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DOCUMENT NO

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HANFORD TECHNICAL RECORD

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HW--64395

DE93 010057

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AN ASSESSMENT OF THE ZIRCONIUM TUBE PROGRAM
C REACTOR PILOT DEMONSTRATION INSTALLATION

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GROUP 1

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AN ASSESSMENT OF THE ZIRCONIUM TUBE PROGRAM
C REACTOR PILOT DEMONSTRATION INSTALLATION

INTRODUCTION

Production Test IP-272-A-FP (1) authorizes the installation of up to 100 smooth bore Zircaloy-2 process tubes in C Reactor to demonstrate the feasibility of self-supported fuel elements for production use. An additional 200 zirconium tubes are expected to be delivered by mid-year and can be used to expand the initial demonstration facility. It is the purpose of this document to assess the status of the pilot demonstration program from the B-C Reactor Operation viewpoint.

SUMMARY

General

1. A total of nine ribless zirconium tubes have been installed in C Reactor to date. Present procurement schedules (2) indicate that approximately 40 tubes will be available on site by late March, an additional 50 tubes will be available on site by mid-April, and an additional 200 tubes are scheduled for delivery by July 1, 1960.
2. Production Test IP-272-A-FP authorizes the installation of only 100 zirconium tubes. If the pilot demonstration unit is to be expanded to 300 tubes (200 additional), a supplement to the Production Test is required.
3. The Fuels Preparation Department can presently manufacture sufficient self-supported fuel elements to sustain the required throughput of 100 tubes on a one shift per day schedule. By converting to two-shift operation, sufficient fuel elements can easily be produced to meet the requirements of 300 tubes. (3)

Operating Aspects

1. Initial studies indicated that overbored inlet nozzles were adequate for the preliminary testing purposes of PT-IP-272-A-FP. Re-evaluation of these studies reveal that they do not provide reasonable assurance that the nozzles are safe for reactor use. On this basis, immediate additional studies and tests have been requested to establish the validity of overboring existing inlet nozzles. The studies and tests will be conducted by Reactor Engineering Operation and Mechanical Development "A" and are scheduled for completion by March 31. (4)
2. Approximately one hour per tube will be required for the installation of the pilot demonstration unit. C Reactor production goals forecast outage time for the installation of only 100 zirconium tubes in CY 1960. If the 200 tubes scheduled for delivery by mid-year are to be installed, the outage time required is expected to result in a net 1.8 per cent reduction in TOE. On this basis, it is probable that the annual production goal will be underrun by approximately 14,000 MWD unless production gains can be achieved by other means.

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- ## Maintenance Aspects

- ## CONCLUSIONS

1. The adequacy of overbored inlet nozzles for safe reactor use is considered to be marginal based on the absence of positive evidence to the contrary. If further tests indicate that simple overboring is safe, or additional modifications are required to strengthen the overbored nozzles, no delays in the program will be experienced. If new nozzles are required, a delay of 4 to 6 months will be incurred to obtain the nozzles. The nine overbored nozzles presently installed should be removed if additional modifications or new nozzles are required.
2. From past experience, optimum performance is achieved by the replacement of a maximum of 50 tubes per outage. Based on the above, the availability of tools and equipment, and manpower and exposure considerations, the installation of pilot demonstration tubes should be accomplished at the rate of approximately 50 tubes per outage per month starting in May, 1960, assuming that the adequacy of overbored inlet nozzles has been conclusively established (Table III). For a 75 tube outage, an additional \$12,000 for tools would be required with a 3 to 5 months delay for tool procurement.
3. The zirconium tubes should be installed in the reactor in the pattern shown in Figure I. This pattern satisfies the requirements for fuel element evaluation, evaluation of channel distortion on tube insertion problems, maintenance requirements, future through-pile decontamination considerations and charge-discharge aspects.

4. All tubes should be inspected on-site for conformance to the established specifications. Tubes which do not meet the specifications may cause unforeseen installation problems and should not be used, at least during the initial installation outages.

RESPONSIBILITIES

Research and Engineering Operation (1)

1. Zirconium tube procurement.
2. Production test supplement.
3. Self-supported fuel element supply.
4. Establishing adequacy of overbored inlet nozzles.

Facilities Engineering Operation (1,6)

1. Establishing adequacy of overbored inlet nozzles.
2. Zirconium tube installation tool development.
3. Zirconium tube removal tool development.
4. Self-supported fuel element charging machine (Dual Purpose).

B-C Reactor Operation (1)

1. Nuclear safety and operating continuity.
2. Procurement of tube replacement tools, equipment and hardware.
3. Scheduling and performance of tube replacement.
4. On-site inspection of zirconium tubes.
5. Revision of stuck rupture removal procedures.

DISCUSSION

General

Two fixed price orders of approximately 50 tubes each have previously been placed for smooth bore zirconium tubes of the C Reactor geometry. The orders were placed with Harvey Aluminum Company and Bridgeport Brass Company with contracted delivery dates of July and August, 1959 (7). To date, a total of 46 tubes (10 Harvey and 36 Bridgeport Brass) have been received on site. Of this total, 9 have been installed, 3 have been inadvertently damaged, one is being used for testing and 36 are ready for inspection and installation. Ten tubes are scheduled to be received from Harvey by late March and 35 Harvey and 15 Bridgeport Brass tubes are scheduled for delivery by mid-April to complete the above two orders.

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In addition to the above, cancellation of the B, D, F size ribbed zirconium tube contracts, and conversion of these efforts to the fabrication of C type smooth bore tubes, is expected to result in an additional 200 tubes being available for installation on or before July 1, 1960 (2).

The installation of zirconium tubes in C Reactor is authorized by Production Test IP-272-A-FP, "Pilot Test of Self-Supported Fuel Elements in Ribless Zirconium Process Tubes". This production test authorizes the installation of only 100 tubes and this number is sufficient for the evaluation of the self-supported fuel element and zirconium tube concepts (3). On this basis, a supplement to the Production Test or a Process Improvement Transition Authorization will be necessary if the demonstration unit is to be expanded to 300 tubes by the installation of the above mentioned 200 tubes.

Fabrication of self-supported fuel elements is presently being accomplished at a rate of about five tubes per shift on a one shift per day schedule to meet the 100 tube requirements of PT-IP-272-A-FP. This production rate should also be adequate to meet the required through-put of 300 tubes based on a minimum exposure of three months per tube. If necessary, however, two-shift per day operation can be obtained which would easily meet the requirements for 300 tubes (3).

Operating Aspects

In order to charge self-supported fuel elements into ribless zirconium tubes, the existing inlet nozzles must be overbored to a diameter of $1.680" \pm .003"$, or new nozzles with this bore diameter must be procured. Because of the long lead time associated with new nozzle procurement, it was decided to establish the feasibility of overboring existing nozzles to avoid delays in starting the pilot demonstration program. Stress calculations were made on the basis that the weakest point of the overbored nozzles was at the lug ring keyway slot. These calculations indicated that although the stresses were significantly increased for the overbored nozzle, the nozzles were safe for reactor use for the purposes of PT-IP-272-A-FP, but should not be considered for full reactor use.

In evaluating this program from the overall B-C Reactor viewpoint, particularly from the nuclear safety standpoint, there was considerable doubt that the initial calculations provided the necessary assurance that the overbored nozzles were, in fact, safe for on-pile use. This doubt was based primarily on the philosophy that if the nozzles were not considered safe for full reactor use, they should not be considered safe for limited reactor use (8). In addition to this, if the nozzles are to be overbored eccentrically, the weakest point of the nozzles would be at the snap ring slot, rather than at the keyway slot as originally assumed.

On the basis of the above considerations, additional studies and tests have been requested to establish the validity of overboring existing inlet nozzles. These activities will be conducted by Reactor Engineering Operation and Mechanical Development "A" Operation and will consist of further theoretical stress calculations and pressure, bending and impact load tests. The scheduled completion date is March 31 (4). If further investigation indicates that simple overboring is safe, or that additional modifications can be made to strengthen the nozzles, no delays in the program will be experienced. If new nozzles are required, a delay of 4 to 6 months will be incurred to

obtain the required nozzles. The nine overbored nozzles presently installed on the reactor should be removed if additional modifications or new nozzles are required.

The CY 1960 production goals for C Reactor were forecast on the basis that only the 100 zirconium tubes authorized by PT-IP-272-A-FP would be installed in the reactor this year (9). For production forecasting purposes, it was assumed that 1.5 hours per tube or 150 outage hours would be required for the 100 tube installation. This is equivalent to 1.7 per cent time operating efficiency. However, an installation time of one hour per tube is a more realistic estimate and would require only 1.2 per cent TOE for 100 tubes, or 0.5 per cent TOE less than was forecast. On the other hand, if the pilot demonstration unit is to be expanded to 300 tubes, by installing the 200 tubes anticipated from the cancellation of the ribbed tube contracts, this will require an additional 2.3 per cent TOE for a net reduction of 1.8 per cent TOE and a production loss of 14,120 MWD beyond that forecast for zirconium tube installation. The magnitude of this loss may preclude goal attainment if some production gains cannot be achieved by other means. To keep the overall production losses incurred by the program to a minimum, the tube installation outages should be confined to the summer months when the river water temperatures are the highest and the production potential the lowest.

From the standpoint of availability of tooling and process tubes, the installation of zirconium tubes could begin in April. From the reactor operation viewpoint, however, it is desirable to delay zirconium tube installation until May and utilize outages in April to remove the rear ball valves in the OCD pattern and complete the exit water thermocouple replacement program. Since the established zirconium tube pattern encompasses a portion of the ball valve installation, it is considered necessary to remove the ball valves prior to installing the tubes in order to avoid compounding the problems which may arise in simultaneously removing the ball valves and installing zirconium tubes. In addition, the presence of the ball valves prevents completion of the exit water thermocouple replacement program due to component interference. Because of this, the repair of "must" thermocouples in this location, prior to startup, results in an average monthly production loss of 980 MWD.

Maintenance Aspects

With the approval of the Production Test authorizing the installation of 100 zirconium tubes in C Reactor, studies of the various maintenance aspects of tube replacement at C Reactor were initiated. Prior to this time, tube replacement at C Reactor was limited to the removal of rupture tubes, leaking tubes, or tubes required for corrosion studies.

Based on an installation time of one hour per tube and existing C Reactor rear face radiation levels, an estimated craft exposure of 250 mr/tube to be replaced will be required. Thus for a 50 tube outage, approximately 12,500 mr of exposure is required; for a 75 tube outage, 18,750 mr is required; and for a 100 tube outage, 25,000 mr of exposure is required. There is an estimated total exposure of 24,300 mr available in IPD for a tube replacement outage at C Reactor, of which 16,500 mr is from B-C and

D-DR forces. This estimate is based on utilization of the entire B-C crew, the D-DR shift crews and 50 per cent acceptance of overtime by all other IPD personnel. On the basis of the above exposure considerations, a 50 tube outage is optimum, a 75 tube outage is practical, but a 100 tube outage would seriously deplete exposure in all IPD maintenance forces (10).

It is assumed that a tube outage at C Reactor would be staffed in the established manner using the B-C and D-DR forces with the additional manpower requirements being provided on an overtime basis. For a 50 tube outage, a total of 137 craftsmen with 100 mr exposure available would be required. By starting the tube work on any Monday day shift, a total of 84 craftsmen will be available from B-C and D-DR crews leaving a total of 53 men with 100 mr exposure available to be provided on an overtime basis. This results in 318 manhours of overtime assuming each man is paid for six hours each. In addition, 120 manhours of exempt overtime would be required for outage supervision for a sum total of approximately 438 manhours of overtime for a 50 tube outage. The direct out-of-pocket cost of this overtime is \$2650. The overtime required for a 75 or 100 tube outage would increase in a direct ratio. For a 75 tube outage, 657 manhours of overtime would be required at a cost of \$3975. For a 100 tube outage, 876 overtime manhours would be required at a cost of \$5300. Also, past outage experience has shown that performance efficiency starts to decline after 48 hours of continuous outage work and decreases rapidly after 72 hours. By this time, home area crews are essentially burned out and work must be continued entirely on an overtime basis (10).

Because routine replacement of corroded aluminum process tubes is not presently required at C Reactor, only minimal tooling has been maintained for tube replacement purposes. However, when it became known that up to 100 zirconium process tubes were to be installed in C Reactor, procurement orders were placed with off-site vendors for the necessary tooling to accomplish the removal of approximately 50 aluminum tubes per outage. These tools are scheduled for on-plant delivery by April 1, 1960. (See Table I). The decision to order tooling for only a 50 tube outage was based on several considerations, namely: 1) Funds were not budgeted for C Reactor tube removal tools in FY 1960 and had to be obtained from other programs, 2) PT-IP-272-A-FP originally scheduled the zirconium tube installation in lots 2, 8, 30 and 60 per outage, and 3) the problems of tube replacement at C Reactor were not fully known and installing the zirconium tubes in several outages would minimize the effects of any difficulties encountered. In order to tool up for a 75 tube outage, an additional \$12,000 in tooling costs and 3 to 5 months delay in procurement would be encountered.

At present, only about 64 spare inlet nozzles and 63 spare outlet nozzles are on hand. An additional 75 outlet nozzles were ordered in September, 1959 (to permit replacement of the OCD rear ball valves) and are scheduled for immediate delivery. No additional inlet nozzles are on order. Because of the limited number of spare inlet nozzles available for overboring to the Production Test requirements, the installation of zirconium tubes is essentially limited to a maximum of 50-60 tubes per outage.

Zirconium tube removal experience has been limited to the removal of two B, D, F type ribbed tubes previously installed in C Reactor (11). Aside from the high radiation levels encountered, no problems were experienced in pushing out the tubes intact. This was probably due to the small size of the B, D, F

type tubes in relation to the C graphite channel bore. All previous aluminum tubes removed from the reactor had to be split to effect removal. At present, there are no adequate zirconium tube splitters available in the event a stuck rupture occurs or a tube becomes damaged in such a manner that its removal is required. Development of this tooling is scheduled for completion in September, 1960 by Mechanical Development "A". Concurrently, existing stuck rupture and tube removal procedures require investigation and revision where necessary for application to self-supported fuel elements and zirconium tubes. This will be accomplished by B-C Maintenance Operation by April 15.

During the previous installation of nine zirconium tubes, tubes supplied by Harvey Aluminum Company were difficult to install while tubes from Bridgeport Brass Company were easily inserted into the reactor. During the installation of a Harvey tube in Channel No. 3582, the broach pulled out of the tube after 30 feet of travel. All subsequent efforts to move the tube either to the front or rear without damaging the tube failed. The tube was then cut off in the front and removed with a tube pushing machine at 6500 pounds force. In Channel No. 3874, a Harvey tube was pulled in with difficulty until the broach pulled out with 6 inches remaining to be inserted. The tube was finally seated by pulling and pushing simultaneously at 4000 pounds force. Similar experience was encountered with a Harvey tube in Channel No. 3874 (5). These installation forces are further evidence that the tubes will require splitting to effect removal.

Measurements have been taken on random samples of both the Harvey and Bridgeport Brass tubes. In general, the tubes from both vendors were found to be out of round and the Bridgeport Brass tubes were smaller than the Harvey tubes. Some Bridgeport Brass tubes had a major diameter of 1.759 and a minor diameter of 1.754. Three Harvey tubes measured 1.773 on the major diameter. The specifications require an OD of 1.764" $\pm$.004". Based on the above data, all tubes should be inspected on-site for conformance to the specifications and tubes which do not meet the established requirements should not be used, at least during the initial installation outages.

G. O. Amy, Supervisor
B-C Maintenance Engineering
B-C REACTOR OPERATION

GO Amy:mbh

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TABLE I

ZIRCONIUM TUBE INSTALLATION TOOL REQUIREMENTS
C REACTOR

Tool	Development Target Date & Responsibility	Tools On Hand And/or On Order For Delivery 4-1-60	No. Required For 50 tube Outage	No. Required For 75 tube Outage
Aluminum Tube Splitters	STANDARD ALUMINUM TUBE REMOVAL EQUIPMENT	64	60	85
Combination Broaches		15	10	Same as 50 tube Outage
Bobtail Broaches		15	10	"
Tugger (Rear)		1	1	"
Tugger (Front)		1	1	"
Cables		6	6	"
Swivels and Connectors		15	15	"
Splitter Starters		4	4	"
Splitter Backup Plates		6	6	"
Tube Grippers		10	10	"
Couplings (quick-acting)		64	60	85
Guillotine (Al. Tube)		1	1	Same as 50 tube Outage
Header Caps		50	50	75
Leak Test Stingers		27	10	Same as 50 tube Outage
Jack Bolts		100	100	150
Hand Tools (Special)		10 sets	5 sets	Same as 50 tube Outage
Van Stone Flanging & Trimming Tool (Zr.)	Complete Mech. Dev. A	2	2	"
Aligning Bars	Complete Mech. Dev. A	4	4	"
Dual Purpose Charging Machine (Self-Supported and Reg. I & E)	3-16-60 Mech. Dev. A	1	1	"
Overbored Nozzles: Front Rear	3-31-60 Mech. Dev. A Reactor Eng.	64 138	55 55	80 80

TABLE II
ZIRCONIUM TUBE MAINTENANCE TOOL REQUIREMENTS
C REACTOR

Tool	Development Target Date & Responsibility	No. On Hand Or on Order	No. Required	Date Required
Ribless Zr. Tube Splitter	9-1-60 Mech. Dev. A	0	5	ASAP
Splitter Starters	7-1-60 Mech. Dev. A	0	2	"
Van Stone Flange Cutter	7-1-60 Mech. Dev. A	0	2	"
Guillotine	Complete	1	1	
<u>ALL OTHER TOOLS REQUIRED ARE THE SAME AS ARE</u> <u>PRESENTLY AVAILABLE FOR ALUMINUM TUBE MAINTENANCE</u> <u>OR ARE REQUIRED FOR INITIAL ZR. TUBE INSTALLATION</u>				

TABLE III
TENTATIVE INSTALLATION SCHEDULE*

<u>Month</u>	<u>Approximate No. of Tubes</u>
May	50
June	50
July	50
August	50
September	50
October	50
TOTAL	300

*Depends upon on-site delivery of the tubes and actual tube replacement performance.

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		1-	2-	3-	4-	5-	6-	7-	8-		
TOTAL FLOW		9-	10-	11-	12-	13-	14-	15-	16-		
TYPE OF MAP:		TEMPERATURE BIAS		AREA C		DATE		PAGE			
OUTLET TEMP.				WORK SHEET		[REDACTED]		HW -			
DELTA TEMP.				AFTER FILL-IN							
PANELLIT PRESSURE											

REFERENCES

- (1) HW-61669, "P.T. - IP-272-A-FP, Pilot Test of Self-Supported Fuel Elements in Ribless Zirconium Process Tubes", R. E. Hall and D. H. Curtiss, August 27, 1959.
- (2) Personal communication with D. H. Curtiss.
- (3) Personal communication with R. E. Hall.
- (4) Meeting with R. E. Trumble, O. E. Adams and C. A. Munro.
- (5) C Reactor Maintenance Log.
- (6) Personal communication with R. M. Smithers.
- (7) HW-63038, "Task Force Report on Zirconium Process Tube Replacement", D. H. Curtiss, January 29, 1960.
- (8) Personal communications with A. R. Maguire.
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