DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Cover Sheet for a Hanford Historical Document Released for Public Availability

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

MASTER

SECRET

DECLASSIFIED

RL-2-14

Hanford Code C-65

Copy No. [REDACTED]

Date 6-1-66

RICHLAND FIVE-YEAR

02 R&D PROGRAM

COLUMBIA RIVER STUDIES

**RICHLAND OPERATIONS OFFICE
DOUGLAS UNITED NUCLEAR, INC.
GENERAL ELECTRIC COMPANY - HAPD
ISOCHEM INC.
BATTELLE - NORTHWEST**

[REDACTED]

[REDACTED]

DECLASSIFIED

SECRET

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DECLASSIFIED

RL 2-14
HANFORD CODE C-65

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of D S Lewis

CG-NMP-1, 8-11-94

By J E Savely 8-18-94

Verified By Jerri Maley,
10-19-94.

This document consists of
35 pages. Copy No.

R I C H L A N D F I V E - Y E A R

0 2 R & D P R O G R A M

C O L U M B I A R I V E R S T U D I E S

Date **JUN 1 1966**

RICHLAND OPERATIONS OFFICE

DOUGLAS UNITED NUCLEAR, INC.

GENERAL ELECTRIC COMPANY - HAPD

ISOCHEM INC.

BATTELLE MEMORIAL INSTITUTE

RESTRICTED DATA

P L E A S E S I G N B E F O R E R E A D I N G

Route To:	P.R. No.	Location	Files Route Date	Signature and Date
<u>E.R. Fitch</u>	<u>30021</u>	<u>325</u>		<u>[Signature]</u> <u>7/5</u>
<u>C. J. Torbue</u>	<u>31968</u>	<u>722-0</u>	<u>SFD 7 5 1966</u>	
<u>D.B. Corlock</u>	<u>30894</u>			

DECLASSIFIED

R I C H L A N D F I V E - Y E A R
O 2 R & D P R O G R A M

C O L U M B I A R I V E R S T U D I E S

PRINCIPAL CONTRIBUTORS

R. G. Geier	DUN
R. F. Foster	BNW

MASTER

DECLASSIFIED

R I C H L A N D F I V E - Y E A R
O 2 R & D P R O G R A M

SUMMARY	RL 2-0
BASIC PRODUCTION MISSION	RL 2-1
COPRODUCT MISSION	RL 2-2
INTEGRATED SITE OPERATION	RL 2-3
NONDEFENSE PLUTONIUM MANAGEMENT	RL 2-4
TRANSPLUTONIUM PROGRAM	RL 2-5
PU-238 PROGRAM	RL 2-6
U-233 PROGRAM	RL 2-7
CO-60 PROGRAM	RL 2-8
PO-210 PROGRAM	RL 2-9
HIGH POWER DENSITY FUEL PROGRAM	RL 2-10
REACTOR MODERNIZATION	RL 2-11
FUNDAMENTAL AND GENERAL STUDIES	RL 2-12
NUCLEAR SAFETY PROGRAM	RL 2-13
COLUMBIA RIVER STUDIES	RL 2-14
WASTE MANAGEMENT	RL 2-15
OTHER ISOTOPES	RL 2-16
HIGHLY ENRICHED FUEL PROGRAM	RL 2-17

DECLASSIFIED

TABLE OF CONTENTS

	<u>Page</u>
<u>SUMMARY</u>	
INTRODUCTION	5
INCENTIVES	5
SCOPE AND OBJECTIVES	5
PROGRESS DURING REPORT PERIOD	6
BUDGET PERIOD PLANS AND EXPECTED RESULTS	7
STATISTICAL SUMMARY	9
EVALUATION OF PROGRESS	10
 <u>EFFLUENT ACTIVITY REDUCTION - DUN</u>	
SCOPE AND OBJECTIVES	11
PROGRESS DURING REPORT PERIOD	12
BUDGET PERIOD PLANS AND EXPECTED RESULTS	14
STATISTICAL SUMMARY	16
REFERENCES	17
PROGRAM CHART	18
 <u>MECHANISMS OF ENVIRONMENTAL EXPOSURE - PNL</u>	
SCOPE AND OBJECTIVES	20
PROGRESS DURING REPORT PERIOD	21
BUDGET PERIOD PLANS AND EXPECTED RESULTS	22
STATISTICAL SUMMARY	24
REFERENCES	25
PROGRAM CHART	26
 <u>EFFECT OF REACTOR EFFLUENT ON THE QUALITY OF COLUMBIA RIVER WATER - PNL</u>	
SCOPE AND OBJECTIVES	28
PROGRESS DURING REPORT PERIOD	30
BUDGET PERIOD PLANS AND EXPECTED RESULTS	30
STATISTICAL SUMMARY	32
REFERENCES	33
PROGRAM CHART	34
DISTRIBUTION	35

DECLASSIFIED

COLUMBIA RIVER STUDIESINTRODUCTION

The plutonium production reactors operated by Douglas United Nuclear, Inc., use treated Columbia River water as coolant on a once-through basis. Thus, radionuclides formed largely from the activation of river salts are released to the river. In addition to the radionuclides, heat and other chemicals are also added to the river by the reactor effluent. These discharges give rise to a program which includes three separate and distinct areas of study. The first involves devising practicable methods of reducing the amount of radioactivity released. The second addresses the mechanisms by which the radionuclide releases could result in radiation exposure to people. The third area of study concerns determining the effects of reactor effluent on the quality of Columbia River water. Both the heat and the chemicals added by the effluent are being investigated in the third study area.

INCENTIVES

Although the incentives for the Columbia River Studies program are not economic in the sense that an assessment in terms of dollar return can not be made, they are indeed large. The radioactivity, chemicals, and heat released to the Columbia River are pollutants. Studies to date have indicated that the releases have an inconsequential effect on the river and population downstream of the Hanford plant. Nevertheless, continuing and increasing emphasis on reducing or discontinuing all pollution necessitates an active and aggressive program in this area. The Water Pollution Control Act of 1965 and the President's Executive Order 11258 of November, 1965, concerning pollution from federal installations, add to the increasing political significance of Hanford effluents and the need for greater knowledge of their actual effect on river characteristics. The heat releases and a detailed knowledge of changes in river temperature are important because of the potential effects of such changes on aquatic life, especially salmon. This subject has considerable regional impact and is receiving close attention by Federal and State agencies.

SCOPE AND OBJECTIVEA. Reduction of Radioactivity in Reactor Effluent

The objective of the program is to devise practicable methods of reducing the amount of radioactivity released with the reactor effluent. The radionuclides in reactor effluent are formed largely by the activation of river water salts. However, the formation of the radionuclides is greatly enhanced by the adsorption of the parent material on the in-reactor films which results in increased irradiation time. There are then three approaches to reducing the radionuclide releases: (1) increase the efficiency of parent isotope removal during the coolant treatment process, (2) find methods to reduce or eliminate the time of adherence of the parent materials by changes in the chemical composition of the water, chemical form of the isotopes

DECLASSIFIED

or changes in the reactor film, and (3) removal of the radioisotopes from the reactor effluent. The studies scheduled in the program encompass basic work in the first two areas with emphasis on the film and the kinetics of parent isotope adsorption and radioisotope release.

B. Mechanisms of Environmental Exposure

The radioactivity released by the Hanford complex follows a variety of pathways that can lead to radiation exposure to people. This study is concerned with the quantitative evaluation of the mechanisms whereby people become exposed to such radiation. These exposure mechanisms studies not only sharpen estimates of existing exposure levels, but provide a basis for extrapolating to other conditions. They permit examination of exposures limiting the release of effluents and of future environmental problems which may result from new products and operating conditions. Whole body counting results for local residents will be used to indicate the isotopes of greatest significance. Their correlation with dietary data obtained from the same individuals can indicate the most important pathways whereby they reach members of the population living near the Plant. By including information regarding the probable concentration levels of the radionuclides in foodstuffs, it may be possible to calculate large-population averages of important metabolic parameters, such as fractional adsorption of nuclides from various foodstuffs.

C. Effects of Reactor Effluent on the Quality of Columbia River Water

In addition to radioactivity, the reactor effluent also adds heat and chemicals to the Columbia River. The study is concerned primarily with determining the extent to which the effluent alters the physical and chemical characteristics of the river. Work will be undertaken to:

1. Determine river temperature effects.
2. Determine chemical changes due to reactor effluents.
3. Determine effluent distributions and travel time.

PROGRESS DURING REPORT PERIOD

A. Effluent Activity Reduction

1. The one-year test to evaluate the effects of adding sodium silicate to process water was completed. The concentrations of P-32, As-76, Np-239, and Cr-51 were reduced by factors of 2, 6, 4.5, and 5.5, respectively. Some fringe tube filming was encountered and a higher dose rate from the rear face on the test side was demonstrated.

DECLASSIFIED

2. An alum feed test was completed at the K Reactors.
3. Additions of sodium silicate, sodium sulfite, and a proprietary film conditioning agent to the coolant were evaluated.
4. Studies to determine the inventory of parent and radionuclides in the films from process tubes, fuel elements, and spacers were initiated.

B. Mechanisms of Environmental Exposure

1. More than 500 children from four Richland elementary schools provided dietary information and were counted in the whole body counter.
2. An experiment to study the uptake of Zn-65 from beef was begun.
3. A statistical study of fishing on the Columbia River was designed and initiated.
4. An experiment was completed to determine the uptake of Zn-65 from oysters.
5. Whole body counting data, dietary information, and environmental sample analyses have been incorporated into a computer program that was used to seek correlations which reveal dietary exposure pathways.

C. Effects of Reactor Effluent on the Quality of Columbia River Water

1. Sufficient data were obtained from the portable meteorological station on the river bank at White Bluffs to permit statistical correlation with time-averaged river temperature.
2. Modifications of a time-sequenced heat budget model to the Plant reach of the river was started.
3. Temperature measurements at and below McNary Dam were begun.
4. An investigation of dysprosium as a neutron activated tracer for replacement of dye as a tracer was started.
5. Dye tests were completed for determination of effluent distribution and travel times from each reactor to below the Plant boundary.

BUDGET PERIOD PLANS AND EXPECTED RESULTS

A. Effluent Activity Reduction

1. Film inventory studies will continue and expand such that radio

DECLASSIFIED

and parent isotope inventory will be determined as a function of exposure in reactor, position in reactor, and surface.

2. Deionized water studies will be used to investigate adsorption kinetics.
3. The influence of component surfaces will be determined.
4. Water treatment optimization tests will continue.
5. The effect of a variety of additives to the coolant will be demonstrated.

B. Mechanisms of Environmental Exposure

1. Whole body counting of Richland and Pasco school children will be completed and counting in the Kennewick schools and in Riverview will be started.
2. The computer file will be used to compute dietary correlations with Cs-137, Na-24, and possibly I-131.
3. The experiment to study Zn-65 uptake from beef will be completed.
4. The mobile whole body counter will be used to measure the radio-nuclide body burden of fishermen.
5. The statistical sampling of fishing performance on the Columbia River will be completed, the data analyzed, and a report issued.

C. Effects of Reactor Effluent on the Quality of Columbia River Water

1. Temperature measurements in McNary reservoir will be continued and valid single-point measurements will be established at McNary Dam.
2. Temperature monitors, portable meteorological instruments, and continuous samplers will be installed on barges located above and below the reactors.
3. Effluent distribution from the PRTR outfall will be determined at several river flow rates.
4. Emphasis will be shifted from temperature and other effects of routine effluents toward better definition of the impact of nonroutine releases, especially fuel element failures, on river usage.

DECLASSIFIED

STATISTICAL SUMMARY SCHEDULE

Dollars (in Thousands)

Douglas United Nuclear

Pacific Northwest Lab

Total

Man. Years

Douglas United Nuclear

Pacific Northwest Lab

Total

Equipment

Douglas United Nuclear

Pacific Northwest Lab

Total

<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>5 Year Total</u>
100	100	100	100	100	500
180	200	200	200	200	980
280	300	300	300	300	1480
6.3	6.8				
6.3	6.8				
10	30				
10	30				

DECLASSIFIED

EVALUATION OF PROGRESS AGAINST PLANS AND OBJECTIVES

The deionized water studies scheduled as a part of the Effluent Activity Reduction Program were delayed several months due to contamination of the ion exchange resin and the need for resin replacement. Other than that exception the various portions of the three programs appear to be largely on the schedule established last year.

DECLASSIFIED

EFFLUENT ACTIVITY REDUCTION

SCOPE AND OBJECTIVES

The once-through use of coolant in the production reactors operated by Douglas United Nuclear, Inc., results in effluent which contains radionuclides. The effluent after a short holdup in the retention basins is sent directly to the Columbia River. There are over 60 identifiable radionuclides in the effluent. Subtracting from the list the radionuclides which have very short half-lives and those which are present in very low concentrations, there remain about 15 radioisotopes potentially capable of contributing to exposure to offsite personnel. Typical release rates of radioisotopes to the Columbia River during calendar year 1965 were:

<u>Isotope</u>	<u>Release Rate</u> <u>Curies Per Day</u>
P-32	35
As-76	370
Np-239	360
Cr-51	1150
Zn-65	40

While the releases appear high, the environmental surveillance of the Hanford environs showed that amounts of radioactive materials present have been well within nationally accepted limits. Even so, continued and intensifying pressure for reducing river pollution of all types necessitates a continuing effort to minimize the releases. Thus, the program objective is to devise practicable means to reduce the release of radioactivity to the Columbia River.

The radionuclides in the reactor effluent are formed by neutron activation of Columbia River salts not removed in the water treatment process, water treatment salt additives, corrosion products from the water system and fuel surfaces, and impurities left on or imbedded in the fuel element jacket surfaces. The parent materials are adsorbed on the film which forms on the reactor tube and fuel element surface and adhere for extended periods of time to further increase radioisotope production. There are then three approaches to reducing radioisotope releases: (1) increase the efficiency of parent isotope removal during the coolant treatment process, (2) find methods to reduce or eliminate the time of adherence by changes in the chemical composition of the water, chemical form of the isotopes or changes in the chemical composition of the water, chemical form of the isotopes or changes in the reactor film, and (3) removal of the radioisotopes from the reactor effluent. The studies scheduled in the present program encompass work in the first two areas. No work is presently planned in the third area. The research and development program through FY-1965 has encompassed both basic studies and the more practical aspects of the problem, such as the possibilities of making process changes to alleviate the situation. By far the major emphasis was placed on the latter in an effort to obtain results and hopefully reductions in effluent releases as

DECLASSIFIED

SECRET

soon as possible. Although some success was achieved and the answers to many specific questions obtained, it appeared that the more readily applicable avenues have been explored. Thus, the program for FY-1966 and beyond was redirected toward more basic studies.

PROGRESS DURING THE REPORT PERIOD

- A. Laboratory and single-tube in-reactor tests had indicated that the addition of sodium silicate to process water at a concentration of 20 ppm SiO_2 would reduce the amount of radioactivity in the reactor effluent. A half-reactor test was initiated at D Reactor on January 25, 1965. Other water treatment parameters such as 18 ppm alum, 1.0 ppm sodium dichromate, and a coolant pH of 6.6 were kept constant on both sides of the reactor during the test. The test, which was terminated on March 11, 1966, showed the following:
- 1) After an equilibration period of from four to six months, the P-32, As-76, Cr-51, and Np-239 concentrations in the reactor effluent were reduced by factors of 2, 6, 4.5, and 5.5, respectively. Isotopes such as Cu-64, Mn-56, and Zn-65 were not affected, and the concentration of Na-24 increased by about 50 percent.
 - 2) It appears that the uniform corrosion rates of aluminum and carbon steel were reduced by the silicate, but also that the tendency toward pitting corrosion is increased.
 - 3) Film formation in the fringe tubes occurred during the cold water months of the year. This did not result in a safety problem but increased the difficulty of interpreting operating data.
 - 4) The dose rate from the rear face on the silicate side of the reactor was a factor of two or three higher than on the control side.
 - 5) The film from a downstream spacer on the silicate side of the reactor was found to have a negative zeta potential as compared to the zero zeta potential of the film from a control side spacer. This may be a partial explanation of the fact that the isotopes whose concentrations are being reduced are those which exist in the anionic state.

The test as originally designed terminated on March 11, 1966. At that time the alum feed to the test side was reduced to 6 ppm in order to permit more parent material to enter the reactor. Thus, it will be possible to assess the effectiveness of the silicate under more severe conditions. It is expected that this test will run to about May 1. At that time the alum feed will be increased to 18 ppm and the silicate feed rate will be reduced to 15 ppm.

DECLASSIFIED

- B. An alum feed test was run at the K Reactors. The alum feed rate at KE Reactor was held at 16 to 18 ppm, and the alum feed at KW Reactor was held for two months at 3, 6, 9, and 13 ppm.

The data obtained were as follows:

Alum Feed Rate, ppm	Ratio KW/KE		
	<u>P-32</u>	<u>As-76</u>	<u>Np-239</u>
3	2.5	7.5	4.5
6	1.5	4.5	4.0
9	1.2	2.5	2.5

It would appear that while 9 ppm is not sufficient alum, 12 ppm may be equally as effective as 18 ppm.

- C. Daily analysis of river water from B Area for sulfate, phosphate, iron, and silica continued. Seasonal peaks were observed for phosphate and iron while sulfate and silicate remained relatively constant.
- D. The addition of activated silica to process water showed effluent activity reductions equivalent to those obtained when sodium silicate is added.
- E. Fuel elements coated with lithium silicate ($\text{Li}_2\text{O} \cdot 0.5\text{SiO}_2$) were charged to two tubes. Some reduction, about 25 percent, in effluent activity resulted early in the irradiation period but were not lasting. Fuel element corrosion was accelerated.
- F. The addition of 30 ppm sodium sulfite as a deoxygenator to process water did not change the effluent activity but did accelerate fuel corrosion.
- G. The addition of a proprietary film conditioning agent to process water was initiated.
- H. Fuel elements have been shipped to Oak Ridge to determine if metallic coatings can be applied using plasma techniques.
- I. A technique was developed for defilming tube samples, fuel elements, and spacers. Punchings from one process tube and one column of fuel elements and spacers have been defilmed, and the film analyzed for both radio and parent isotopes.
- J. Investigations were started in the water treatment pilot plant to define the relationship between coolant pH, coagulant feed rate, zeta potential, and effluent activity.
- K. Contacts have been established with ORGDP so that the ultracentrifuge can be evaluated as a research tool.

DECLASSIFIED

- L. Studies were undertaken to determine the practicability of flocculation in the 107 basins as well as the isotope retention by the floc. It was found that ferric chloride or a mixture of ferrous sulfate-potassium permanganate were quite effective for certain isotopes. The retention of the isotopes was unsatisfactory for the ferrous sulfate-potassium permanganate but was quite promising for the ferric chloride.

BUDGET PERIOD PLANS AND EXPECTED RESULTS

- A. Film inventory studies will continue and expand such that the radio and parent isotope inventories will be determined as a function of exposure in reactor, position in reactor, and surface. The results from the studies will be used to determine the kinetics of parent isotope adsorption and radioisotope release.
- B. Deionized water in the single-pass tubes will be used to investigate the effect of changing the relative salt concentrations in the coolant. In this manner the mechanisms by which film characteristics are changed upon the adsorption of ions can be deduced. The selection of additives or conditions which optimize potential reductions in effluent activity can be intelligently made. The deionized water tests will also provide useful information on the kinetics of the adsorption-desorption process.
- C. Previous data obtained using Zircaloy fuel and tubes with deionized water as the coolant indicate that effective reductions in effluent water radioisotopes if more inert surfaces able to withstand conditions in the flux zone. Testing on a small scale using Zircaloy fuel cladding in process water will be undertaken. If application proves feasible at Oak Ridge, fuel coated with copper, nickel, and tungsten will also be tested to determine the effect on effluent radioactivity.
- D. Investigations correlating the zeta potential of the floc with pH, flocculant feed rate and effluent radioactivity will continue in the water treatment pilot plant. In addition, a half-reactor test will be initiated at K Reactor to explore the concept of variable coagulant feed based on zeta potential control. Alternate flocculating agents and acidulating will be studied.
- E. The relative concentrations of radioisotopes in the reactor effluent are found to vary as the concentrations of salts in the incoming water vary. In some cases it is possible to reduce the concentration of a given radioisotope by increasing the concentration of a seemingly nonrelated ion. Investigations will be carried out to determine the factors involved in the interplay of water salts with the expectation of discovering additives which will result in significant effluent activity reductions. Both inorganic as well as organic materials will be tested.
- F. It has been shown that the water treatment is quite efficient in

DECLASSIFIED

removing many of the parent isotopes. However, there is still room for improvement and one of the key areas in the process is filtration. Studies in the area of filtration will include an investigation of floc loading, polyelectrolyte additions, flow surges, and backwash techniques. The chemical characteristics of floc formation and impurity adsorption as well as the colloidal characteristics of the floc will be undergoing study. The effect of irradiation on flocculation and settling will be determined.

- F. The sequence of testing in the program involves laboratory tests, single-tube in-reactor tests, and half-reactor tests. Therefore, engineering effort is required to design and prepare for the larger scale tests. Engineering effort is also necessary to guide the research and development program and assess the economics and practical aspects of the application of promising results.

DECLASSIFIED

RICHLAND
OPERATIONS OFFICE

RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY

02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>14 - Columbia River Studies</u> MISSION SUB-PROGRAM TITLE <u>Effluent Activity Reduction</u>		2. BUDGET ACTIVITY NO. _____
3. CONTRACTOR AND A. <u>Douglas United Nuclear, Inc.</u> <u>AT(45-1)-1857</u> CONTRACTOR B. _____ NUMBER C. _____		4. PERSON IN CHARGE: <u>T. W. Ambrose</u> INVESTIGATOR: <u>R. G. Geier</u> INVESTIGATOR: _____

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *					5 YEAR TOTAL
	FY 19 67	FY 19 68	FY 19 69	FY 19 70	FY 19 71	
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	0	0				
B) OTHER	0	0				
TOTAL	0	0				
6. COSTS (\$000'S)	\$	\$	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)	0	0				
B) MATERIALS, TECH. SERV., SUB CONTRACTS	0	0				
C) SPONSORED WITH BNW	92	92				
TOTAL DIRECT	92	92				
D) INDIRECT EXPENSES	8	8				
TOTAL OPERATING COSTS	100	100	100	100	100	500
E) EQUIPMENT (NEW)						
F) IRRADIATION UNIT COSTS						

7. COMMENTS:

DECLASSIFIED

RL 2-14
Page 16

REFERENCES

- A. Geier, R.G. Richland Integrated Process Development Program - Columbia River Studies, RL-GEN-22 SUP14, REV1. July 30, 1965.
- B. Geier, R.G. Interim Report I - Production Test IP-728, Half-Plant Sodium Silicate Test, RL-REA-2546. September 16, 1965.
- C. Geier, R.G., and R.L. Heid. Production Test IP-802, In-Reactor Testing with Coolant Prepared in the Water Treatment Pilot Plant, RL-REA-2515. September 3, 1965.
- D. Silker, W.B. The Contribution of 1706-KE Process Piping to Effluent Radioactivity, BNWL-CC-264. September 22, 1965.
- E. Silker, W.B. Cross Mixing of Reactor Coolant, BNWL-CC-274. September 30, 1965.
- F. Geier, R.G. Production Test IP-728, Supplement I - Half-Plant Sodium Silicate Test, DUN-766. February 28, 1966.
- G. Silker, W.B. A Potential Method for Reducing Exposure from Reactor Effluent Radioisotopes, BNWL-CC-550.

DECLASSIFIED

COLUMBIA RIVER STUDIES (EFFLUENT ACTIVI

FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER

DECLASSIFIED

COLUMBIA RIVER STUDIES (EFFLUENT ACTIV

1965

1966

OCTOBER

NOVEMBER

DECEMBER

JANUARY

FEBRUARY

MARCH

APRIL

MAY

FILM INVENTORY
STUDIES

ENV
OBTAIN DUMMY
SAMPLES TO
DEVISE TECHNIQUE
FOR DETERMINING
RADIO AND PARENT
MATERIAL IN FILM

ENV
ANALYTICAL METHOD
FIRMED UP

DUN
OBTAIN PUNCHINGS
FROM AL PROCESS
TUBE AGED 6 MO.,
1, 2 OR 3 YRS.

ENV
DELIVER TO LAB
AND BEGIN FILM
ANALYSIS

ENV
COMPLETE ANALYSIS

DUN
OBTAIN PUNCHINGS
FROM SECOND TUBE

ENV
DELIVER
AND BEGIN
ANALYSIS

DUN
PREPARE PRODUCTION
TEST FOR
REMOVAL OF AL
CLAD FUEL AT 2,
4, 8 AND 12
WEEKS

DUN
PRODUCTION TEST
APPROVED

DUN
CHARGE FUEL

DUN
WEIGH AND NUMBER
FUEL AND DUMMIES

DUN-1
OBTAIN 1
FROM 2ND
TUBE SAMPLE
AT RADIO-

DUN
DISCHARGE
AT 2 AS

ENV
TRANSPORT
TO RADIO
AND DET.

WATER TREATMENT
STUDIES

ENV
INITIATE TESTS
IN WATER TREAT-
MENT PILOT PLANT
VARYING ZETA
POTENTIAL, PH
AND POINTS OF
CHEMICAL ADDITION

COLUMBIA RIVER STUDIES (EFFLUENT ACTIVITY REDUCTION)

1966

DECEMBER

JANUARY

FEBRUARY

MARCH

APRIL

MAY

JUNE

JULY

AUGUST

S

ENV
ANALYTICAL METHOD
FIRMED UP

ENV
DELIVER TO LAB
AND BEGIN FILM
ANALYSIS

ENV
COMPLETE ANALYSIS

DUN
OBTAIN PUNCHINGS
FROM SECOND TUBE

ENV
DELIVER TO LAB
AND BEGIN FILM
ANALYSIS

ENV
COMPLETE ANALYSIS

DUN
OBTAIN PUNCHINGS
FROM THIRD TUBE

ENV
DELIVER TO LAB
AND BEGIN FILM
ANALYSIS

DUN-ENV
OBTAIN PUNCHINGS
FROM ZINCALLOY
TUBE SAMPLES
AT RADIONET.

ENV
DELIVER TO LAB,
DEFILM, AND
BEGIN ANALYSIS

ENV
COMPLETE ANALYSIS

DUN
PREPARE PRODUCTION
TEST FOR
REMOVAL OF AL
CLAD FUEL AT 2,
4, 8 AND 12
WEEKS

DUN
PRODUCTION TEST
APPROVED

DUN
CHARGE FUEL

DUN
WEIGH AND NUMBER
FUEL AND DUMMIES

DUN
DISCHARGE FUEL
AT 2 AND 4 WEEKS

ENV
TRANSPORT FUEL
TO RADIONET
AND DEFILM

DUN
REMOVE FUEL AT
8 WEEKS

ENV
BEGIN ANALYSIS

DUN
REMOVE FUEL AT
12 WEEKS

ENV
TRANSPORT FUEL TO
RADIONET AND
DEFILM

REC

ENV
INITIAL TESTS
IN WATER TREAT-
MENT PILOT PLANT
VARYING ZETA
POTENTIAL, PH
AND POINTS OF
CHEMICAL ADDITION

1967

SEPTEMBER OCTOBER NOVEMBER DECEMBER JANUARY FEBRUARY MARCH APRIL MAY

DECLASSIFIED

MECHANISMS OF ENVIRONMENTAL EXPOSURE - PNLSCOPE AND OBJECTIVES

Numerous pathways exist whereby various segments of the population living adjacent to the Hanford plant may become exposed to radiation originating in the Plant. This study is concerned with the quantitative evaluation of the mechanisms whereby people become exposed to such radiation. In particular, the radiation exposure resulting from the release of Hanford effluents to the Columbia River and into the atmosphere entails complex mechanisms that need further study to evaluate. The exposure mechanisms studies not only sharpen estimates of existing exposure levels, but provide a basis for extrapolating to other conditions. They permit examination of exposures limiting the release of effluents and of future environmental problems which may result from new products and operating conditions.

One requirement for the evaluation of radiation exposure which results from Hanford effluents released to the environment is an estimate of the average and extreme dietary habits of the population with respect to affected foodstuffs. The current importance of such dietary estimates is illustrated by Columbia River fish. Credible ingestion rates of local fish can result in P-32 intakes which are in excess of the limits now recommended for members of the public. The calculation is sensitive to the amount and frequency with which fish are eaten, as well as species and seasonal fluctuations. One objective of this study is to obtain dietary data which can be statistically analyzed for application to average exposure calculations. Other foodstuffs, such as milk, meat, drinking water, some kinds of seafood, and game birds also contribute to the radiation exposure of portions of the local population.

The technical basis for establishing acceptable limits for the rate of release of radionuclides in Plant effluent involves an assumption that the exposure pathways are identified and the relationships between release rates and the resulting dose to man or animals are defined. However, the current level of knowledge is insufficient to quantitatively estimate the effect of various pathways on the total population exposure. Changing Plant conditions such as new areas being opened for industrial or agricultural exploitation, and waste effluents arising from new-product operations contribute to the continued need for investigation of exposure pathways. A study of whole-body counting results for local residents can help to indicate the radionuclides of greatest significance, and their correlation with dietary data obtained from the same individuals can indicate the most important pathways whereby they reach members of the population living near the Plant. By including information regarding the probable concentration levels of the radionuclides in foodstuffs, it may be possible to calculate large-population averages of important metabolic parameters, such as fractional absorption of nuclides from various foodstuffs.

To assure realistic population estimates of exposure mechanisms, it is important that the study be extended to include representatives from all

DECLASSIFIED

important segments of the population where diet or habits may differ markedly from the average. In particular, special efforts are justified to include children, fishermen, and families living on farms irrigated with Columbia River water. Thus, it is considered within the scope of this study to obtain dietary and whole-body counting data from those special population segments.

PROGRESS DURING REPORT PERIOD

Children in the upper three grades in four Richland elementary schools were contacted and invited to participate in this mechanism study by providing diet information and permitting themselves to be counted in the Hanford Mobile Whole-Body Counter. A special diet sampling technique which, together with a simple questionnaire, provided the necessary diet information for correlation with whole-body counting results. These data were added to the computer file for studying the effects of diet on the body burden of radionuclides. More than 85 percent of the children contacted participated in the diet sampling and whole-body counting project, resulting in more than 500 data added to the file. An important part of the development work for this phase of the study is the design of a procedure for eliciting the required information from the children and a public relations plan to obtain acceptance of the project by parents and school officials. This procedure was successfully developed and tested.

A one-year old steer was purchased and an experiment begun to study the uptake of Zn-65 from beef. The animal was raised on a pasture irrigated with Columbia River water obtained downstream from the Hanford plant. After butchering, grinding, and mixing, the flesh from the animal was found to contain 5.5×10^{-3} nCi Zn-65 per gram. The experiment begun this year will follow the build-up of Zn-65 in test subjects during periods in which weighed portions of this meat are eaten at regular intervals. Some of the highest Zn-65 body burdens detected by the Hanford Whole-Body Counter were traced to beef raised on a pasture irrigated with Columbia River water. The experiment will help to evaluate this exposure pathway. The Zn-65 is expected to display an effective half-life in the subjects' bodies in excess of 150 days, requiring an extended period of measurement.

A statistical study of the fishing on the Columbia River was designed and initiated in cooperation with the Washington State Fish and Game Department. The experiment is designed to last for one year, about half occurring in each of the fiscal years 1966 and 1967. Attempts to come up with realistic estimates of the number of Tri-City residents that fish in the Columbia River and the number of fish they catch did not provide results that could be considered representative of the area. The present experiment is designed as a sampling exercise that will provide data to fit a selected statistical model. It requires the full-time attention of one man, who was specifically hired for this study by the State Game Department. He is provided with a randomly-selected sampling schedule

DECLASSIFIED

which will sample fishing data throughout the stretch of river of interest and at different times. By extending the program through a complete year, the seasonal variations in fishing habits will be obtained.

Whole-body counting data, dietary information, and environmental sample analyses are included in an electronic data program (DIB) that was used to seek correlations which reveal dietary exposure pathways. For example, the data indicated that on the average 69 percent of Tri-City residents' body burden of Zn-65 comes from drinking water and 27 percent is obtained from seafood. Other diet items contributing Zn-65 (in order of importance) are game birds, Columbia River fish, and fresh meat. Some of the attempts to correlate Zn-65 with fresh milk consumption gave a consistently negative correlation. This has not yet been satisfactorily explained. The file was also used to calculate new estimates of the diet of Richland residents. The population distribution of various consumption levels of water, milk, meat, seafood, game birds, and Columbia River fish were obtained from the data on the file. The calculation assures that the tabulated data are a representative sample of the Richland population. The file does not yet contain the data obtained for children.

An experiment was completed in which a test subject ate measured quantities of oysters collected on the Pacific coast near the mouth of the Columbia. The oysters contained significant amounts of Zn-65 transported to the sea by the Columbia River. The oysters were first analyzed for Zn-65 and then eaten. The accumulation of Zn-65 in the body of the subject was followed by whole-body counting in the Hanford Whole-Body Counter. He ate 81 meals of oysters over a period of 20 months and attained a maximum Zn-65 body burden of 40 nCi. The data indicated a fractional absorption of 13.5 percent and an effective half-life of 100 days. The differences between those values and those obtained from controlled fish-consumption experiments probably reflects metabolic differences among the individuals participating in the experiments.

A preliminary design for an additional mobile whole-body counter was selected and the components ordered. Studies were conducted to provide data needed to complete the design.

BUDGET PERIOD PLANS AND EXPECTED RESULTS

The new mobile whole-body counter will be completed and tests conducted to provide necessary calibration curves. It is expected that the new counter will be compact and easily transported to remote locations. It will be equipped to either operate in conjunction with available power sources and change-room facilities or as a completely self-contained unit.

Whole-body counting of Richland school children will be completed and the data analyzed by means of a computer program. Dietary averages for Richland school children will be computed and the diet data integrated with that for Richland adults to obtain a population average. The mobile whole-body

DECLASSIFIED

counter will be used to count children in Pasco schools, subject to the agreement of school officials. The entire Pasco school system should be included during the year. A beginning will be made at counting school children in Kennewick schools. These data will not only add to the statistical significance of the file by increasing its size; but by covering a variety of communities, a range of values will be obtained which will assist with regression calculations. For example, distinct differences are found among the mean radionuclide concentrations in drinking water in the three cities. An experimental design will be completed and work begun on a whole-body counting effort in the Riverview district of Pasco. This region is of particular interest because Columbia River water is widely used to irrigate pastures and gardens in this district. The experiment will involve preliminary contact with residents by mail followed by an invitation to visit the whole-body counter located in the district.

The statistical sampling of fishing performance on the Columbia River will be completed soon after mid-year. The data will need considerable analyses for application to Hanford problems. The results will be used to compute fishing-pressure curves for each sampling location on the river and for the entire stretch of river included in the survey. The data will be used to calculate the mean length of fishing periods, the average catch for various species, and seasonal changes in fishing pressure. Those results will be used to adjust the current data used in population exposure calculations and will help guide the river monitoring program. Analyses of data from the statistical study of fishing pressure will be completed and a report published during the year. Additional whole-body counting of fishermen using the mobile counter located near the Columbia River is planned.

The DIB computer file will be used to compute dietary correlations with Cs-137 and Na-24. A program will be developed to use the file for calculating dietary parameters such as effective half-life and fractional absorption. Those results will be particularly meaningful because they will reflect average values for a large population sample. The Cs-137 regression equation study should be ready for reporting by the end of the year. It is anticipated that a regression equation for Na-24 with various diet items will be completed and readied for publication during the next year. If enough whole-body data are obtained to warrant it, a program will be written to examine correlations of I-131 with the diet file. It is anticipated that additional program development will be needed to extract further metabolic information from the DIB file.

DECLASSIFIED

RICHLAND
OPERATIONS OFFICE

RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY

02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>14 - Columbia River Studies</u>		2. BUDGET ACTIVITY NO. _____	
MISSION SUB-PROGRAM TITLE <u>Mechanisms of Environmental Exposure</u>		_____	
3. CONTRACTOR AND CONTRACTOR NUMBER	A. <u>Battelle Memorial Institute</u>	<u>AT(45-1)-1830</u>	
	B. <u>Pacific Northwest Laboratory</u>	_____	
	C. _____	_____	
4. PERSON IN CHARGE: <u>R. F. Foster</u>		_____	
INVESTIGATOR: <u>J. F. Honstead</u>		_____	
INVESTIGATOR: _____		_____	

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *		FY 19	FY 19	FY 19	5 YEAR TOTAL
	FY 19 67	FY 19 68				
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	1.2	1.5				
B) OTHER	1.0	1.0				
TOTAL	2.2	2.5				
6. COSTS (\$000'S)	\$	\$	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)	34	40				
B) MATERIALS, TECH. SERV., SUB CONTRACTS	19	16				
C) SPONSORED WITH BNW	(Incl)	(Incl)				
TOTAL DIRECT	53	56				
D) INDIRECT EXPENSES	42	51				
TOTAL OPERATING COSTS	95	107	128,	107,	84	521
E) EQUIPMENT (NEW)	10	24				
F) IRRADIATION UNIT COSTS						

7. COMMENTS:

DECLASSIFIED

 RL 2-14
Page 24

REFERENCES

- A. Foster, R.F. Accumulation of Zn-65 from Prolonged Consumption of Columbia River Fish, HW-SA-3060. May 29, 1963.
- B. Nelson, I.C. Ringold - A Hanford Environmental Study, HW-78262. May 29, 1963.
- C. Soldat, J.K. "The Relationship Between I-131 Concentrations in Various Environmental Samples," Health Physics, Vol. 9, pp 1167-1171.
- D. Honstead, J.F., and D.N. Brady. The Uptake and Retention of P-32 and Zn-65 from the Consumption of Columbia River Fish, BNSA-45. June 15, 1965.
- E. Honstead, J.F., and P.W. Hildebrandt. Uptake and Retention of Zinc-65 from Certain Foods, BNWL-SA-239. September 13, 1965.

DECLASSIFIED

COLUMBIA RIVER STUDIES (MECHANISMS OF ENVIRONMENTAL EXPOSURE)

1966

1967

1ST QUARTER

2ND QUARTER

3RD QUARTER

4TH QUARTER

1ST QUARTER

1968

2ND QUARTER

3RD QUARTER

4TH QUARTER

1ST QUARTER

2ND QUARTER

2ND

1970

QUARTER

3RD QUARTER

4TH QUARTER

1ST QUARTER

2ND QUARTER

DECLASSIFIED

EFFECT OF REACTOR EFFLUENT ON THE QUALITY OF
COLUMBIA RIVER WATER - PNL

SCOPE AND OBJECTIVES

Effluent cooling water from the Hanford reactors measurably changes Columbia River water temperatures, chemical characteristics, and content of radioactive materials. The substantial quantities of these effluents released to the river disperse slowly with the main flow of the river and measurably alter some characteristics of the entire river below the Plant. This study is concerned primarily with the extent to which the effluents alter the physical and chemical characteristics. Routine radiological aspects are not included directly, since these are studied as a part of the regular radiological evaluation program or in other research and development programs, but river hydrology and effluent distribution data obtained in this program are used for the radiological assessment of Plant emergencies and changes in Plant operations.

The Water Pollution Control Act of 1965 and the President's Executive Order 11258 of November, 1965, concerning pollution from federal installations add to the increasing political significance of Hanford effluents and the need for greater knowledge of their actual effect on river characteristics.

Detailed knowledge of the changes in river temperature from reactor effluent is needed principally because of the potential effects of such changes on aquatic life, especially salmon. This problem has considerable regional impact and is receiving close attention by Federal and State agencies.

Detailed knowledge of the chemical characteristics of the river water and how these are changed by the Hanford operations is needed:

- A. to evaluate the status of the river with respect to quality criteria for drinking water and aquatic life (the concentration of dichromate in the river at times closely approaches Hanford's control limit established for the protection of fish), and
- B. to provide assurance to Federal and State agencies that Hanford does not seriously affect the quality of the river water.

Detailed knowledge of the concentration profiles and travel times of the effluents in the river below each reactor is needed in order:

- A. to determine the extent of zones in which aquatic life might be affected (principally by high temperature or dichromate),
- B. to predict potential exposures from partially diluted effluent to persons downstream, especially in the event of unusual releases,
- C. to evaluate the effects of changes in Plant operations or Plant boundaries, and
- D. to assess inter-reactor effects.

DECLASSIFIED

Within the Plant boundaries, river temperature changes computed from the heat load added by the reactors are insufficient to define accurately the impact on the river because of uneven distribution, rapid variations in river flow from Priest Rapids Dam regulation, and the external influences of weather and ground water return flow. Below the Plant boundary and within the McNary pool, the influence of reactor effluents is further confused by incomplete mixing of the main river with water from the Yakima and Snake Rivers and thermal stratification in the pool during the summer months.

Work in progress or completed has included the following specific work items:

A. Determination of river temperature effects.

- 1) Establishment of valid continuous downstream temperature measurements either by installation of temperature recorders at appropriate locations, or by relating available measurements to true mean temperatures by a series of cross section measurements.
- 2) Measurement of heat losses in the reactor retention basins to refine heat input calculations.
- 3) Installation of instruments at a location more appropriate than previously available for the measurement of the pertinent meteorological parameters of wind speed, solar radiation, air temperature, and humidity.
- 4) Time of travel measurements with dye tests from each reactor outfall to the downstream temperature locations selected over a range of river flows for use in heat budget calculations.
- 5) Direct temperature measurements in reactor effluent plumes and in shoreline areas of effluent seepage over a range of river flows.
- 6) Cross-sectional temperature measurements above, within, and below McNary reservoir to define the relative importance of main-stem temperature (containing Plant effluents) to Snake River temperature and atmospheric effects.
- 7) Formation and testing of mathematical models.

B. Determination of chemical changes due to reactor effluents.

- 1) Establishment of an optimum downstream location for continuous sampling for chemical analysis.
- 2) Validation of results from this location by cross-section sampling over a range of river flows, and by comparison with known chemical inputs to the river via reactor effluents.

DECLASSIFIED

- 3) Comparison of upstream and downstream concentrations of water quality characteristics for evidence of plant-caused changes not previously known to occur.

C. Determination of effluent distributions and travel times.

- 1) Performance of dye tests using both spot and continuous dye additions to determine effluent concentrations at selected locations over a range of release times, of river flows, and for each reactor outfall.
- 2) Investigation of materials using activation analysis to replace dye as a tracer in McNary reservoir.
- 3) Correlation of effluent concentration data at different locations, for use in the radiological evaluation of Plant emergencies and proposed changes in Plant operations and Plant boundaries.

PROGRESS DURING REPORT PERIOD

Sufficient data were obtained from the portable meteorological station on the river bank at White Bluffs to permit statistical correlation with time-averaged river temperatures. Improved correlation and reduced standard deviation of the prediction equation was obtained as compared with those obtained with Meteorological Tower data. Modification of a time-sequenced heat budget model, already developed for the reservoirs upstream, to the Plant reach of the river was started.

Periodic measurements of cross-section temperatures in McNary reservoir for comparison with incoming temperatures was initiated. Temperature measurements at and below the dam, required for an evaluation of a continuous monitoring point, were also begun. Dye releases from the reactors were made to determine effluent distribution in the reservoir and at the dam, but the technique was found to be insufficiently sensitive to determine distribution at the dam. Investigation of dysprosium as a neutron-activated tracer for possible replacement of dye as a tracer was started.

Dye tests were completed for determination of effluent distribution and travel times from each reactor to below the Plant boundary.

BUDGET PERIOD PLANS AND EXPECTED RESULTS

A modified time-sequenced heat budget model will be tested using accumulated temperature and weather data for comparison with the best time-averaged model developed to date.

Temperature measurements in McNary reservoir will be continued and a valid single-point measurement established at McNary Dam. Further attempts will be made to measure effluent distributions and travel times in the reservoir

DECLASSIFIED

using either dyes, a neutron-activated tracer or a fission product from fuel element failures.

Temperature monitors, portable meteorological instruments and continuous samplers will be installed on barges anchored in the river above and below the reactors under the Division of Biology and Medicine R&D Program to provide improved river sampling and temperature data.

Effluent distributions will be rechecked at the proposed Automatic Columbia River Monitoring Station at 181-F when completed. Effluent distribution from the PRTR outfall will also be determined at several river flow rates when that reactor resumes operation.

The previous emphasis on temperature and other effects of routine effluents will be shifted toward better definition of the impact of nonroutine releases, especially from fuel element failures, on river usage. The need for operational control of such releases and appropriate action levels will be reevaluated using accumulated dispersion data and new data as warranted. Included in this effort will be travel time studies extending downstream from McNary Dam.

DECLASSIFIED

U. S. ATOMIC ENERGY COMMISSION

RICHLAND
OPERATIONS OFFICE

RESEARCH AND DEVELOPMENT STATISTICAL SUMMARY
02 PROGRAM

HAN- _____

1. MISSION NO. AND TITLE <u>14 - Columbia River Studies</u>		2. BUDGET ACTIVITY NO. _____		
MISSION SUB-PROGRAM TITLE <u>Effect of Reactor Effluent on the Quality of Columbia River Water</u>		_____		
3. CONTRACTOR AND CONTRACTOR NUMBER	A. <u>Battelle Memorial Institute</u> <u>AT(45-1)-1830</u>	4. PERSON IN CHARGE: <u>R. F. Foster</u>	_____	
	B. <u>Pacific Northwest Laboratory</u>			INVESTIGATOR: <u>J. P. Corley</u>
	C. _____			INVESTIGATOR: _____

FIVE YEAR FORECAST

	CURRENT BUDGET YEARS *					5 YEAR TOTAL
	FY 19 67	FY 19 68	FY 19 69	FY 19 70	FY 19 71	
5. MAN-YEARS						
A) SCIENTIFIC AND TECHNICAL	0.9	1.0				
B) OTHER	1.4	1.5				
TOTAL	2.3	2.5				
6. COSTS (\$000'S)	\$	\$	\$	\$	\$	\$
A) DIRECT LABOR (INCL. COST OF SERV.)	30	36				
B) MATERIALS, TECH. SERV., SUB CONTRACTS	16	22				
C) SPONSORED WITH BNW	(Incl)	(Incl)				
TOTAL DIRECT	46	58				
D) INDIRECT EXPENSES	39	46				
TOTAL OPERATING COSTS	85	104	105	89	52	435
E) EQUIPMENT (NEW)	10	10				
F) IRRADIATION UNIT COSTS						

7. COMMENTS:

DECLASSIFIED

RL 2-14
Page 32

REFERENCES

- A. Corley, J.P. Interim Report - Effect of Hanford Operations on Columbia River Temperatures, HW-76210. February 13, 1963.
- B. Corley, J.P. Interim Report - Effect of Hanford Operations on Columbia River Temperatures, HW-80888. December 3, 1964.

DECLASSIFIED

COLUMBIA RIVER STUDIES (EFFECT OF REACTOR EFFLUENT ON COLUMBIA RIVER WATER QUALITY)

1st QUARTER - 1966

2nd QUARTER - 1966

3rd QUARTER - 1966

4th QUARTER - 1966

1st QUARTER - 1967

DECLASSIFIED

DISTRIBUTION

RICHLAND OPERATIONS OFFICE

1-23. D. G. Williams

DOUGLAS UNITED NUCLEAR, INC.

24. T. W. Ambrose	29. W. M. Mathis
25. P. A. Carlson	30. R. Nilson
26. R. G. Geier	31. G. F. Owsley
27. C. D. Harrington	32. R. W. Reid
28. C. W. Kuhlman	33. O. C. Schroeder
	34. J. T. Stringer

GENERAL ELECTRIC COMPANY - HAPD

35. R. L. Dickeman	41. W. S. Nechodom
36. D. W. Leiby	42. G. W. Nicholas
37. M. C. Leverett	43.-44. J. W. Riches/D. L. Condotta
38. M. Lewis	45. R. H. Shoemaker
39. J. S. McMahon	46. R. E. Trumble
40. J. Milne	

ISOCHEM INC.

47. R. F. Campbell	53. A. J. Scott
48. R. A. Connell	54. H. P. Shaw
49. J. B. Fecht	55. A. E. Smith
50. O. F. Hill	56.-57. R. E. Tomlinson
51. J. N. Judy	58. J. H. Warren
52. P. E. Reed	

BATTELLE-NORTHWEST

59. F. W. Albaugh	67. E. R. Irish
60. C. A. Bennett	68. A. R. Keene
61. J. J. Cadwell	69. G. A. Last
62. F. G. Dawson	70. R. S. Paul
63. D. R. de Halas	71. A. M. Platt
64. E. A. Eschbach	72. C. A. Rohrmann
65. J. J. Fuquay	73. E. E. Voiland
66. H. Harty	74. M. T. Walling, Jr.
	75. E. C. Worlton

DECLASSIFIED

COLUMBIA RIVER STUDIES (EFFLUENT ACTIVITY)

SECTION)

1967

JANUARY

FEBRUARY

MARCH

APRIL

MAY

JUNE

INITIAL

2E FUEL

DECLASSIFIED

SECRET

COLUMBIA RIVER STUDIES (EFFLUENT)

VITY REDUCTION)

AY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER 1961 JANUARY 1962

DECLA