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EFFLUENT ACTIVITY STUDIES IN THE
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PRODUCTION TEST IP-449-A
EFFLUENT ACTIVITY STUDIES IN THE
1706-KE IN-REACTOR FACILITY

By
R. G. Geier

October 14, 1961

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HW-71338
Page 3

OBJECTIVE

The objectives of this test are: (1) to operate two single pass tubes in the 1706-KE in-reactor facility using demineralized water either as produced or with chemical additions as the coolant, (2) to obtain samples of the effluent water, and (3) to obtain corrosion measurements on fuel elements, dummies and coupons.

BASIS AND JUSTIFICATION

The Irradiation Processing Department has undertaken a research and development program to develop processes capable of achieving a ten-fold reduction in the biologically significant radioisotopes occurring in reactor effluent. A major portion of the program is directed toward determining the mechanisms and kinetics involved in the formation and removal of radioisotope forming films on in-reactor tube and fuel element surfaces. In order to achieve a better understanding of the phenomena, this test will permit a study of the characteristics of films formed when using demineralized water and demineralized water containing small amounts of particular radioisotope parents.

Corrosion studies will also be conducted in parallel with the effluent studies. Measurement of corrosion will be carried out by measurements on the fuel elements and downstream dummies and coupons and by periodically probologging the tubes.

DESCRIPTION OF FACILITY

There are eight tubes in the KE Reactor which can be supplied with either specially treated water from the 1706-KE Building or normal 105-KE process water. The tubes are single pass and equipped to permit individual sampling of the effluent streams. A schematic diagram of the piping arrangement is shown in Figure 1.

The facilities to be operated under the terms of this test are SP-7 (Tube 4963) and SP-8 (Tube 5063).

THERMAL HYDRAULICS

Thermal hydraulic considerations give rise to the operating criteria discussed below.

A. General

In case of failure of the 1706-KE pumps for any reason, the safety of the tubes depends on the process water back-up system. The system is simple and can be considered highly reliable. As shown in Figure 1, process water is supplied to the system through inter-connecting lines. During normal operation, process water is excluded from the system by check valves. The check valves are normally held shut by maintaining pressure in the 1706-KE tube supply system higher than the reactor process water pressures. When pump failure occurs, the pressure in the normal supply line decays and the check valves in the interconnecting lines open. A second check valve is situated in the 1706 supply lines upstream from the point of interconnection. The function of this valve is to prevent flow of water from the back-up system back to the 1706-KE pumps.

The second check valve also protects the system from the remote chance that a line rupture will occur in the piping between the 1706-KE pumps and the point of inter-connection.

In order to insure protection, it is necessary to lock and tag open all stop valves on the interconnecting lines during operation.

Inasmuch as under the provisions of this test the tubes will be supplied by 1706-KE pumps both during normal operation and during shutdown, it is necessary that locked rear caps be provided to avoid the consequences of inadvertent rear cap removal.

B. Instability Limits

In order to insure safe and stable operation at the high trip conditions, the high trip pressure must be no greater than given by the following equation:

$$HTP = 0.51 FHP + 0.49 Pan.$$

where HTP = Maximum high trip pressure, psig.

FHP = Front header pressure, psig.

Pan. = Normal operating Panellit (venturi throat) pressure, psig.

The tube outlet temperature must not exceed 130 C or the limit given by the following equation, whichever is lower:

$$T_o = T_i \left[\frac{41.45 FHP^{0.709}}{(FHP-RHP-15)^{0.5}} - T_i \right] \left[\frac{LTP-RHP-15}{Pan-RHP-15} \right]^{0.5}$$

where T_o = Maximum outlet temperature, C

T_i = Inlet Temperature, C

RHP = Rear header pressure, psig

LTP = Low trip pressure, psig

These trip settings are valid for front header pressures greater than 325 psig and a differential between high pressure and low pressure trips of less than 90 psi. All pressures are measured at a common elevation.

C. BPA Outage Limits

In case of a BPA outage, the 1706-KE pumps trip out and the tubes are supplied with coolant from the regular process water system through inter-connecting lines. In such an event, two critical periods exist. The first critical period comes within a few seconds after the BPA outage. The flow to the 1706-KE tubes decays after the power decays. The flow decay can be

considered to occur in two steps. First, the supply pressure to the tubes immediately drops to that supplied by the process water system. Next, the supply pressure supplied by the process water system decays as the flywheel energy on the 190-KE pumps is used up.

In order to pass through the first critical period safely, it is necessary to insure that the total flow decay before the beginning of power decay is not excessive. Such protection is obtained by the limits shown in Figure 2. The limits are based on preventing a flow reduction of more than 20 per cent before tube power decay commences.

The second critical period occurs about 100 - 150 seconds after the outage. At this time, the tube flow has decayed about 89 per cent and tube power has decayed about 88 per cent. Both the flow and power will remain relatively constant at these values for a considerable period of time. It is desirable that the tube exit temperature not exceed the rear crossheader saturation temperature. This is prevented by limiting the outlet temperature to 139 C during normal operation. Inasmuch as this is above the 130 C maximum outlet temperature specified under instability limits, safe conditions are assured.

DETAILS OF TEST

A. Phase I

During the first reactor outage following completion of the shakedown of the demineralizer currently being installed in the 1706-KE facility, the cooling water for tubes 4963 and 5063 will be changed from normal process water to demineralized water as produced. The demineralized water will be supplied by the 1706-KE pumps and is expected to have a pH between 6.0 and 6.5. The tubes with the then existant fuel charges will operate until the reactor outage which occurs after at least two weeks of operation.

B. Phase II

1. Retubing

During the outage which terminates Phase I of this test, SP-8 (Tube 5063) will be retubed with a C size, smooth-bore Zirconium tube. The use of a Zirconium tube in this channel has been authorized previously⁽¹⁾. HW-66868 also specifies the special front nozzle required. This production test authorizes the retubing of SP-7 (tube 4963) with a standard K size, ribbed, aluminum tube during the same outage.

2. Fuel Elements

To satisfy the requirements of Phase II, it is necessary that the power, the coolant flow and the flow split be as close to identical as possible. Therefore, Tube 4963 (ribbed, aluminum) will be charged with

(1) HW-66868 - "Production Test IP-361-A, Modification of Water Quality Tubes in KE Reactor", by N. R. Miller and R. B. Hall, October 20, 1960.

DECLASSIFIED

HW-71338
Page 6

KIVN fuel elements, and tube 5063 (smooth-bore, Zirconium) will be charged with KIVNS fuel elements for all segments of Phase II of this test.

Normally a full charge of 38 fuel elements will be used in each tube. However, if it becomes necessary to investigate temperature as a variable, a shorter charge may be required. At such times the charge length will be negotiated between KE Processing Operation, KE Process Engineer, Coolant Testing Operation, and the author of this production test.

3. Water Quality

The water to be supplied by the 1706-KE pumps both during normal operation and during shutdown will be the effluent from the demineralizer currently being installed in the 1706-KE facility either as produced or with the chemical additions as specified below. In all cases the pH will be between 6.0 and 7.5.

In case of malfunction of 1706-KE equipment, process water may be used.

4. Chemical Additions

The following chemicals may be added through the 1706-KE addition facilities. The maximum concentration to be used is shown opposite the material name. It is anticipated that cations will be added as the nitrate salts and anions as the sodium or ammonium salts. Compounds containing halides will not be added. The total addition of the listed materials will not exceed 50 ppm.

<u>Compounds Containing</u>	<u>Maximum Concentration ppm</u>
Arsenic	10
Sulfur	10
Phosphorus	10
Iron	10
Manganese	10
Zinc	10
Lanthanum	10
Chromium	10
Silicon	10
Uranium	2

Chemicals and addition rates will be selected by Chemical Research and Development Operation, HLO, alone or jointly with Coolant Systems Development Operation, HLO. Brief descriptions of each addition will be transmitted to Coolant Testing Unit, KE Processing Operation, and the signatory of this test.

5. Sampling Schedule

The maximum effluent sampling frequency is shown below. Revisions may be required as the test progresses. The sampling will begin at the start of the test, The schedule will be repeated before and after the start of a different chemical addition. A detailed description of sampling needs will be provided in the description of each segment of the test.

<u>No. of Samples Required</u>	<u>Sampling Interval</u>	<u>Time After Start</u>
8-10	5-10 min.	1st hour
4	15 min.	2nd hour
6	30 min.	next 3 hours
19	1 hr.	next 19 hours
60-80	4 hrs.	10-14 days

Previous experience has shown that erroneous results are obtained if the flow in the effluent sampling line is disturbed. To eliminate this possibility, the sample line will remain open and flowing for the duration of the test. The plastic tubing will be inserted into the drain funnel between sampling operations to eliminate the possibility of contaminating the sample room.

6. Corrosion Tests

Corrosion measurements will be made on fuel elements and on downstream dummies and coupons to determine in-reactor corrosion rates in demineralized water for comparison with corrosion rates in process water under similar conditions. The fuel elements charged shall be numbered and measured, and the downstream 19 elements from each tube shall be weighed before and after exposure for corrosion measurements.

Some of the downstream perforated or tubular dummy elements will be fitted to hold coupons for corrosion studies. Others will be specially fabricated for periodic weighing. The number, type, and location of special corrosion samples will be selected by Coolant Systems Development Operation, HLO with the concurrence of Coolant Testing Operation and KE Processing Operation, IPD.

7. Probologging

As a minimum, both tubes will be probologged at the termination of this test. Although improbable, it is possible that the corrosion coupons might indicate the desirability of additional probologging. Thus, two intermediate probologgings are authorized.

8. Duration of Test

Operation for a period of one to three months will be required between changes in coolant composition. In as much as from eight to twelve

DECLASSIFIED

HW-71338
- Page 8

changes in composition are anticipated, it is expected that Tubes 4963 and 5063 will operate on demineralized water for approximately two years.

9. Decontamination

Decontamination prior to each change in coolant composition will not be required. However, test results may indicate that periodic decontaminations are required. Thus, six decontaminations throughout the test duration are authorized.

One of the following decontaminating agents will be supplied from the 1706-KE Building and will enter the tubes in the 105-KE valve pit.

- a. 0.3 m sulfuric acid - 0.1 m oxalic acid plus 1.5 gm/gal 1-phenyl - 2-thiourea.
- b. Turco 4306-C at 6 oz/gal.
- c. Wyandotte 5061 at 6 oz/gal.

The decontamination solution will be flushed through the tube at a rate of 5 gal/min. for at least 45 minutes but not more than 75 minutes and at a temperature not less than 45 C but not more than 60 C.

Detailed procedures for the decontaminations will be supplied by Coolant Testing Operation.

10. Discharges

One premature discharge at the start of Phase II of this test is authorized. Subsequent exposures will be based on the variable goal limit used for regular production metal in KE Reactor. However, if required to provide the information expected from this test, six additional premature discharges (coincident with decontaminations) are authorized.

11. Film Formation

The addition rates of the chemicals will be maintained at a low enough rate so that filming difficulties are not encountered. Should a significant change in inlet pressure to either tube be observed during an addition, the addition will be stopped.

12. Effluent Activity

The results of previous tests indicate that effects on effluent activity will not be observable in the reactor effluent or on the rupture detection system.

13. Corrosion

Experimental data indicate that the corrosion of aluminum is lower in demineralized water than in normal process water. (1)(2)

Previous tests have indicated that corrosion rates will not be adversely affected by the additions of the small amounts of chemicals proposed.

Coolant Systems Development Operation, HLO has conducted corrosion studies on the chemicals and conditions chosen for decontamination, if required. Decontamination will have no effect on the Zirconium tube (5063), and the corrosion rate of the aluminum tube (4963) will be very low.

14. Hazards

The hazards introduced by this test include:

- a. Those associated with the handling of chemicals.
- b. Those associated with the inadvertant removal of the end caps of the tubes during shutdown.

COSTS

A. Outage Time

Two hours for each decontamination of the two tubes. Two hours for each charge-discharge of the two tubes and special pickup of metal before decontamination.

B. Operator Time For Sampling

Operator time for sampling will be required in amounts depending upon the specific sampling schedule chosen. Charges for sampling over and above that which can be carried out by the normal operating staff will be born by Process and Reactor Development Operation

C. Cost Code

XXXX-5R26-XXX.71

RESPONSIBILITIES

KE-KW Reactor Operation

KE Processing Operation will be responsible for:

- (1) HW-42656 - "Final Report - Production Test -105-506-E, Recirculation of Reactor Cooling Water", by R. J. Lobsinger, September 16, 1957.
- (2) HW-59778 Rev., - "Summary Report on Corrosion of Aluminum in High Temperature Dynamic Water Systems", by R. J. Lobsinger, February 1, 1961.

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HW-71338
Page 10

1. The operational safety of the reactor
2. Production continuity
3. Retubing
4. Obtaining samples
5. Charge-discharge of the tubes
6. Probologging the tubes

Research and Engineering Operation

Coolant Testing Operation will be responsible for:

1. Operation of the 1706-KE equipment
2. Chemical additions
3. Recording of operating data
4. Decontamination of process tubes
5. Reactor safety and operational continuity as affected by this test

Component Testing Operation will be responsible for:

1. Weighing and weaseling of irradiated fuel elements

Process and Reactor Development Operation will be responsible for:

1. Making process recommendations
2. Issuing the final report
3. Termination of the test

HANFORD LABORATORIES OPERATION

Chemical Research and Development Operation

Radiological Chemistry Operation will be responsible for:

1. Observation, pickup, and delivery of samples to the laboratory
2. Analyzing effluent data
3. Issuing technical reports

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HW-71338
Page 11

Reactor and Fuels Research and Development Operation

Coolant Systems Development Operation will be responsible for:

1. Analyzing corrosion data and issuing technical reports
2. Supplying special non-fuel corrosion samples

R. G. Geier
Process and Reactor Development
Research and Engineering
IRRADIATION PROCESSING DEPARTMENT

RG Geier/bc

FIGURE 1
1706KE COOLANT SUPPLY TO TUBES 4963 and 5063

Pump PW-2 will supply coolant during normal operation and during shutdown until reactor goes on crossunder. Pump PT will then be manually started and will supply coolant for the duration of the outage.

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FIGURE 2
BPA FAILURE LIMIT

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