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EFFECTIVE RETENTION TIME

OF THE

HANFORD 107 REACTOR EFFLUENT RETENTION BASINS

HW--28830

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by

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EFFECTIVE RETENTION TIME OF REACTOR EFFLUENT BASINS

INTRODUCTION

The effective retention time of the waste effluent basins in the reactor areas is important in determining the concentrations of beta particle emitters in the reactor effluent water admitted to the Columbia River. This report summarizes the study of retention times performed by the Biophysics Regional Survey forces of the Radiological Sciences Department. The values obtained are used for calculating decay correction factors in order to determine more accurate figures for the beta particle activity density of water leaving the various retention basins.

SUMMARY

Studies of the radioactive decay of the gross beta particle emitters in reactor effluent water indicated that the retention time for basins at the different reactor areas varied from 1.5 hours to 4.0 hours for flow rates occurring during the last three years. A statistical analysis of the data from 100-B, 100-D, and 100-F indicated a significant relationship between the two variables, effective retention time and water flow rate. The limited data from 100-DR and 100-H showed no significant relationship. The uranyl nitrate tests, which were conducted at the 107-H West basin by Pile Physics personnel, indicated that a fraction of the uranium passed through the basin in less than one hour and that a maximum concentration was reached in approximately 2.5 hours. This test indicated a more complicated system of flow through the basin than the decay studies had shown and it further explained the large fluctuation in results obtained for the retention time by the decay method.

A study of the variation with time of the activity density of water leaving the 107-H basin indicated that a cyclic effect might be occurring in which the variation from the mean was found to be as high as 15 percent.

PROCEDURES

A. Retention Time by Decay of Gross Beta Particle Emitters

The effective retention time was determined from the counting rates obtained on water samples collected at the inlet and outlet sides of each basin. The inlet samples were maintained on decay study until the counting rate of the beta particle emitters in the inlet water equaled the initial counting rate of the beta particle emitters in the outlet water at sampling time. The time interval after sampling required for the inlet water to reach equality with the outlet water was considered as the effective retention time. A sufficient number of measurements was made to define the radioactive decay of inlet and outlet samples of water; minimum, maximum, and mean values of each set of measurements were determined.

Sampling at the outlet of the basins was accomplished after the reactor effluent water had flowed over the lip of the weir at 100-H, 100-DR, and 100-C. At 100-B, 100-D, and 100-F, the samples were taken from the end of the spillway. Inlet samples were obtained by dipping the samples from the bubble where the water enters the basin in all areas except 100-C where a sampling port is available at the cushion box which is located approximately twenty feet from the 100-C inlet point.

A two-cc aliquot of water, collected from the inlet and outlet sampling points, was placed on a one-inch diameter stainless steel plate, dried under an infra-red lamp and then placed in an aluminum holder for counting. The water was filtered for the latter measurements to remove possible interference by particulate contamination. Earlier samples collected in 1950 were not filtered. Counting was accomplished by use of a mica-window G.M. tube enclosed in a vertical lead shield and connected to a conventional scaler. The equipment was mounted on a mobile unit equipped with a 1.5 KW AC generator.

B. Retention Time by Isotopic Analysis

Measurements of the retention time of the 107-H effluent retention basin were also made by specific analysis for uranium after uranyl nitrate was injected into the reactor effluent water during tests by Pile Physics personnel[1]. The effective retention time was determined as the interval between the time at which the maximum concentration of uranium was determined in the inlet water and the time at which the maximum was observed in the outlet water. Samples were analyzed for uranium in the Biophysics Control Laboratory of Radiological Sciences Department by means of a fluorophotometer[2].

C. Variation in Effluent Water Activity Density

The effect upon retention measurements caused by variation in sampling time and sampling location was studied by collecting samples from five equally spaced points on the 107-H basin outlet weir. Samples were collected at frequent intervals over a four hour period and treated by the Control Laboratory in the same manner as those for the determination of retention time by the decay method. The time interval between sampling and counting was maintained constant to eliminate decay corrections and all samples from a single position were counted on the same equipment to facilitate comparison over the sampling period.

D. Statistical Analysis

Statistical analysis was directed at correlating the relationship between effective retention time and flow for basins of the same volume with significance being determined in each case by the 99 percent probability level. Correlation coefficients were tested by a T-test.

Data from samples which were collected from various points on the 107-H weir were tested for significant difference by the same method.

RESULTS

The values of the retention time as determined by the decay method are shown in Table I together with the theoretical value determined by calculating the period required to fill the basin at the given flow rate. The capacity of the 107 basins, as determined from structural blueprints, was 6.1 million gallons for 107-B, 107-D, and 107-F; 9.1 million gallons for 107-H and 107-DR, and 10.2 million gallons for 107-C.

TABLE I
RESULTS OF 107 BASIN RETENTION TIME DETERMINATIONS

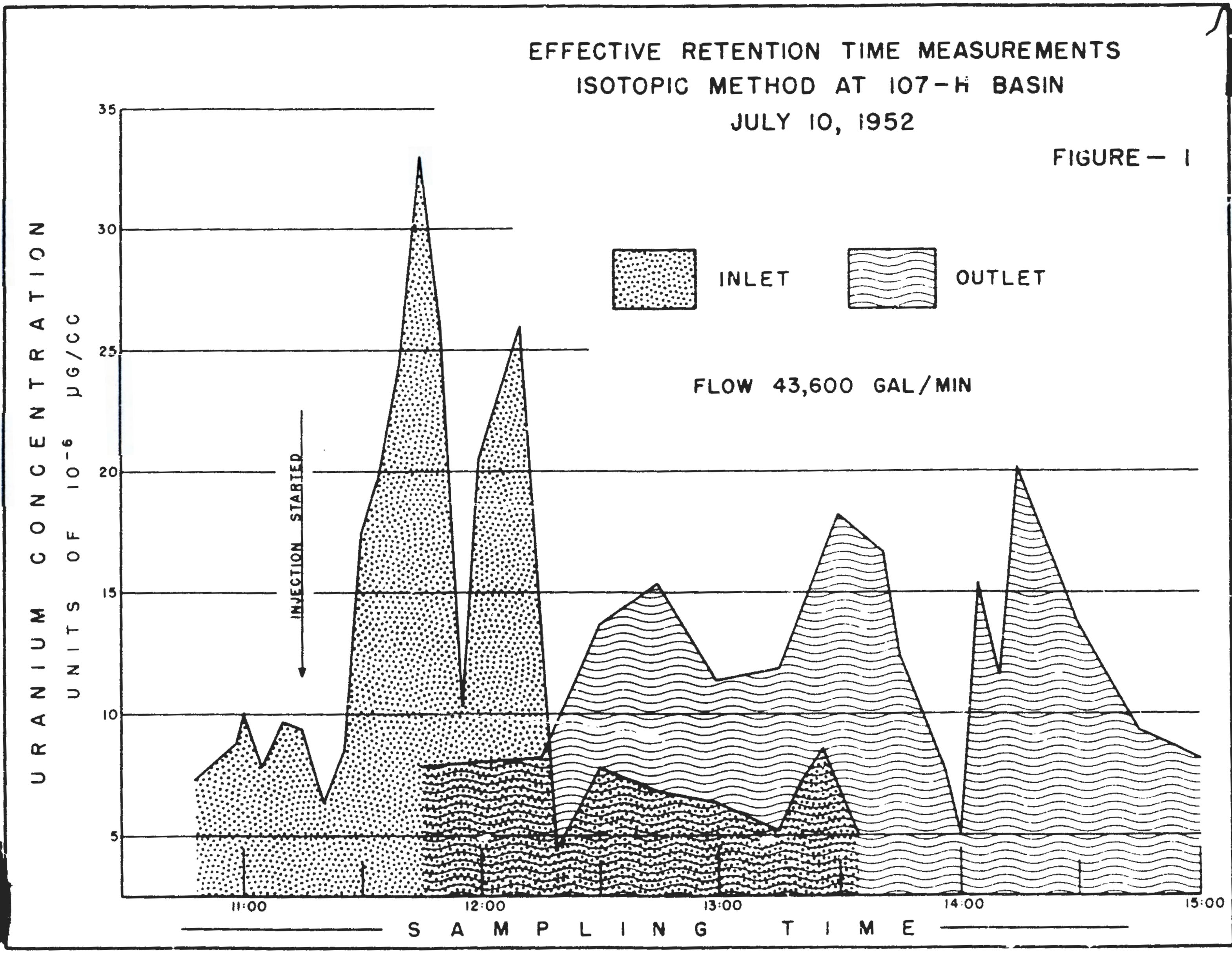
Area	Date	Basin	Water Flow Gal/Min.	Experimental Hold-up Hrs. Min.	Experimental Hold-up Hrs. Mean	Experimental Hold-up Hrs. Max.	Theoretical Hold-up Hrs.
100-B	6-1-50	South	32,300	2.0	2.4	2.8	3.1
100-B	6-15-50	South	32,300	2.1	2.5	2.9	3.1
100-B	6-28-50	South	32,300	2.3	3.0	3.7	3.1
100-B	6-12-52	North	36,630	1.5	1.9	2.3	2.8
100-B	6-24-52	North	36,250	1.8	2.0	2.2	2.8
100-B	7-28-52	South	38,280	1.9	2.1	2.3	2.7
100-B	9-18-52	North	39,060	1.3	1.6	1.9	2.6
100-B	9-25-52	North	38,920	1.7	2.0	2.3	2.6
100-B	11-18-52	North	37,650	1.6	1.9	2.2	2.7
100-D	5-2-50	South	32,400	2.7	3.2	3.8	3.1
100-D	6-22-50	North	32,600	2.7	3.2	3.7	3.1
100-D	6-18-52	North	39,700	1.7	2.1	2.5	2.6
100-D	6-25-52	North	39,580	1.7	2.2	2.7	2.6
100-D	7-24-52	South	39,820	1.2	1.7	2.2	2.6
100-D	9-12-52	South	39,940	1.9	2.2	2.5	2.5
100-C	12-8-52	East	65,000	1.2	1.5	1.8	2.8
100-C	12-10-52	East	64,700	1.3	1.5	1.7	2.8
100-C	1-28-53	East	64,100	1.5	1.6	1.7	2.8
100-F	4-26-50	East	31,000	3.5	4.2	4.8	3.3
100-F	6-21-50	East	32,300	3.6	4.0	4.5	3.1
100-F	6-11-52	West	36,550	2.1	2.5	2.9	2.8
100-F	7-1-52	East	36,950	2.2	2.5	2.8	2.8
100-F	7-7-52	East	37,400	2.4	2.8	3.2	2.7
100-DR	10-13-50	West	37,000	2.4	2.8	3.1	4.1
100-DR	6-19-52	West	42,250	2.1	2.5	2.9	3.6
100-DR	6-23-52	West	41,870	2.1	2.7	3.3	3.6

TABLE I (Cont'd)
RESULTS OF 107 BASIN RETENTION TIME DETERMINATIONS

Area	Date	Basin	Water Flow Gal/Min.	Experimental Hold-up Hrs. Min.	Mean	Max.	Theoretical Hold-up Hrs.
100-H	4-19-50	West	38,000	3.0	4.4	5.7	4.0
100-H	6-26-50	West	38,600	2.3	2.6	2.9	3.9
100-H	6-30-50	West	38,800	2.6	3.4	4.1	3.9
100-H	9-21-50	West	41,600	2.0	3.9	5.8	3.6
100-H	6-16-52	East	43,780	2.5	2.7	2.9	3.5
100-H	6-20-52	West	43,440	2.2	2.5	2.8	3.5
100-H	7-17-52	East	44,070	2.0	2.2	2.4	3.4
100-H	7-18-52	East	37,865	2.7	3.1	3.5	4.0

The results as determined by the isotopic method are given in Figures 1 and 2. Figure 1, representing the results of the test conducted on July 10, 1952, shows that the first indication of uranium in the 107-H outlet water was approximately one hour after positive amounts were detected at the inlet, and that there was a period of 2.0 to 2.5 hours between the maximum indication at the inlet and the maximum indication at the outlet. The concentrations of different outlet samples collected at the northwest corner of the weir were non-uniform and somewhat cyclic in nature.

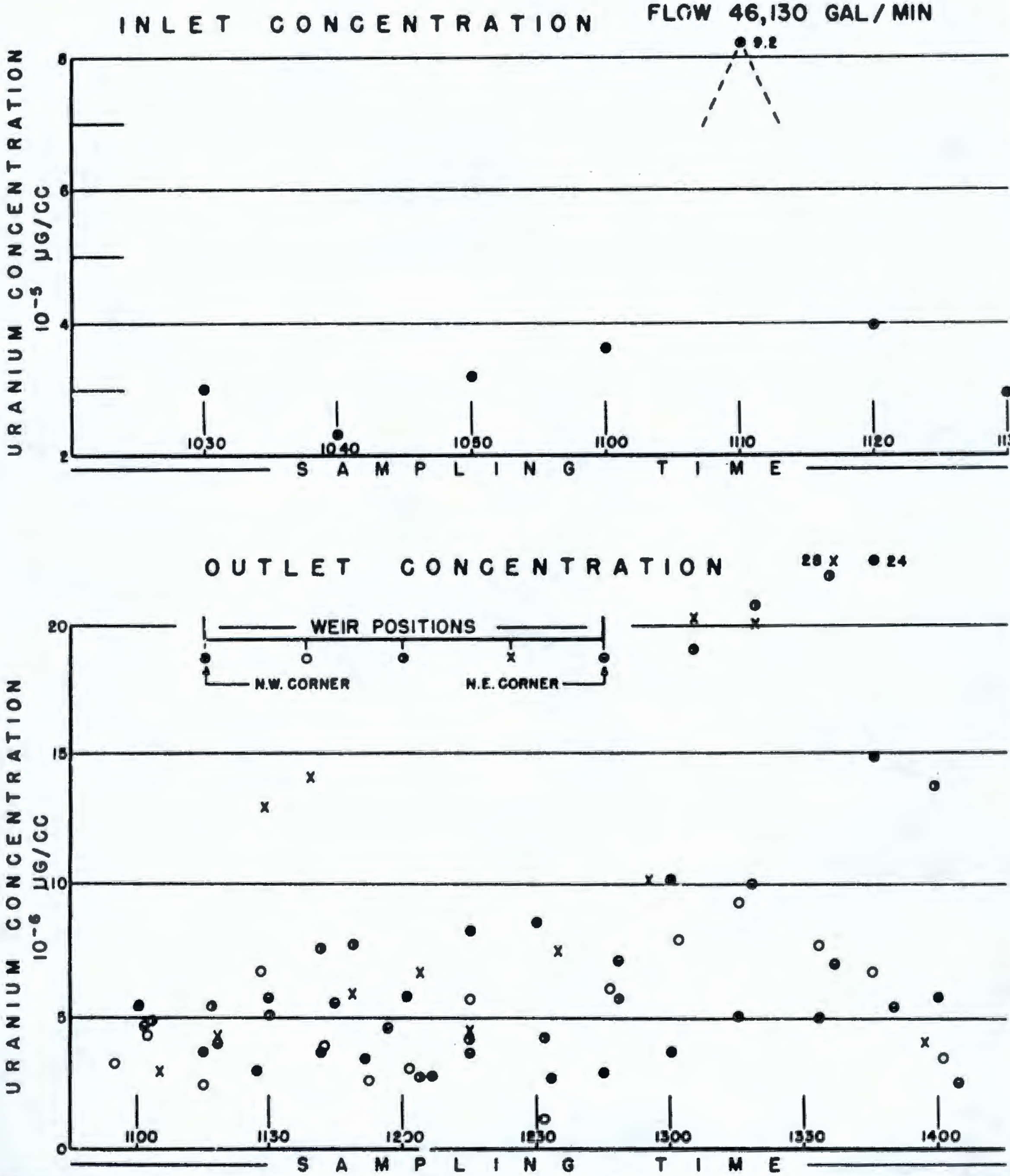
The plot of inlet sample concentrations shown in Figure 2 for the test conducted on September 5, 1952, indicates that the maximum concentration occurred at approximately 1110. A plot of the concentrations of samples from five positions on the outlet weir which were sampled for the same tests (Figure 2) indicates that a fraction of the uranium passed the outlet approximately thirty minutes after the first indication in the inlet and that the maximum concentration in the outlet samples appeared about 2.5 hours after that in the inlet. Results from this test agree with those from the previous test run on July 10, 1952, and also agree relatively well with the retention time as determined by the decay method. A study of the sample concentrations for the particular test shows that the highest



EFFECTIVE RETENTION TIME MEASUREMENTS
ISOTOPIC METHOD AT 107-H BASIN
JULY 10, 1952
FIGURE — 1
INLET
OUTLET
FLOW 43,600 GAL/MIN
INJECTION STARTED
URANIUM CONCENTRATION
UNITS OF 10-6 μG/CC
35
30
25
20
15
10
5
11:00
12:00
13:00
14:00
15:00
SAMPLING TIME

EFFECTIVE RETENTION TIME MEASUREMENTS
ISOTOPIC METHOD AT 107-H BASIN
SEPTEMBER 5, 1952

FIGURE-2



percentage of the uranium flowed over the weir near the middle.

Since the background concentration of uranium in the water was low before the test, variations in the water flow rate pattern in the basin had a marked effect on the distribution of the uranium with sampling location and time. Similar variations have a less marked effect on the concentrations of gross beta particle emitters in the outlet water when all the water in the basin contains residual concentrations of these isotopes. The data plotted in Figure 3 represent concentrations of samples collected at the same locations on the 107-H weir and analyzed for gross beta particle emitters. These data also indicate higher average concentrations near the center of the weir although differences are not so marked as in the uranium test.

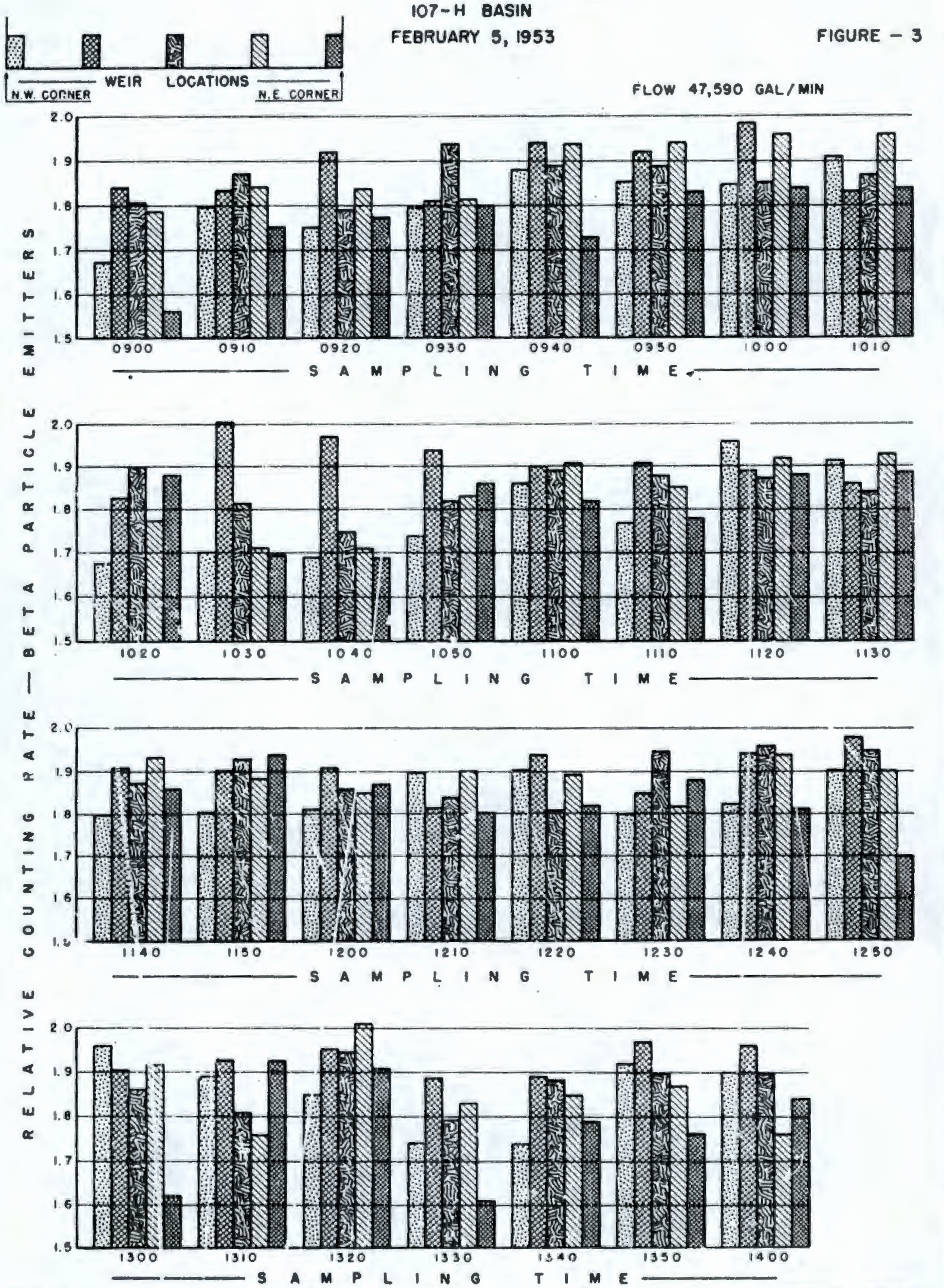
Figure 4B is a plot of the inlet concentrations of gross beta particle activity during the same period as that shown in Figure 3. The variation in inlet gross beta activity density, in general, has the same magnitude as that found for the outlet samples. The minimum and maximum for the outlet samples during the five hours in which the samples were taken were of the ratio 1:1.3. The inlet sample minimum and maximum for that same period were of the ratio 1:1.4. Figure 4A is a graph of sample results obtained from the outlet on January 23, 1953, at which time the variation was similar to that found in the above mentioned data. The cyclic pattern was again indicated from these data.

DISCUSSION

The measurements at 100-B, 100-D, and 100-F areas were grouped together for simplicity in calculation since the design of the retention basins in these areas is the same. The measurements made at 100-DR and 100-H areas were also treated together for the same reason. The effect of differences in baffling at the similar basins was not allowed for, although data from different basins of the same group may be materially affected by this variable as the baffling

VARIATION IN COUNTING RATE WITH
SAMPLING POSITION AND TIME
107-H BASIN
FEBRUARY 5, 1953

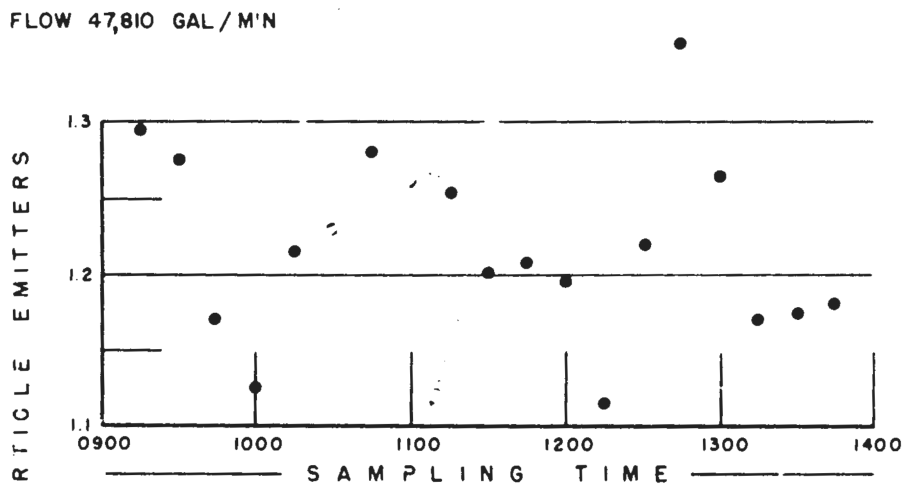
FIGURE - 3



VARIATION IN RELATIVE COUNTING RATE

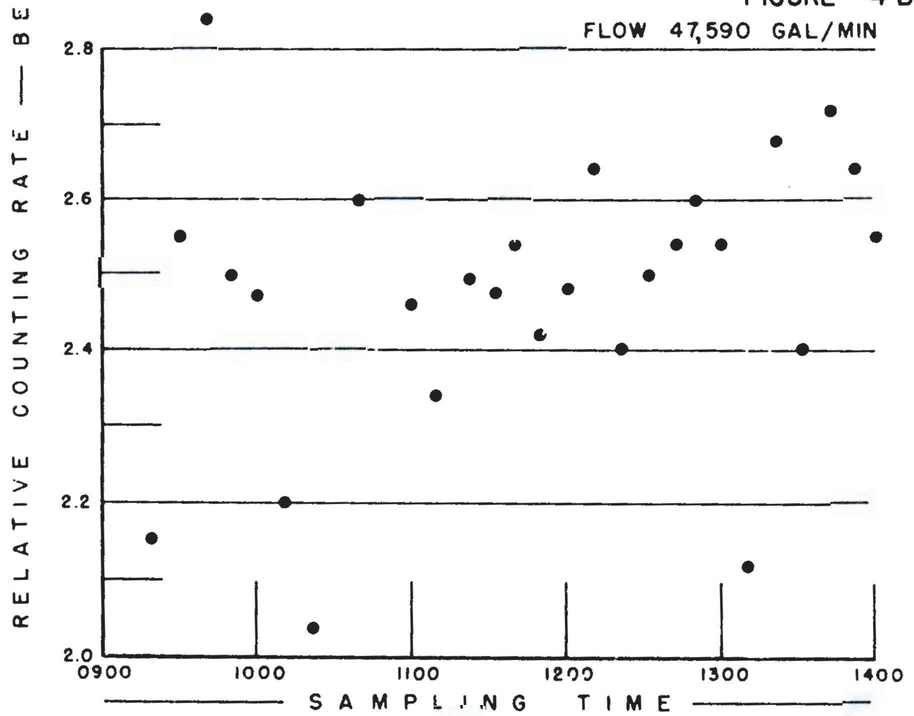
OUTLET SAMPLES - N.W. CORNER 107-H BASIN
JANUARY 23, 1953

FIGURE - 4 A



INLET SAMPLES 107-H BASIN
FEBRUARY 5, 1953

FIGURE - 4 B



becomes defective.

Statistical investigation of a possible relationship between water flow and retention time of the basins in 100-B, 100-D, and 100-F revealed that the relationship followed a hyperbolic function; a significant correlation coefficient of 0.78 was obtained. Eleven measurements at 100-DR and 100-H areas showed no correlation.

A satisfactory expression of the relationship between retention time and water flow in the data from the older basins was obtained by using an "effective" basin volume determined as the product of the experimental retention time in minutes and the water flow in gallons per minute. This "effective" basin volume was less than the true volume in all cases, a condition possibly existing because of channeling of the effluent stream in the basin. The relationship was adequately described for data previously obtained at low flow rates[3] as well as for the data reported here by the following relationship:

$$xy = 5 \times 10^6$$

where y = retention time in minutes

where x = water flow in gallons per minute.

Assuming that the same type of relationship holds for 107-H and 107-DR basins where measurements at lower flow rates were not made, the data at higher flow rates indicate that the best equation for such relationship may be expressed as:

$$xy = 7 \times 10^6$$

The different physical shape of the 107-C basin prevents application of such an equation until more data are obtained.

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The data represented in Figure 3 were investigated to determine if there were any differences in activity density of the water at the five locations sampled that could not be attributed to laboratory or counting measurement error. A study of the measurements at eight random times during the sampling period indicated that any variation in the sample concentration due to sampling location was of questionable significance, although concentrations near the center of the weir averaged significantly higher and varied less than those at the ends of the weir. The variations noted in sampling position and in the retention time measurements for various flow rates indicated that more accurate evaluations of the activity density of gross beta particle emitters entering the Columbia River would be desirable. A possible improvement would be the relocation of sampling equipment in the effluent line downstream from the outlet weir where the sample taken would more nearly represent a composite of all water flowing over the weir.

[redacted]

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