GEAP 3905
Informal AEC Research
and Development Report

# MARITIME LOOP IRRADIATION PROGRAM

## SAVANNAH I FUEL IRRADIATION

## QUARTERLY PROGRESS REPORT

October 1, 1961 - December 31, 1961

by

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The GETR operations engineer supervising the loop operation was F. R. Ulrech through August, 1961, with C. A. Dalke fulfilling the responsibility starting in September, 1961.

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SECTION I

## INTRODUCTION

This report covers the S-I-5-B-M fuel irradiation in the GETR Maritime Loop during the second quarter of fiscal year 1962. The data are summarized in Section II. Discussions on fuel performance, fuel environment (water chemistry), problems with loop operations, and the crud deposition program are included. For detailed data reports for this report period, refer to Loop Operation Data Summary Reports #9, #10, and #11. These individual cycle reports include summary graphs of significant loop operation parameters and water chemistry data.

SECTION II

## SUMMARY

### 2.1 Irradiation Summary

| | Summary Report No. | Reactor Cycle No. | Reactor Operation Dates | Reactor MWD | S-I-5-B-M Burnup MWD/Tonne U |
|---|---|---|---|---|---|
| Previous Reports | 1 | 18 | 12/2/60-12/12/60 | 266.3 | 130 |
| | 2 | 19 | No reactor operation | 0.0 | 0 |
| Total as of December 31, 1960 | | | | 266.3 | 130 |
| | 2 | 20 | 1/6/61-2/5/61 | 815.0 | 397 |
| | 3 | 21 | 3/21/61-3/26/61 | 163.7 | 85 |
| | 4 | 22 | 3/28/61-3/31/61 | 90.8 | 46 |
| Total as of March 31, 1961 | | | | 1335.8 | 658 |
| | 4 | 22 | 4/1/61-4/20/61 | 533.1 | 266 |
| | 5 | 23 | 5/7/61-6/4/61 | 815.0 | 399 |
| | 6 | 24 | 6/11/61-6/30/61 | 562.9 | 284 |
| Total as of June 30, 1961 | | | | 3246.8 | 1607 |
| | 6 | 24 | 7/1/61-7/9/61 | 238.3 | 119 |
| | 7 | 25 | 7/14/61-8/13/61 | 864.3 | 419 |
| | 8 | 26 | 8/18/61-9/17/61 | 884.0 | 453 |
| | 9 | 27 | 9/23/61-9/30/61 | 151.0 | 74 |
| Total as of September 30, 1961 | | | | 5384.4 | 2672 |
| This Report | 9 | 27 | 10/61-10/22/61 | 551.0 | 270 |
| | 10 | 28 | 10/30/61-11/26/61 | 749.5 | 340 |
| | 11 | 29* | 12/2/61-12/31/61 | 860.2 | 389 |
| Total as of December 31, 1961 | | | | 7545.1 | 3671 |

*Cycle #29 continued through 1/1/62.

The irradiation corresponds to the equivalent of 252 days reactor operation at full power.

## 2.2 Typical Operating Conditions

| | Cycle 29 |
|---|---|
| Total power generation in facility | 113 KW |
| Gamma heating in facility outside fuel | 9 KW |
| Total heat generation in fuel | 104 KW |
| Gamma heating in fuel | 6 KW |
| Fission heating in fuel | 98 KW |
| Average heat flux (averaged over cycle) | 100,000 Btu/hr-ft$^2$ |
| Peak to average heat flux (Maximum at beginning of cycle) | 2.06 |
| Peak heat flux | 220,000 Btu/hr-ft$^2$ |
| Average thermal neutron flux (from Physics calculation) | $1.91 \times 10^{13}$ nv |
| Total flow | 52 gpm |
| Flow inside fuel channel | 48 gpm (6.5 ft/sec) |
| Pressure | 1300 psi |
| Temperature, facility tube inlet | 509°F |
| Temperature, facility tube outlet | 525°F |
| Differential pressure across facility tube | 1.7 psi |
| Cleanup loop flow | <0.1 gpm |

## 2.3 Typical Coolant Conditions

| | Cycle 29 | Maritime Specification |
|---|---|---|
| Conductivity | 0.4 μmho cm$^{-1}$ | -- |
| Ionic dissolved solids (from conductivity | 0.2 ppm | <1 ppm |

| | Cycle 29 | Maritime Specification |
|---|---|---|
| Turbidity | <3 Nephelos | -- |
| pH | 6.7-7.5 | 6.5-8.5 |
| Chloride | <0.02 ppm | <0.1 ppm normal<br>1.0 ppm, 24 hr. max. |
| Dissolved oxygen | 0.01-0.04 ppm (after first 3 days) | <0.01 ppm normal<br>0.05 ppm max. |
| Dissolved hydrogen | Not added | 1.8-3.6 ppm |

2.4 Operation Summary

The loop operated continuously during the report period for the full duration of reactor operation (i.e., no loss of irradiation exposure hours). All water chemistry conditions were maintained within specifications during reactor operation with the exception of the dissolved hydrogen.

SECTION III

# MARITIME FUEL OPERATION

## 3.1 Heat Generation and Peak Heat Flux

The total heat generation as calculated from the loop flow and temperature data averaged 116 KW for the report period and was slightly lower than the previous average. The highest peak heat flux also calculated from loop flow and temperature data during the report period was 222,000 Btu/hr-ft$^2$ (Cycle 27). The estimated peak-to-average ratio, nominally 2.22, dropped to 2.06 for the report period as a result of the particular reactor core fuel loadings used for the cycles.*

## 3.2 Burnup

The loop fuel burnup accumulated during the report period was 999 MWD/Tonne Uranium with the total burnup at 3671 MWD/Tonne Uranium based on fission heating as calculated from the loop flow and temperature data.

## 3.3 Differential Pressure Across Facility Tube

The differential pressure across the facility tube has remained within the range of 1.0-2.0 psi throughout the fuel irradiation. The variations from cycle to cycle have not shown a trend toward increased differential pressure. A temporary increase in the order of 0.2 psi has been observed following reactor scrams or shutdowns (loop remaining in operation). The increase is approximately that expected on the basis of coolant density increase, following reactor scram, in the pipe leg rise between the test section and the facility tube exit differential pressure tap (differential pressure taps are 27 ft. above the reactor core zone).

## 3.4 Fission Product Check of Cladding Integrity

The fission product levels during each cycle since the irradiation began have remained essentially constant. A sample taken December 27 gave the iodine-133 level of 388 disintegrations per minute per milliliter of

*Subsequent operation starting in January 1962 returned to regular core loadings with an increase in the peak-to-average ratio.

loop coolant (dpm/ml) and the iodine-131 at 37.3 dpm/ml. The levels are consistent with those expected from background surface contamination of the fuel.

SECTION IV

MARITIME FUEL ENVIRONMENT - COOLANT CONDITIONS

4.1 Conductivity

The conductivity was maintained in the range of 0.2-0.6 μmho $cm^{-1}$ during reactor operation with a typical value of 0.4 μmho $cm^{-1}$. The corresponding ionic dissolved solids was 0.1 to 0.3 ppm.

4.2 pH

The pH remained within the range of 6.7-7.6 as measured by the colorimetric method. Data indicating a pH of 8.2 on October 17, and 8.1 on October 20, are believed to be attributable to sample contamination.

The pH was measured on November 10, 24, and December 11, with the readings in the range of 5.65-6.15 pH units. The reading was essentially the same, however, when the pH of laboratory demineralized ultra-high-purity water was tested with the identical electrodes.

The water sample temperature is normally close to 37°C where the theoretical pH of neutral water is 6.8 units. On the basis of theoretical considerations, assuming the extreme case of the entire conductivity (about 0.4 μmho $cm^{-1}$ at 40°C) being due to nitric acid in pure water, the pH at 24°C must be 6.1 units or greater.

A few additional parts have been ordered to adapt the Beckman number 40297 glass flow cell for installation in the sample station to be used by Chemistry for non-routine special samples.

4.3 Chlorides

The chlorides as measured daily by the nephelometer method at the loop location were less than 0.02 ppm, except for a few samples slightly higher, with the highest sample indicating 0.11 ppm. All of the weekly laboratory analyses yielded less than 0.02 ppm chloride by the more accurate Hellige turbidimeter procedure.

4.4 <u>Dissolved Oxygen</u>

The dissolved oxygen was within specification (0.05 ppm tentative maximum) during periods of reactor operation for the report quarter.

The dissolved oxygen ranged between 0.015 and 0.025 ppm for the first three weeks of reactor Cycle 27, and between 0.025 and 0.040 ppm for the last week of the cycle. Levels of oxygen in Cycle 28 were typically in the range of 0.02-0.045 ppm. The oxygen levels were highest during the initial portions of Cycle 29. Ten readings taken at various times during the first 48 hours of reactor operation were all in the indicated range of 0.048 ppm to 0.058 ppm oxygen (0.041 to 0.049 ppm oxygen when a temperature correction based on assumed sample temperature of 35°C was applied). The oxygen decreased during Cycle 29, with a few samples toward the end of the cycle indicating less than 0.01 ppm.

The dissolved oxygen during much of the report period was higher than that normally experienced during several previous cycles. Two attempts to reduce the oxygen level by pressurizer blowdown during Cycle 28 were unsuccessful. The pressurizer blowdown operation, normally very effective in reducing the oxygen level, was repeated 14 times during the first 48 hours of reactor operation of Cycle 29 with little success in reducing the oxygen level. The insensitivity of the oxygen level to the pressurizer blowdown suggested (1) the presence of an oxygen source such as a dead leg or pocket of relatively high oxygen concentration, or (2) an increase in the equilibrium dissolved oxygen level attributed to water decomposition. Whichever the cause, the oxygen level decreased to more normal low levels by the end of the report period.

The thallium column operation was checked by replacing it with a freshly loaded column of identical construction on November 10, 1961, which yielded essentially the same dissolved oxygen results. No change was observed, therefore, in the performance of the original thallium column after 7 months of service (originally installed April 14, 1961).

An additional check of the thallium column method was made on December 5, by comparing data with that utilizing an indigo carmine procedure. The following results were obtained:

| | Thallium Column Method ppm $O_2$ | Indigo Carmine Method ppm $O_2$ |
|---|---|---|
| Loop Water | 0.040 | 0.05 |
| Makeup Water | 0.007 | 0.005 |

The results agree well within the accuracy of the procedures and support the reliability of the thallium column method.

4.5 Dissolved Hydrogen

Approval was granted by the Maritime Administration early in the report period to proceed with the design and construction of a new system for hydrogen additions. The new system is now partially complete, with installation scheduled for January 1962. The routine additions were discontinued June 26, 1961, (Cycle #24) because of hazards involved with the old addition system.

The new system utilizes a compressor to inject hydrogen into the loop. Hydrogen gas will be piped from a hydrogen bottle (located outside the GETR containment building) to the compressor suction at about 250 psig. The compressor suction at about 250 psig. The compressor, when running, will inject the hydrogen into the loop at approximately the system pressure of 1300 psig. The compressor operation will be controlled by a timer so that additions will be made automatically; with the timer setting adjusted according to the resulting hydrogen concentration within the loop.

SECTION V

LOOP OPERATION

5.1 General

The loop operated continuously during the report period for the full duration of reactor operation (i.e., no loss of irradiation exposure hours). The leak rate was high during Cycles 27 and 28, with no water samples taken the last day of Cycle 28 in order to conserve loop water. The leak rate was reduced somewhat during Cycle 29 but is still considered excessive, and efforts are continuing to further reduce the leak rate.

The cleanup loop flow was low during Cycle 28 and essentially zero for most of Cycle 29 because of inability to cool the flow sufficiently. The loop conductivity remained at a normal low value, typically 0.4 μmho $cm^{-1}$. The loop makeup water was generally less than 0.2 μmho $cm^{-1}$ conductivity, contributing to the maintenance of the low conductivity of the loop water. Corrective measures are planned for the end of cycle shutdown to restore normal cleanup loop flow.

5.2 Sample Station Modification

Verbal approval was received from SAN in October to proceed with the fabrication of a re-designed water-chemistry sample station. The existing sample station has proven reliable, but experience has shown that it requires more operator manipulation and interpretation than is desirable, with the result that closer supervision is required, and the probability of errors is greater. The new design will reduce the number of valve manipulations required for routine sampling, will simplify the conductivity and dissolved oxygen readout, and will reduce the time required for a dissolved oxygen measurement. The new station will include a sample cooler and thermometer for a more accurate determination of conductivity and dissolved oxygen. The modifications include a re-design of the total-gas sampler used in control of the hydrogen concentration. The planned revisions to the sample station are part of a continuing program to develop techniques and equipment which will permit semi-skilled technical personnel, such as loop operators, to maintain surveillance of water chemistry variables.

Most of the equipment needed for this change is on hand, and fabrication of the station is underway. The revised sample station is scheduled to be installed during the Cycle 33 (April 15) shutdown.

## SECTION VI

## FUEL INTERIM EXAMINATION

The first interim examination of the S-I-5-B-M fuel assembly was performed in September, 1961, after 2500 MWD/Tonne Uranium exposure. The second interim examination is scheduled for May 21, 1962, after 5000 MWD/Tonne Uranium exposure.

## SECTION VII

## CRUD DEPOSITION PROGRAM

A coupon exposure program was established at the beginning of the irradiation program for the purpose of comparing the crud deposition levels on coupons of two different initial surface roughnesses. The test consists of exposure of a total of 30 coupons, 15 each of the 125 RMS and 250 RMS surface roughnesses. The coupons are 304 S.S. and are located in a coupon holder in the test section effluent line in the loop equipment cubicle (not exposed to reactor neutron flux). The exposure history for the individual coupons is shown in Table 1.

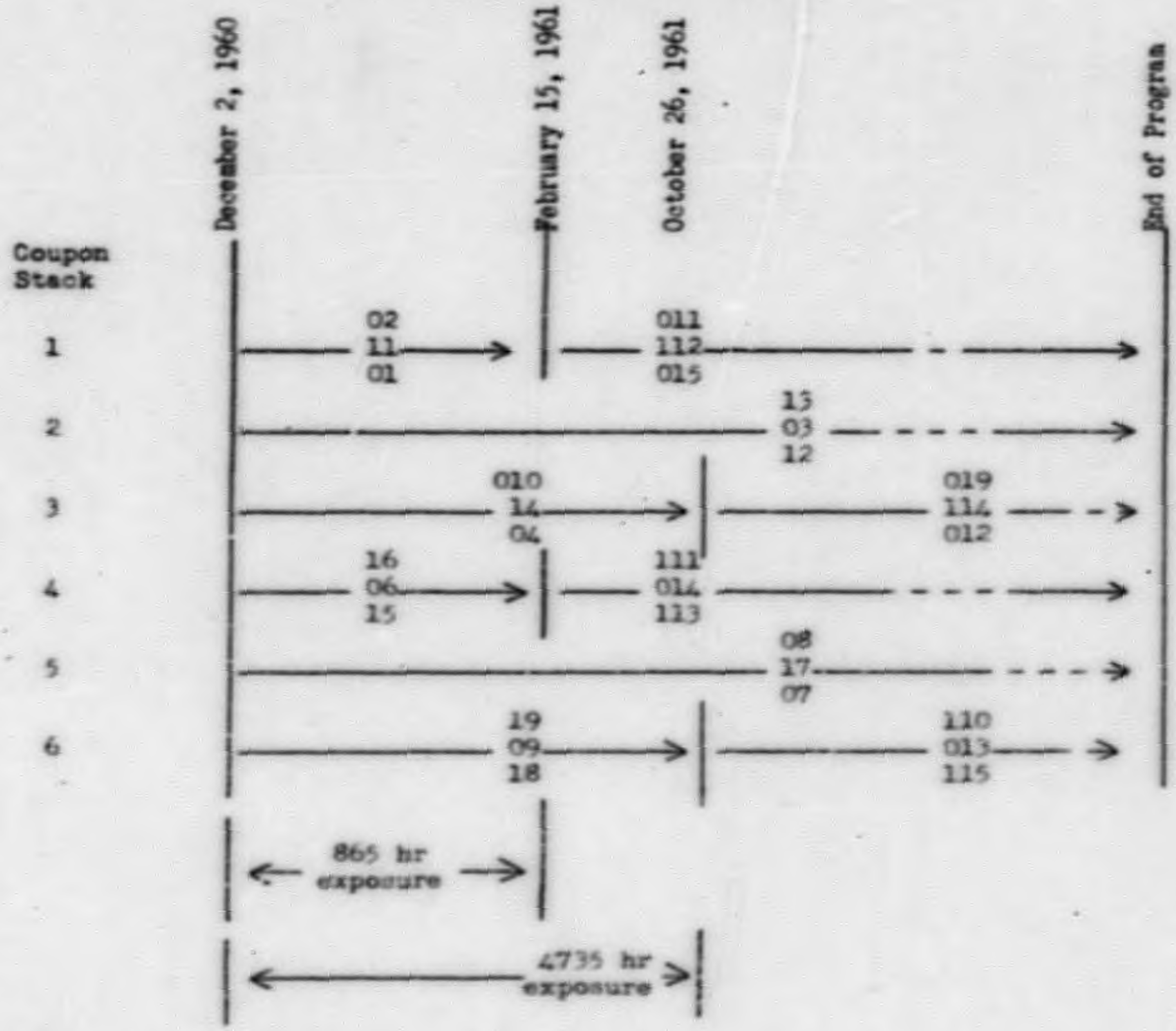
To date a total of 6 coupons of each surface roughness has been removed, and all have experienced a weight loss during exposure, based on weights determined before and after exposure (no descaling). The data show 2.3 mg average loss (3 coupons) for 865 hours exposure, and 5.4 mg average loss (6 coupons) for 4735 hours exposure. Statistically there was no significant difference in weight loss between the coupons having the two surface roughnesses. The coupons have not been descaled since the program objectives do not include corrosion rate determination. Three coupons removed after 865 hours exposure showed an average of 19.9 mg loss, with most of the loss caused during loop operation by abrasion against a defective support screw.

The coupon surface after 865 hours exposure was covered with a very thin film producing interference colors; the original surface roughness pattern was clearly visible. After 4735 hours exposure, the deposit had increased in thickness, became darker (black with a tinge of deep red), but the original surface pattern was still visible. The deposit observed on the coupons was considerably less than that observed on the fuel section when inspected during the first interim exam after 4187 hours of fuel exposure.

The activity deposition levels are shown in Table 2. Gross gamma counts with the scintillation crystal provide an accurate comparison of

Table 1

MARITIME COUPON EXPOSURE SCHEDULE




NOTES:

All coupons: Material 304 SS

First number 0 designates 125 RMS microinch surface roughness.
First number 1 designates 250 RMS microinch surface roughness.
Nominal dimensions 7.6 cm x 1.9 cm x 0.3 cm.
Nominal surface area (from dimensions) 0.35 $dm^2$.
Nominal weight 30 grams.

the activity of the two types of coupons. As noted from Table 2, the difference between the two surfaces was somewhat greater after 865 hours exposure than observed later after 4735 hours exposure. However, in both cases, the difference was 5 per cent or less, with the difference after 4735 hours exposure not statistically significant.

The composition of the gamma activity on a few coupons was observed on a multichannel analyzer. The results indicate the presence of normal stainless steel corrosion products. Note that the majority of the dose rate after 4735 hours exposure was due to Co-60, and that the proportion of the total activity due to Co-60 increased with time. For the difference in exposure time of a factor of 5.5, the MEV/sec gamma activity increased a factor of 9.4, and the Co-60 increased a factor of 23.

The coupons currently installed are scheduled to be removed at the conclusion of the irradiation program.

Table 2

RADIOACTIVITY DEPOSITION ON MARITIME COUPONS

| Measurement | 865 hour exposure | | 4735 hour exposure | |
|---|---|---|---|---|
| | 125 RMS surface | 250 RMS surface | 125 RMS surface | 250 RMS surface |
| Surface "cp" gross gamma readings of individual coupons | ≈ 1 mR/hr @ 2" | ≈ 1 mR/hr @ 2" | 9.2 ± 0.3 mR/hr @ 2" | 9.5 ± 0.5 mR/hr @ 2" |
| Average (3 coupons each group) Gross gamma count per 5 minutes using 1-3/4" x 2" NaI(Tl) well crystal biased at 30 KEV (865 hr exposure coupons 9 cm above crystal) (4735 hr exposure coupons 26.7 cm above crystal) | 401,000 | 423,000 | 460,700 | 471,650 |
| | Difference<br>22,000 ± 9,900 (90% confidence limits)<br>22,000 ± 19,800 (95% confidence limits) | | Difference<br>10,950 ± 13,440 (90% confidence limits)<br>10,950 ± 19,800 (95% confidence limits) | |
| Multichannel analyzer gamma activity determination | Coupon #02<br>$1.3 \times 10^5$ MEV/sec total in-luding<br>$2.9 \times 10^4$ MEV/sec Co-60<br>(Co-60 23% of total)<br>(0.9 μc Co-60 per $dm^2$ surface) | | Coupon #09<br>$1.2 \times 10^6$ MEV/sec total including<br>$6.7 \times 10^5$ MEV/sec Co-60<br>(Co-60 57% of total)<br>21 μc Co-60 per $dm^2$ surface) | |

## BIBLIOGRAPHY


1. Maritime Loop Irradiation Program, Loop Operation Data Summary Reports, D. W. Danielson and R. S. Gilbert.

| Report No. | Date | GETR Cycle |
|---|---|---|
| 1 | January 20, 1961 | 18 |
| 2 | February 20, 1961 | 19-20 |
| 3 | April 25, 1961 | 21 |
| 4 | May 29, 1961 | 22 |
| 5 | July 14, 1961 | 23 |
| 6 | August 14, 1961 | 24 |
| 7 | September 11, 1961 | 25 |
| 8 | October 18, 1961 | 26 |
| 9 | November 17, 1961 | 27 |
| 10 | December 29, 1961 | 28 |
| 11 | January 31, 1962 | 29 |

2. Maritime Loop Irradiation Program, Savannah I Fuel Irradiation, Quarterly Progress Reports.

| | Period Covered | Date | Author |
|---|---|---|---|
| GEAP-3652 | July 1960-December 1960 | February 13, 1961 | I. L. Marburger |
| GEAP-3752 | January 1961-March 1961 | June 13, 1961 | D. W. Danielson |
| GEAP-3808 | April 1961-June 1961 | August 25, 1961 | D. W. Danielson |
| GEAP-3869 | July 1961-September 1961 | December 21, 1961 | D. W. Danielson and R. S. Gilbert |

3. Maritime Loop Irradiation Program, S-I-5-B-M Irradiation, 2500 MWD/Tonne Interim Examination Report by P. W. Mathay, November 15, 1961.

4. GEAP-3604: Maritime Loop Irradiation Program for Savannah I Fuel, Pre-Irradiation Examination of NMSR-GETR Test Fuel Assemblies 1 and 2 by P. W. Mathay, January, 1961.


END