure testing of modified nozzles.

FACILITIES ENGINEERING SECTION

Equipment Development Sub-section shall be responsible for charge machine modifications and development and for provision of an acceptable prototype charge machine to support the C Reactor testing program

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Reactor Fuels Unit
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IRRADIATION PROCESSING DEPARTMENT

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